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MEDICAL ASPECTS OF RADIOLOGICAL FALLOUT

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~~Presented at the Fifth~~ F.C.D.A. Regional Medical Conference, Phoenix, Arizona, April 18, 1955.

Introduction

The advent of the "super" bomb has emphasized problems of a different nature from those generally associated with the "conventional" atomic weapon, particularly those problems associated with the spread of a large amount of radioactive fallout material over an area of many square miles. It is the purpose of this presentation to outline certain modifications in thinking and planning that may result from these differences. I shall deal mainly with the fallout radiations and their medical effects, and shall endeavor to give something of current thought on the diagnosis and treatment of disease states resulting from exposure to these radiations. In what follows, the views expressed are my own and do not necessarily reflect those of any institution or government agency.

Effects of the "Conventional" Weapons

For purposes of contrast, I shall mention briefly the effects of conventional atomic weapons which have been considered chiefly in the context of a high air burst. The familiar blast and heat effects from such a burst have been reviewed in many publications and no additional comment is necessary. The radiation hazard is due to the initial gamma radiation, and exposure to this radiation is only a few seconds in duration. Fallout is of relatively no significance with this type of burst. Thus, there is no significant contamination of skin and, therefore, no

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skin beta lesions. Likewise, there is no significant problem from ingestion or inhalation of radioactive material, and hence, no "internal emitter" problem. Radiation under these circumstances was considered responsible for approximately 15% of the total casualties that were treated at Hiroshima and Nagasaki. It perhaps should be noted, however, that radiation superimposed upon thermal or mechanical injury undoubtedly contributed to the severity of such injuries. Also, if blast and thermal damage were reduced by substantial buildings or shelters, the percentage of casualties from radiation damage would increase.

Effects of the "super" bomb

With the "super" bomb, the same problems encountered with earlier atomic weapons will also be encountered, only magnified many times. The area of total destruction, instead of one or two miles in diameter, may extend to many miles, depending upon the size of the weapon. There will be blast, heat and radiation casualties as before, and the same problems of handlingmass casualties on an unprecedented scale with minimal or no facilities will pertain. In addition, the problem of extensive fallout may enter.

The possibility of extensive and serious fallout is not restricted to super weapons. With surface, underground and underwater burst of conventional weapons, fallout has been long considered; however, its possible seriousness was not completely appreciated until information on fallout from the "super" bomb was released by Chairman Strauss (press release of Feb. 15, 1955). From his statement, it appears that the bomb's cloud could drop radioactive ashes in a cigar-shaped zone about 220 miles long and 20 to 40 miles wide, an area extending from Phoenix to well into California or New Mexico. Essentially all unprotected persons in the contaminated area for thirty-six hours or more within 140 miles of ground zero would die from radiation exposure and some deaths might result among persons as far as 220 miles from the blast. The zones thus outlined for potential morbidity and lethality will depend obviously on weapon size, wind and other weather conditions, etc. Chairman Strauss emphasized that possible casualty figures given are for the worst possible situation. Casualties might be reduced greatly in number because many in the area would take shelter or evacuate the area. Also, the pattern of fallout might be spotty in nature, and thus, many would escape exposure. Nevertheless, the area where potentially serious casualties may result will exceed by orders of magnitude the relatively small areas for conventional weapons, and in the following I should like to investigate the problems involved in the contaminated area that should be considered in your planning.

Significant fallout results only when the fire ball comes in contact with the surface of the earth. With the high air burst, radioactivity condenses only on solid particles from the bomb casing itself, and on dust in the air. The particles are small, are drawn high into the atmosphere and do not settle to the earth for a period of days or even months. By the time they reach the earth's surface, the major part of their radioactivity has been dissipated harmlessly in the atmosphere and no significant hazard results. If, however, the weapon is detonated on the surface or close enough so that the fire ball touches the surface, then large amounts of material will be are heavy enough to descend rapidly while still intensely radioactive. The result is a comparatively localized area of extreme radioactive contamination and a much larger area of some hazard.

The fallout area will consist of a large contaminated plane, emitting alpha, beta and penetrating gamma radiation. It will be apparent that most of this fallout area will be beyond the range of destruction by blast or heat, and thus, we are dealing with essentially a "pure" radiological situation. Let us consider the possible medical effects of these radiations, their relative importance and possible methods of preventing the effects.

Effects of Gamma Radiation from Fallout

The gamma radiations are penetrating and will produce the same type of injury produced by the initial radiation from the conventional weapon. In the one case radiation is delivered from a "point source"; in the other from a plane field. In both situations, penetrating radiation of the entire body results. Qualitatively, the results are identical. Quantitatively (e.g., dose-effect relationships), there may be differences due to incompletely known and understood differences in the energy of radiation and geometry of exposure under the two conditions, and to differences in dose rate. For these reasons, and for additional reasons to be advanced later, instrument readings of roentgen dose measured in air and published dose-effect tables for man should be used only as a rough guide in casualty estimation.

For order of magnitude of doses that may be encountered in the fallout area, the following figures for total dose for the first thirty-six hour period, are quoted from Chairman Strauss' release. Ten miles downwind from the large device fired at the Bikini Atoll on March 1, 1954 within the test site, a total dose of 5,000 roentgens was delivered over a period of thirty-six hours. The largest total dose delivered outside the test site was 2,300 r for the same period at the north-west end of Rongelap Atoll about 100 miles from Bikini. Two other areas in Rongelap, 110 and 115 miles from Bikini, received 2,000 and 150 r respectively. Another area, 125 miles from Bikini received 1,000 r over the thirty-six hour period.

Effects that may be expected for given doses of penetrating radiation given over a few minutes or hours are indicated in Table I (Handbook of Atomic Weapons for Medical Officers, prepared by the Armed Forces Medical Policy Council for the Army, Navy and Air Force. June, 1951). It is emphasized that such tables are derived from animal data and thus, should be taken as approximations only. NYOO

With regard to the problem of dose rate, there is essentially no difference in effect of a given dose delivered over a few seconds, a few minutes or a few hours. However, a dose delivered over several days or weeks will be much less effective for some effects, than will the same dose delivered over a few minutes. Some data indicate that the effect of a given total dose decreases roughly as the fourth root of the number of days over which the dose is given; thus, a dose delivered over 16 days would be one-half as effective as the same dose delivered over one day. These relationships were worked out on animals, using the so-called "rectangular" dose schedules, e.g., doses delivered at a constant rate. There are no data available to evaluate

TABLE I

Effects of Acute Total Body Irradiation on Human Beings

50 r	No casualties. No reduction in effectiveness.
100 r.	Two per cent may be casualties, (Nausea and/or vomiting) for short period of time. No evacuation contemplated. No significant reduction in combat effectiveness.
150 r	Twenty-five per cent casualties in a few hours. First definite reduction in effectiveness. Fifty per cent of the casualties in this group will have to be evacuated.
200 r	All must be evacuated as soon as possible. 50 per cent will be non-effective.
300 r	Approximately 20 per cent deaths. All need evacuation immediately. All are combat non-effectives.
450 r	Fifty per cent deaths.
Over 650 r	Lethal dose, but no necessarily for all so exposed.

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adequately the effect of a constantly changing dose rate as is encountered in a fission product field. Also, the relationships were worked out using acute effects, such as 30-day mortality and it is not at all certain how closely they apply to longer-range effects such as cancer production, shortening of life span, etc. Genetic effects are dependent on total dose and show little or no dependence on dose rate.

Some warning of possible fallout will be available and the falling radioactive material may actually be visible. As stated, the pattern of fallout will depend on wind velocities and other weather conditions, and the pattern is thus difficult to predict under the best of circumstances. However, it will be apparent that in closer-in areas, fallout may not occur for several minutes after the blast and this period may extend to several hours at greater distances and with slower wind velocities (the fallout began approximately eight hours after the March, 1954 detonation 160 miles from Bikini, and lasted several hours). Thus, there is some time for evasive action. Consideration might be given to evacuating the area if possible fallout patterns have been investigated and are believed to be predictable. Or it may be possible to take shelter. Sufficient time probably would be available to allow relatively complete preparation for an extended stay in adequate shelters with storing of sufficient food and water to allow some advantage to be taken of the decay of fission product radiation with safer evacuation of an area a few days after the fallout. Facilities may, for the most part, be essentially intact, such as water, power, fire-fighting equipment, etc. In this sense, at least, one is immeasurably better off than within the area of blast and thermal damage.

With regard to effectiveness of shelters in the fallout area, the following estimates have been released. A frame house would reduce the total dose received by one-half, and a brick or concrete structure would be more effective. A basement would reduce the total exposure to one-tenth of its value. In a shelter of thickness equivalent to three feet of earth, the dose would be reduced to one five-thousandth of its value, affording complete protection in the most heavily contaminated areas.

It should also be noted, on the other hand, that while the decay of fission product radiations is extremely rapid over the first few minutes after detonation, the rate of decay becomes considerably less rapid in the succeeding hours. Thus, with fallout occurring some hours after the blast, if adequate shelter is not available, earlier evacuation may be better than relying on partial shelter and on rapid decay of the radiation field. Starting at one hour after the blast, a given dose rate will fall to about 44% of its value by one hour later. However, at ten hours after the blast, a given dose rate will fall by only 11% of its value in a period of one hour, e.g., the dose rate at 11 hours will be 89% of what it was at 10 hours. Such statements as "more than 80% of the radiation dose from atomic debris will be delivered within 10 hours of the explosion time" are true only if fallout occurs immediately after the detonation. If the maximum fallout and thus maximum exposure rates in a fallout area have not occurred for several hours, the rate of fall-off in the area obviously will not be as rapid as it would be for earlier fallout material.

Skin Effects of Beta Radiation from Fallout NYOO

It is known from reports of the fishermen exposed to fallout "ashes" in the Pacific area on March 1, 1954, and from reports on Marshallese exposed at the same time (A.E.C. 16th Annual Report, quoted in Bull. Atomic

Scientists, 10:352, 1954) that the fallout was visible and that it clings to the hair, skin and clothes. It is also apparent from these reports that extensive lesions of the skin and epilation can result from this fallout material. It is known from the extensive literature of beta effects of the skin that following exposure, there may be itching and burning which may or may not be followed in a few hours by an erythema. The erythema lasts only one or two days, following which a latent period occurs. Approximately two weeks after exposure, pigment alterations and ulceration of the exposed skin are seen. With more superficial irradiation and smaller doses, these lesions may heal rapidly with no known residual damage. It seems probable from published reports that this has occurred in the exposed Japanese and Marshallese. With higher doses of more penetrating beta radiation, the lesions may progress to chronic radiodermatitis.

Several points should be made regarding beta lesions from fallout radiations. Beta lesions of the skin and depilation can occur in the absence of lethal doses of gamma rays and can be serious and, thus steps should be taken to prevent them. And it would appear that, with reasonable precautions they can be prevented, or at least markedly reduced in severity. Contact of the fallout with the skin can be prevented by remaining within suitable shelters or by wearing ordinary clothing. Damage to the exposed Japanese occurred only in areas where the population was not protected by clothing. If exposure cannot be prevented, early and complete decontamination of the skin and hair would prevent or lessen the severity of the lesions. Particular attention should be given to the hair because of the likelihood of activity being trapped there.

<u>The Internal Hazard from Fallout</u>

The fallout material can be inhaled or ingested and it will, of course, contaminate exposed food or water supplies. Thus, as with beta burns, the possibility of a hazard from this source is possible. As with the beta burns, however, there is evidence that the problem may not be too serious and relatively simple measures will aid in minimizing exposure. The particle sizes of the fallout material, reported by both Japanese and American scientists, exceed the optimal size for a major inhalation hazard. From published preliminary reports on the Marshallese exposed to fallout (Bull. Atom. Sci., <u>10</u>: 352, 1954), the A.E.C. considers the degree of internal hazard in the exposed persons to be small. This is encouraging, since it can be presumed that these people lived in a relatively primitive state where maximum probability of contamination of food and water supplies existed. If the hazard was minimum under those conditions, it should be even less under conditions of modern American living. With all of the testing of nuclear devices in Nevada and elsewhere, the level of strontium, the most important fission product as far as internal hazard is concerned, is still 1/1000 of the conservative A.E.C. tolerance.

I do not wish to imply that the problem should be neglected, since effects of internally-deposited radioactive materials may not become apparent for many years and, thus, the problem will not be fully evaluated for years. Every possible precaution against inhaling radioactive material, or of ingesting contaminated food and water should be taken. Gas masks that efficiently remove fission product particles from the air are available and even a wet cloth over the face is of considerable value for this purpose. Sprinkling of an area is effective in reducing the amount of dust in the air. Plain water, or soap and water will remove a large proportion of contaminant from most surfaces. That remaining is firmly fixed and is not likely to become airborn easily. If a personnel decontamination center is established, it should be relatively mobile and isolated from more permanent buildings where definitive care is given. This stems from the fact that contamination can only be transferred, not destroyed, and the decontamination area is likely to become quite "hot" in a relatively short time. Tinned goods can be eaten with complete safety and it is highly unlikely that city water systems outside the area of blast damage will be contaminated soon after a burst. One thing appears to be certain — any effects from internal radiation will be long range and will be of no concern in the acute period. Total-body radiation from gamma rays, and skin irradiation from beta-emitters will be the chief radiological concern at early times following an explosion.

Estimation of the Severity of Exposure to Gamma Radiation

The problems involved with estimation of dose received by the individual are difficult. It is possible that dose estimates may be available from dosimetry devices, or from dose-contour lines and the position of the individual during exposure. Some of the difficulties of relying heavily on dose estimates have been pointed out. The exact position of the individual and the degree of shielding will not be known. A dosimetry device records the dose the instrument received, which may not reflect accurately (because of shielding, energy dependence of the device, etc.) the dose received by the individual. More important, because of individual differences in sensitivity, two individuals exposed to the

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same measured dose may differ widely in their response. Thus, no estimate of dose derived from dosimeters or from the position of an individual duri exposure should be taken as an accurate index of the probable fate of an individual, or as a final index for therapy, triage or prognosis.

The best approach for estimating the seriousness of exposure of the individual may be termed the symptomatic approach. As with any disease, an accurate appraisal of the patient's condition results only from a thorough evaluation from the history (including physical estimates of dose a physical examination and pertinent laboratory data. If heavy exposure h occurred, nausea and vomiting will follow in most individuals within a few hours. This does not necessarily indicate a poor prognosis, however. Hea exposed individuals can be divided into three groups in which survival is respectively, improbable, possible and probable. It will be apparent that there is no sharp line of demarcation between the groups.

Group I. If vomiting is followed in rapid succession by prostration, diarrhea, anorexia and fever, the prognosis is grave and death will occur essentially 100% of individuals in the first or second week. The neutroph and lymphocyte counts are early and profoundly depressed. Therapy in this group is at present to no avail.

Group II. If vomiting has occurred early, followed by a period of well-be the patient should be watched closely and serial blood counts should be followed if possible. The lymphocytes are profoundly depressed within hou and remain so for months. The neutrophile count is depressed to low level the degree and time of maximum depression depending on dose. Signs of infection may be seen when the total neutrophile count has reached virtua zero (at approximately seven to nine days). The platelet count may reach very low levels after approximately the ninth day, and external signs of bleeding may follow. In higher exposure groups in this category, the latent period may extend from one to three weeks with little in evidence but mild malaise. At the termination of the latent period, the patient may develop purpura, epilation, oral and cutaneous lesions, infection of wounds and diarrhea or melena. The mortality may be high with no therapy, and in this group, therapy may be of maximum benefit.

Group III. Many individuals who are nauseated and may even vomit early after exposure show no further systemic effects of the exposure. Information on this group of individuals has been obtained from patients subjected to total-body radiation in the course of isotope therapy for paliation of metastatic bone lesions, particularly at Brookhaven National Laboratory. These data, coupled with that from animals and from other human exposures in this high sublethal dose range have yielded considerable information on this group. Evidence of exposure, in addition to early nausea and vomiting if it occurs, can be obtained only from laboratory data, chiefly blood counts. The lymphocytes reach low levels and may show little evidence of recovery for months after exposure. The granulocytes may show some depression during the second and third week; however, considerable variation is encountered. A late fall in the sixth or seventh week may occur and should be watched for. Platelet counts reach a low on approximately the thirtieth day, at the time when maximum purpura was observed in the Japanese exposed at Hiroshima and Nagasaki.

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In this group, individuals with neutrophile counts below $1000/mm^3$ may be completely asymptomatic. Likewise, patients with platelet counts of $75,000/mm^3$ or less may show no external signs of bleeding. It is well known that all defenses against infection are lowered even by sublethal doses of radiation and thus, patients with severe hematological depression should be kept under close observation and administered appropriate therapy as indicated.

Therapy of Radiation Injury

The treatment of acute radiation injury has been discussed in many publications and is essentially that which sound clinical judgment would dictate. Supplies and medications are those indicated for any mass casualty situation, and emphasis should lie chiefly on the magnitude of the supply problem. Antibiotics will be required in large amounts to combat the infection that plays a large role in morbidity and mortality among irradiated individuals, and blood, plasma and other intravenous fluids will be required to correct the shock, anemia and fluid imbalance. These agents should be used, as in all clinical conditions, when clinical and laboratory findings (if laboratory work is possible) indicate their need. Any marked prophylactic value of these agents has not been demonstrated, and considerations of probable short supply in the face of overwhelming demand would militate against their use in the absence of clear clinical indications. There are no drugs specific for radiation injury in man. Considerable progress is being made in developing agents effective in animals if given prior to irradiation. A promising new approach to post-exposure therapy lies in preparations of spleen and bone marrow found to be effective in animals. A second promising approach lies in the administration of separated neutrophiles to combat infection, and in giving separated platelets which will prevent hemorrhage. At present, none of these preparations is developed sufficiently to warrant consideration of stockpiling.

There are no specific drugs for the treatment of beta lesions of the skin. Scrupulous cleanliness should be observed and bland, water-soluble lotions may be applied. Infections should be treated with antibiotics as may be indicated.

A similar situation pertains with regard to the internal radiation hazard. Certain chelating agents and metals such as zirconium have shown considerable promise in animals both in preventing deposition of certain of the fission products in the bones and in accelerating their removal following deposition. The earlier these compounds are given following exposure, the more effective they are. However, as indicated above, it is doubtful that the need for such agents in the acute period following an attack would be great.

The following additional suggestions regarding the care of bomb victims are submitted for consideration. Although civil defense organizations in general have made great strides, it is apparent that even with a well-integrated plan some degree of chaos will be present and early aid to many victims will not be forthcoming. Hence, the importance of self-aid and mutual-aid in effecting survival must be stressed. Doctors and medical facilities of any kind will be in critical short supply; thus, training of lay individuals in more definitive treatment, rather than only first aid, deserves your careful consideration. Since accurate prediction of where a bomb will fall is impossible, central civil defense organization in critical target areas should be augmented by a "cellular" plan, a plan of geographical units within the area that are essentially self-sufficient in terms of supplies and communications, and which can render aid to other cells damaged by the bomb. Thinking in terms of damage within a target area adequately handled by the facilities of the region must be replaced with consideration of possible complete immobilization of facilities, with resultant dependence on adjacent non-affected regions for aid.

Summary and Conclusions

1) The medical problems in the immediate vicinity of a conventional atomic weapon or a super bomb will be essentially similar. With the larger weapon, of course, the areas of damage are much larger and, thus, the numbers of victims with mechanical, thermal, or radiation injury will be greatly increased.

2) In addition, with large weapons, an area of fallout can extend for thousands of square miles beyond the range of thermal and blast injury, resulting in gamma irradiation, beta irradiation of the skin and a potential internal hazard in the absence of blast or thermal injury. Serious fallout can occur several hours after detonation and at great distances. At this late time, the early, very steep fall in dose rate has already occurred and the dose rate falls off at a much slower rate. There may be adequate time for countermeasures and early evacuation or other effective evasive action will reduce by a large amount the total dose received.

3) The gamma radiation is by far the most serious hazard on the fallout area. It is penetrating, and exposure can result in the same acute radiation injury observed in the Japanese at Hiroshima and Nagasaki. The quantitative dose-effect relationships may be altered because of dose rate and other differences between the two types of exposure. NYOO

4) Beta radiation of the skin from fallout definitely can be a problem in the absence of lethal doses of associated gamma radiation. Although late in appearing, the skin lesions may be sufficiently serious

to result in a "casualty". Of equal importance, however, is the consideration of the effectiveness of rather simple countermeasures in preventing the lesions. The lesions apparently result mainly from material deposited directly on the skin, although beta radiation from the ground, building, or even clothes may contribute to a small degree. Thus, shelter within a building covering exposed skin areas with clothing and early skin and hair decontamination would go far toward preventing this hazard.

5) Some degree of internal contamination will occur in persons exposed to fallout. The amounts deposited in the body, however, will be relatively small. It appears certain that no contribution to the acute medical picture seen will result from this cause. It appears also, although data are incomplete, that little or no long-term hazard is likely to result from this cause, particularly if reasonable precautions are taken to avoid excessive inhalation or ingestion of the material. The acute medical problems in the fallout area will be concerned principally with total-body gamma exposure; some with beta irradiation of the skin.