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Prepared statement by Eugene P. Cronkite, M. D. on topic X (Somatic Effects) - B Marshallese etc., for testimony to the Joint Committee on Atomic Energy, Congress of the United States, for 3 June 1957 at the open hearings on "The Nature of Radioactive Fallout and Its Effects on Man".

Mr. Chairman, Congressmen and Observers:

I have been asked to summarize the early effects of exposure of animals and man to external radiation with particular reference to the effects of fallout radiation on the Marshallese, the Los Alamos accident and radium. In addition I have been asked to comment on the beta burns in the Marshallese and other examples of beta burns. Since my personal experience is limited to the Marshallese and animal experimentation I shall limit myself to these and supply reference material for the others.

It is quite impossible to cover all of this material in a reasonable period of time so I shall concentrate upon the effects of exposure to external radiation on animals and man with a clinical description of the syndrome of radiation sickness as a function of dose of radiation and highlight the discussion with illustrative material collected in the study of the Marshallese (1).

My prepared statement includes numerous references and further material that time will not permit discussion of at length here.

Radiation syndromes vary as a function of the type of exposure, the dose and the time after exposure to radiation. In general radiation injuries can be divided into three general classes:

a) The syndromes of whole body radiation injury produced by penetrating ionizing radiation which are dose and time dependent.

b) Superficial radiation burns produced by soft radiations (beta and low energy x or gamma radiations).

c) Radiation injury produced by the deposition of radionuclides within the body.

In the latter case the clinical picture varies with the site and amount of deposition.

Each of the above is associated with an early phase in which acute symptoms and signs may be observed, and a late phase in which chronic changes or manifestations such as cancer may be observed. I wish to emphasize also that the degree

of injury and the clinical manifestations are proportionate to the dose. This is particularly true of the syndromes of whole body radiation. The latter is and I repeat, highly dependent on dose and time after exposure. There is no simple description. The problem is subtle and complex and one must always bear dose and time in mind.

THE SYNDROMES FROM TOTAL BODY PENETRATING RADIATIONS

The dose dependent syndromes resulting from total body exposure in the mammal have been described in detail and I shall only summarize them here. For further details one is referred to the following references (1 - 12). After large doses (approximately 6000 r or more) the central nervous system syndrome which can be abbreviated CNS is produced. Death may occur under the beam while being irradiated or after some hours. The clinical picture is characterized by hyperexcitability, disorders of equilibrium, incoordination, respiratory distress and intermittent stupor. Convulsions may precede death. Doses capable of producing this syndrome are always uniformly fatal. If an occasional animal, and presumably man, survives this CNS he has yet to experience the gastrointestinal syndrome (GIS), which when produced by doses in excess of 1500 r is always fatal within three to nine days for mammals. Presumably man also will respond in a comparable manner as laboratory animals. The GIS is so named because of the marked nausea, vomiting, diarrhea, and denudation of the lining of the small bowel. The GIS is a uniformly fatal syndrome in most laboratory animals. If the short duration GIS of a few hours resulting from lower doses, does not produce the three to nine day death, the survivors of this syndrome have yet to experience the sequelae of bone marrow depression which has been termed the hemopoietic syndrome (HS). The HS is not necessarily fatal. It is the clinical picture that is seen in the lethal range for all mammals and in general the 50% lethal dose values reported, represent the LD^{50} for the sequela of hemopoietic depression - namely granulocytopenia, depressed defenses against infection, thrombopenia, and anemia with the possible resulting infections, diffuse pur-

purpa, and hypoxia due to anemia, any one of which may be fatal. Many detailed descriptions of the pathogenesis of these phenomena have been published (1-4,12-16).

The above picture of radiation syndromes is based on animal experimentation; however, human experience particularly as observed at Hiroshima and Nagasaki and in the Marshallese natives has indicated that man probably corresponds quite closely to the general mammalian response outlined above with the exception of some differences in time of occurrence. The CNS apparently was not observed by the Japanese at Hiroshima and Nagasaki. One would not expect it to have been observed since doses to produce this syndrome were well within the area of almost total destruction. The GIS with deaths in the first week are well documented clinically and pathologically as are deaths from the HS. However in the case of man, deaths from infection were most prevalent in the second to fourth weeks (maximum incidence during the third week) and from hemorrhagic phenomena in the third to the sixth weeks (maximum incidence in the fourth week). In the Japanese, after the bombing of Hiroshima and Nagasaki, deaths from radiation injuries were occurring as late as the seventh week. This is in contrast to other animals where deaths from the acute phase are uncommon after the 30th day.

PROBABILITY OF SURVIVAL AS RELATED TO SYMPTOMS

Predictions of the effects of various doses of gamma radiation are essential to military and civil defense planning. If the absolute sensitivity of man to radiation were known, and if it were practical to determine the dose to groups under catastrophe conditions, a realistic statistical prognosis could be made. However, these predictions cannot be made accurately at the present time. Problems involved with estimation of dose received by the individual, present real practical difficulties. It is probable that dose estimates will be available from dosimetry devices or from dose contour lines and the position of individuals during exposure. The difficulties of relying heavily on the dose estimates for a single individual are apparent. The exact position of the individual and the degree of shielding

will not be known precisely. The dosimetry device, records the dose or dose rate, which may not reflect accurately, because of shielding and energy dependence of the device, the deposition of radiant energy at the site of interest, namely the bone marrow and the lining of the intestinal tract.

The problems associated with predicting medical effects from physical estimation of dose can be further illustrated as follows: it is apparent that dose estimates available will be air doses. The dose received by the air is of academic interest only, since the degree of effect in living things is due to the deposition of energy and its distribution in the critical tissues. Accordingly one must know the depth dose pattern or more precisely the pattern of absorbed dose in sensitive critical tissues. This problem has been explored experimentally at great length and is described in detail in references (17). More need not be said here other than the fact that the uniform field of radiation coming at an individual from all directions is more effective per r in air than dose of radiation of directional quality. In urban areas there may be shielding from the fallout field by buildings or inhomogeneities in the field due to drift in dry windy areas. With the prompt radiation shielding may be significant and the proximity of large buildings may seriously influence scatter and perturb the uniformity of the radiation. Lastly a fallout field may be made unidirectional by heavy shielding from buildings on one side. Thus estimates of dose calculated from dose rates or derived from an integrating type of dosimeter that adds up to the total dose received, or form position of an individual during exposure, cannot be accepted as the best index of the probable fate of this individual, or as the final guide to treatment. The physician is interested in the individual from the standpoint of sorting casualties with some chance of survival and those for whom nothing can be done, and of equal importance the troop-commander is interested in the over all prognosis of large groups of individuals in order to make plans for disposition and replacement. These two different desires cannot be completely met by physical estimates of dose. However, nature has been helpful. The manifestations of radiation injury vary with

the amount of radiation received. In other words, the symptoms of the individual or groups of individuals becomes in a sense a personal indicator of ones' own fate. Experience with human radiation injury in Hiroshima and Nagasaki (4,5,10,11) with reactor accidents (3,6,9) and the fallout accident (1,18) to be described later strongly suggest that the best incex of the seriousness of exposure of the individual is the symptomatology, in addition to the physical estimate of dose.

Radiation injury is complex and subtle, and the manifestations of the injury vary considerably. In a general sense, individuals exposed in the lethal range, (here some, but not all, will die in the first several weeks following exposure) can be divided according to symptoms and signs, into groups having a different prognosis. Thus they may 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 among the groups. The distinguishing features are severity and persistence of vomiting and diarrhea.

Group I Survival Improbable:

If vomiting occurs promptly or within a few hours and continues and is followed in rapid succession by prostration, diarrhea, anorexia and fever the prognosis is grave: death will almost definitely occur in 100% of the individuals within the first week. There is no known therapy for these people; accordingly in a catastrophe attention should be devoted principally to others for whom there is some hope or in whom therapy is clearly indicated.

Group II Survival Possible:

Vomiting may occur early but will be of relatively short duration followed by a period of well being. In this period of well being marked changes are taking place in the hemopoietic tissues. Lymphocytes are profoundly depressed within hours and remain so for months. The neutrophil count is depressed to low levels, the degree and time of maximum depression depending upon the dose. Signs of infection may be seen when the total neutrophil count has reached virtually zero

(7 - 9 days). The platelet count may reach very low levels after two weeks. External evidence of bleeding may occur within two to four weeks. This group represents the lethal dose range in the classical pharmacologic sense. In this group the symptom free period (the latent period) lasts from one to three weeks with little clinical evidence of injuries other than slight fatigue. At the termination of the latent period, the patient may develop purpura,* epilation oral and cutaneous lesions, infections of wounds or burns, diarrhea or melena**. The mortality will be significant. With therapy the survival time can be expected to be prolonged and if sufficient time is provided for bone marrow regeneration the survival rate will be increased.

In group 1 (Survival impossible) and group 2 (Survival possible) the blood picture is not as well documented as in group 3 (Survival probable). There are good clinical reasons to believe that in the lethal range the granulocyte depressions will be marked and below 1,000 per mm^3 during the second week. Observations made in Japan confirm this contention. However in the sublethal range it takes much longer for the granulocyte and platelet count of man to reach minimal values, as compared to other mammals. Despite the chaotic conditions that existed in Hiroshima the data of Kikuchi and Wakisaka (11) shows that there was a more rapid and marked decrease in groups 1 (Survival improbable) and group 2 (Survival possible) than in group 3 (Survival probable). Before going on to group 3 survival probable, I cannot refrain from a comment on therapy.

Much has been learned from the experimental therapy of radiation injury in animals. It has been conclusively shown that protection can be afforded by the transplantation of bone marrow from one strain of animal to another. The protection afforded by transplantation of genetically specific material, that is from one member of the same strain to an irradiated member of the same strain, is very good and long lasting. If the material for transplantation has its source in another strain of mouse, the protection is less marked and not as long lasting. If the

* Bleeding into skin
** Black stools from digested blood

If the protective material comes from another species of animal the protection is very short lived and not nearly as effective. In principal the transplantation of bone marrow would significantly increase the survival rate of exposed human beings in the group 2 (Survival possible) and possibly to a lesser extent in the group 1 (Survival improbable) casualties. The amounts of bone marrow needed are large and the mongrel nature of man takes it unlikely that very much could be expected in the way of long term protective effect. In my opinion it would be the worst type of wishful thinking to expect that one could have an effective bone marrow bank in the case of an atomic catastrophe. Much work is yet to be done under carefully controlled clinical conditions before one could be optimistic about the use of this procedure in man under highly controlled conditions, for an individual patient let alone under conditions of a nuclear catastrophe.

However, the treatment of group 2 casualties is not at all hopeless. There is ample clinical experience in conditions where the bone marrow is severely depressed and in which there are inadequate numbers of circulating cells. In these relatively common clinical conditions produced by sensitivity to drugs, or occurring naturally as disease processes, the combined use of the wide spectrum antibiotics that are now available, and the judicious use of blood transfusions significantly increases the survival time of the individuals, thus giving nature a longer period of time to repair spontaneously the damages that has been suffered. Accordingly one could feel optimistic in respect to increasing significantly the survival rate of the group 2 (Survival possible) casualties by wide spread controlled use of antibiotics.* Preparation and stockpiling for such an emergency is obviously required.

Group III Survival Probable

This group consists of individuals who may or may not have had fleeting nausea

* Blood transfusions would be helpful to a limited extent for anemia. The probability of availability of enough blood for burns and other injuries is low. Hence when blood may be needed for radiation injury supply may be exhausted.

and vomiting on the day of exposure. In this group there is no further evidence of effects of the exposure except the hematologic (blood) changes that can be detected by serial studies of the blood with particular reference to lymphocytes and platelets. The lymphocytes reach low levels early, within 48 hours, and may show little evidence of recovery for many months after exposure. The granulocytes may show some depression during the second and third week. However, considerable variation is encountered. The late fall in the granulocytes, during the 6th or 7th week, may occur and should be watched for. Platelet counts reach lowest levels on approximately the 30th day at the time when maximum bleeding was observed in Japanese who were exposed at Hiroshima and Nagasaki. This time trend in the platelet count and the development of hemorrhage is in marked contrast to that seen in laboratory animals where platelets reach their lowest levels between the 10th and 15th days and hemorrhage occurs shortly thereafter.

In this group inidviduals with neutrophil counts below 1000 per cubic mm. may be complete by asymptomatic. Likewise, patients with platelet counts of 75,000 per cubic mm. 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 hematologic depression should be kept under close observation and administered appropriate therapy as indicated. There is reasonably good animal experimentation to indicate that sublethally exposed colonies of animals are more susceptible to endemic and epidemic infection.

The numbers of individuals in group 3 (Survival probable) will be greater than in group 2 (Survival Possible) and the number in group 2 will be greater than in group 1 (Survival improbable). Group 1 casualties will be helplessly injured. Group 2 casualties will be able to help in their own care to a limited extent. Group 3 casualties will be useful and a moderate amount of work will not be harmful. No therapy other than observation is needed for this group.

The rest of my comments will be focused on the fallout accident that occurred

on March 1, 1954. Following detonation, unexpected changes in the wind structure deposited radioactive materials on inhabited atolls and on ship of Joint Task Force #7 which was conducting the tests. Radiation surveys of the areas revealed injurious radiation levels; therefore evacution was ordered, and was carried out as quickly as possible with the facilities available. Althouth the estimated accumulated doses to human beings were believed to be below dangerous levels that would produce lasting injury or mortality the Commander of the Task Force requested assistance of the Department of Defense and the United States Atomic Energy Commission. A medical team was requested which would be organized to provide the best possible care of the exposed persons and to make a medical study of the exposures. The responsibility for organization of the medical team was shared between the Armed Forces Special Weapons Project D. O. D. and the Division of Biology and Medicine, United States Atomic Energy Commission. Since speed was essential and since the United States Navy Medical Department had experienced personnel available at the Naval Medical Research Institute and the United States Naval Radiological Defense Laboratory, the Surgeon General of the Department of the Navy was requested to provide assistance. He promptly complied and directed the organization of a team from the two above mentioned laboratories. I had the privilege to be the director of this team. Within a period of three days equipment was assembled and packed and the team was airlifted to the Marshall Islands arriving on the 8th day after the explosion. The interim care and study of the exposed individuals had been ably taken care of by the limited medical facilities of the United States Naval Station, Kwajalein. I am pleased to call attention to the fact of the very high degree of cooperation between all government agencies concerned and to the numerous individuals who selflessly gave of their time and efforts. The number is large and due credit and acknowledgments are given in the official report of the incidence published by the United States Government Printing Office and listed in reference (1).

NATURE OF THE EVENT AND DESCRIPTION OF THE EXPOSED GROUPS

The radioactive material fell on the inhabited atolls of Rongelap, the heaviest

dose; on Ailinginae; on Rongerik where American servicemen were stationed, and Utirik where the smallest dose was received but by the largest number of people. The Marshallese were living under relatively primitive conditions in lightly constructed palm houses.

The American military personnel had the second highest exposure. They were more aware of the significance of the fallout then were the Marshallese, and promptly put on additional clothing to protect their skin. As far as duties would permit, they remained inside of aluminum buildings. In contrast to this the Marshallese in general remained outside and accordingly were more heavily contaminated by the material falling upon the atoll and upon them.

All of the exposed human beings were evacuated by air and surface transportation to the United States Naval Station, Kwajalein, as promptly as facilities would permit. Since a survey of the individuals showed that there was significant contamination of the skin, clothes and hair, the clothes were removed and laundered and repeated washings of the skin and hair was carried out with fresh water and soap. The hair of the Marshallese was decontaminated with difficulty because of the heavy coconut oil hair dressing they used. On Rongelap there were 64 individuals that received an estimated dose of 175 r. On Ailinginae there were 18 individuals receiving approximately 69 r. On Rongerik there were 28 American servicemen receiving approximately 78 r. On Utirik there were 157 individuals receiving approximately 14 r.

Whole Body Gamma Doses

The determination of the whole body gamma doses are dependent upon the surveys that were made with calibrated instruments approximately 3 feet above the ground several days after the inhabitants were evacuated. In addition certain assumptions had to be made about the arrival time of the cloud and the rate of fallout of the material. Only on Rongerik where there was a recording dosimeter is arrival time known precisely. The dose rate of the continuing fallout of material was in part

neutralized by the progressive radioactive decay. In addition the transit dose from the cloud passing over the atolls could not be estimated. All of these variables were taken into account and the doses calculated. These doses were consistent with the doses that were actually measured on Rongerik by film that was stored in refrigerators and by film exposed outside on this atoll. In view of this internal consistency it is believed that the dose of radiation on the atolls is reasonably accurate. Details of the calculation of the dose are in the official report which discusses in detail the probable range in values (ref. 1, Chapter 1)

CHARACTERISTICS OF THE GAMMA RADIATION

The fallout material when deposited on the ground formed a large planar source of radiation. The energy distribution of the radiation reaching an exposed individual is influenced by its passage through the intervening air. A knowledge of the inherent gamma spectrum as it emminates from the material itself is essential in order to determine the spectrum that impinges upon exposed individuals. When one takes into account the spectometric data on the mixed fission products and the degredation by Compton scattering along the path in air, a dose energy histogram can be constructed, showing that there are roughly three regions with maxima at 100, 700, and 1500 KEV. The total exposure is thus the resultant effect of partial doses from each energy region, making the exposure energy condition significantly different from those of radiation therapy, experimental biology or from the prompt gamma radiation of the bomb. Details of the characteristics of the exposure are discussed in reference. (Ref. 1, Chapter 1).

THE CHARACTERISTICS OF THE FALLOUT MATERIAL

The fallout material consisted predominantly of flakes of calcium oxide resulting from the incineration of the coral. Upon the flakes of calcium oxide fission products were deposited. At Rongelap Atoll the material was visible and described as snow like. It stuck to the skin, adhered to the hair and clothes, the vegetation

and the habitations.

GEOMETRY OF THE EXPOSURE

Time does not permit a discussion of the effect of this but it has been eluded to earlier and details of the influence of geometry of the exposure to biologic effect are in references (3,17).

SUPERFICIAL DOSES OF RADIATION FROM BETA AND SOFT GAMMA RADIATION

There is no doubt that the dose of radiation to the first few millimeters of the skin is substantially higher than that at the midline of the body from the more penetrating gamma component. Problems concerned with the estimation of the dose of radiation to the skin are discussed in detail in reference 1, chapter 1.

To arrive at some physical estimate of the skin dose an attempt must be made to add up the contributions of the penetrating gamma, the less penetrating gamma, the beta bath to which the individuals were exposed from the relatively uniform deposition of fission products in the environment and the point contact source of material deposited on the skin. By all means the largest component of skin irradia- resulted from the spotty local deposits of fallout material on exposed surfaces of the body. It is completely impossible to estimate the dose from material that was deposited on the skin. The relative hazard of the beta bath is discussed in detail in the previously mentioned reference (1).

CLINICAL OBSERVATIONS AND TREATMENT

SYMPTOMS AND SIGNS RELATED TO RADIATION INJURY

Itching and burning of the skin occurred in 28% of the people on Rongelap, 20% of the group on Ailinginae and 5% of the Americans. There were no symptoms referable to the skin in the individuals on Utirik. In addition to the itching of the skin there was burning of the eyes and lacrimation in people on Rongelap and Ailinginae. It is probable that these initial skin symptoms were due to irradiation since all individuals who experienced the initial symptoms later developed unquestioned radiation induced skin lesions that will be described in detail

later. It is possible however that the intensely alkaline nature of the calcium oxide when dissolved in perspiration might have contributed to the initial symptoms.

About 2/3rds of the Rongelap group were nauseated during the first two days and 1/10th vomited and had diarrhea. One person in the Ailinginae group was nauseated. No one in the Rongerik or Utirik group had gastrointestinal symptoms.

CLINICAL OBSERVATIONS AND LEUKOCYTE COUNTS

Between the 33rd and the 43rd post exposure day 10% of the individuals from Rongelap had an absolute granulocyte level of 1,000 per cubic millimeter or less. The lowest count during this period was 700 per cubic millimeter. During this interval the advisability of prophylactic administration of antibiotics was seriously considered. However prophylactic administration of antibiotics was not instituted for the following reasons:

1) All individuals were under continuous medical observation so that infection if it developed would have been discovered in its earlier stages.

2) Premature administration of antibiotics might have obscured medical indications for treatment, and might also have led to the development of drug resistant organisms in individuals with lowered resistance to infection.

3) There was no accurate knowledge of the number of granulocytes required by man to prevent infection with this type of granulocytopenia.

The observed situation was not strictly comparable to agranulocytosis with an aplastic marrow as seen following known lethal doses of radiation. In the latter instant, granulocytes fall rapidly with practically none in the circulation and no evidence of granulocyte regeneration when infection occurs. In the present group of individuals exposed to radiation, most counts reached approximately 1/4 the normal value, but the fall to that level was gradual and the presence of immature granulocytes in the peripheral blood during the period of granulocytopenia was indicative of some new granulocyte production. The few individuals that received antibiotics had conditions that would have been treated with antibiotics in the absence of any

previous exposure to irradiation. During the 4th and 5th exposure weeks an epidemic of upper respiratory infection occurred. The respiratory infection consisted of moderate malaise, pharyngitis with prominent lymphoid follicles, fever during the first day and a surulent nasal and tracheal discharge for about 10 days. It was of interest to determine whether this respiratory infection could be correlated with the dose of radiation received or changes in the leukocyte count. There was no correlation The respiratory infection in the medical personnel involved in the care and study of the irradiated individuals was similar in incidence and severity.

Clinical Observations and Platelet Counts

Eleven individuals had platelet counts that fell as low as 35,000 to 65,000/mm^3. All individuals with platelet counts less than 100,000 per mm^3 were examined daily for evidence of hemorrhage into the skin, mucuous membranes and retina. Urine was examined daily for red cells and albumin. Women were questioned concerning excessive menstruation. The only evidence for any undue bleeding were two women who menstruated profusely at the time of their maximum platelet depression. It was not sufficient to cause them concern and subsided without any specific treatment.

The Effects on Pregnancy

Four women in the Rongelap group were pregnant when brought to Kwajalein. Two were in the first trimester, one in the second trimester and one in the third trimester. There were no abnormal symptoms referable to pregnancy. As far as could be determined the pregnancy continued in the normal fashion. In the Ailinginae group, one woman was in the second trimester. Fetal movements were unaffected in the individual in the third trimester. The pregnant women had a marked depression of platelet counts but at no time was there any vaginal bleeding. At the twelve month reexamination of the above women all had delivered. One baby was born dead the others were normal. In the case of the one stillborn, irradiation occurred to the mother either before conception or early in the first trimester. It is possible that the irradiation may have contributed but there is no way to prove this.

Special Examination of Eyes

At all followup examinations an ophthalmologist has examined the eyes of all individuals. To date no lesions ascribable to ionizing radiation have been found. Similar studies have been made on the eyes of non exposed Marshallese and the incidence of eye lesions is identical in the two groups.

SKIN LESIONS AND EPILATION

As mentioned earlier there was burning of the skin. On first examination by the medical team on the 9th post exposure day the exposed people appeared to be in good health and the skin was definitely normal in external appearance. Evidence for the development of skin lesions commenced approximately two weeks after exposure. During the early stages of development of the lesions, itching, burning and slight pain were experienced with the more superficial lesions. With deeper lesions the pain was more severe. The deeper foot lesions were the most painful and caused some of the people to walk on their heels for several days during the acute stages. Some of the more severe lesions of the neck and axillae were painful. There were no constitutional symptoms associated with the skin lesions. The characteristic sequence of events in the development of the lesions was the occurrence of symptoms, then of black pigmented areas, small in size which grew larger in size and coalesced. Later the skin began to shed from the inside of the pigmented plaques to the outside and in some cases resulted in the production of large depigmented areas. In most of the lesions the shedding was limited to the superficial layers of the skin. In some the process continued with the development of superficial ulcers. A few became infected. The appearance of these skin burns can best be illustrated by referring to Chapter III reference (1) where kodachrome pictures illustrate the sequence of events. In addition to the skin burns, loss of hair, spotty in nature occurred in some of the individuals. The hair grew in again with normal color and texture and the regrowth was complete in all except possibly one middle aged man in whom it came in somewhat sparsely. Small pieces of skin were

removed surgically from some of the burned areas for microscopic study. These pieces of skin demonstrate the typical findings of radiation injury. Some of the skin burns became infected particularly those on the feet and were treated locally by cleansing and applications of antibiotic ointments. The skin burns healed in most cases with return of normal color and texture of the skin and in some cases scars were left with depigmented areas. The worst burn occurred on the back of the ear of a middle aged man. It produced a permanent scar with absence of pigment and abnormal blood vessels and a slight horny growth of the overlying skin has developed. The skin has been carefully observed at 6 months, 12 months, 2 years and 3 years after exposure and there is no evidence at the present time of any breakdown in the early burns of the skin. There is no evidence of the development of cancer at this time. In some the depigmented scars are still evident. The individuals have been seen on two occasions by a plastic surgeon, Dr. Bradford Cannon of the Harvard Medical School who feels that no plastic repair is necessary and that the prognosis in general is good.

FACTORS INFLUENCING SEVERITY OF THE LESIONS

Certain lessons were learned from the Marshallese experience.

Burns were caused by direct contact of the radioactive material with the skin. The perspiration as common in the tropics, the delay in decontamination and the difficulties in decontamination certainly favored the development of the skin burns. Those individuals who remained indoors or under trees during the fallout developed less severe skin burns. The children who went wading in the ocean developed fewer lesions of the feet and most of the Americans who were more aware of the dangers of the fallout, took shelter in aluminum buildings and bathed and changed clothes. Consequently they developed only very mild beta burns. Lastly a single layer of cotton material offered almost complete protection as was demonstrated by the fact that skin burns developed almost entirely on the exposed parts of the body. The prognosis of beta skin burns and radiation burns of the skin is excellently described

in Chapter III of reference (1).

HEMATOLOGIC OBSERVATIONS

It is generally considered that changes in the blood are the most sensitive biologic indices of exposure of living human beings to radiation. Accordingly extensive simple hematologic studies were performed on the Marshallese. Since there were no previous hematologic studies on the exposed Marshallese, it was necessary to set up control groups of non exposed Marshalled of the same age and sex distribution for comparative purposes. I shall restrict my comments to the findings in the group from Rongelap since the temporal sequence of events are identical in all of the exposed groups. Of course the depression was less marked in the less severly exposed groups.

Neutrophile Count

The absolute neutrophile count of both the younger and older age groups fell during the second week to a value approximating 70 to 80% of that of the controls. Following the depression there was an oscillation roughly around the control value until about the 30th post exposure day at which time there was a progressive decrease in the blood count with minimum values being attained around the 45th day after exposure. It is of interest, that the depression in the children, less than 5 years of age was greater than in the individuals who were greater than 5 years of age. Following this maximal depression there was a slow return of the neutrophile counts towards normal. However at 6 months they were still depressed. At one year and two years the neutrophile counts were back to the control level. However at 3 years there was a drop in the absolute mean neutrophile count but this also occurred in the control population. It is not known whether lowered counts represent a population trend as has been noted in the Japanese for both irradiated and non irradiated populations, or whether it is merely a statistical fluctuation that is to be expected in this type of study. More work is necessary on this point.

Lymphocyte Count

By three days the lymphocytes dropped to 50% of the controls. The percent drop in the children less than 5 years of age was greater than that of the people greater than 5 years. The lymphocyte count remained at approximately the same level through the exposure period. At 6 months, twelve months, two years and three years the level though increasing had not quite reached that of the control population.

Platelets

The maximum depression in platelets was obtained approximately 28 to 30 days after exposure in contrast to laboratory animals that attain their minimum values between the 10th and 15th days after exposure. In this case the children under 10 years of age had a greater percentage drop than those who were older. The platelets began to recover after the 30th day attained a maximum about the 45th day. There was then a seconcary drop with a leveling off for the remainder of the post exposure period and at 6 months, 12 months, two years and three years slow recovery was still under way. The levels of the population were approaching the controls but have not yet reached it. In all of the hematologic studies mentioned above it is stated that the present levels are not equal to that of the controlled population. However I wish to emphasize that the current levels of the blood cells of all types is more than adequate to take care of the infections and the various troubles of everyday existence. This statistical expression of a inadequate recovery probably represents the residual radiation injury that is of considerable interest to study but does not appear to be overtly harmful to the individuals. One can be reasonably confident in this because they are not faring less well in resistance to disease than are the Marshallese who were nonexposed and living in the same area.

INTERNAL ABSORPTION OF RADIONUCLIDES

During the two days before evacuation, the Rongelap people lived under conditions of extreme contamination without any concerted efforts to protect themselves against the dangers of internal contamination. These individuals drank contaminated water, and ate their natural foodstuffs which were contaminated externally, Their hands

were contaminated; they inhaled and obviously ingested certain indeterminate amounts of material.

The body burdens of isotopes in these individuals was evaluated by radio chemical analysis of the urine of the exposed people and assisted by studies on swine. These swine were removed from the island at a later date. The urinary and fecal excretion was studied and ultimately the animals were killed. Extensive radio chemicals anslysis were made of their entire bodies. By comparison approximations of body burdens of radionuclides was made.

Rare and alkaline earths accounted for about 70% of the urine activity. Strontium 89 was about at the maximum permissable level at one day. Iodine ^{131} and other members of the iodine family which had to be present early, resulted in a dose of radiation to the thyroid glands, estimated between 100 and 150 rep. To this of course, must be added the penetrating external gamma component. By 6 months radiation was barely detectable in the urine. At 2 years from analysis of pooled urine samples and individual samples very tiny amounts of Sr^{90}, Ca^{45}, Pr. and Cs were present*. The results of the three year radiochemical analysis of the urines that were recently collected are not completed as yet. It was believed that the body burdens of these people was very low and probably biologically insignificant. However it was decided to bring some of the individuals to the United States for study with the total body gamma counter at the Argonne National Laboratory. This decision was made not because of any fear but because the analysis of the urine and the animal analysis was an indirect means to obtain probable body burdens. It was obviously desireable to obtain a firm direct measurement of the body burden from the scientific standpoint and to determine the precise body burdens. Four individuals from the Rongelap group, two from the Utirik group and one control Marshallese (a total of 7) were brought to the United States and taken to the Argonne National Laboratory. There , under the direction of Drs. Marinelli, Rose and Miller the total body gamma activity was measured. The

* Studies performed both at U. S. Naval Radiological Defense Laboratory and Walter Reed Army Medical Center.

results are yet incomplete and have to be analyzed further. It was found that the exposed Marshallese had counts that were higher than non exposed peoples in the United States. However the values were far below the current permissable levels.

Since there has been some misunderstanding in the press about children being brought to the United States for study I would like to state that all the individuals brought to the United States were adults with the exception of one 16 year old boy. They have subsequently been returned to the Marshall Islands.

THE CONTINUING STUDY OF THE MARSHALLESE

My associate in the Medical Department of Brookhaven National Laboratory, Dr. Robert A. Conard, a member of the original team that took care of and studied the Marshallese and director of the two and three year surveys has retained an abiding interest in the Marshallese. On behalf of the Atomic Energy Commission and Brookhaven National Laboratory he has undertaken the continuing responsibility of yearly surveys of these people. These surveys are being made possible by the cooperation of the Medical Department of the United States Navy and its activities, the Medical Research Institute at Bethesda, Maryland and the United States Naval Radiological Defense Laboratory in San Francisco. The continuing project is a joint effort directed by Dr. Conard and participated in by the Medical Department of Brookhaven National Laboratory, the two Navy institutions mentioned earlier and interested physicians and scientists of various American universities and medical schools.

One cannot leave this tremendously important subject of fallout and the unfortunate accident that occurred in the Marshall Islands in 1954 without the frank recognition that late effects of ionizing radiation are possible. Many late effects have been observed in man and in animals. These are condensed in detail in the National Academy of Sciences report (8). Accordingly a search for late effects is an essential part of the continuing survey. A summary of the 3 year status of these people follows.*

* It will be reported in detail in reference 22 now being prepared.

Fertility

Effects of radiation exposure on fertility is difficult to assess in the Marshallese. If there has been any effect on fertility it must have been very short lived since pregnancies are occurring normally and at rate similar to other groups of Marshallese.

Pregnancy

There has been no apparent effects of radiation on the course of pregnancy in the Marshallese. Since the delivery of the four women who were pregnant at the time of the event, there have been twelve pregnancies which have terminated. Ten of these terminated normally, one terminated in a stillbirth and one baby died several hours after birth apparently of an infection of the cord. The lack of vital statistics makes this data difficult to interpret. However it does not appear that this incidence of still births is greater than that of other comparable native groups in the mid Pacific area.

Effects on the Fetus

The three babies irradiated in-utero have not shown any abnormalities such as was observed in some of the Japanese babies irradiated in-utero (for example microcephaly).

Growth and Development

On each resurvey the exposed and control children have been matched for age and sex. Measurements on growth and development have been carried out. Anthropometri measurements have been incompletely analysed as yet. Since the numbers of children are small the data is not easily subjected to statistical analysis. However there does appear to be evidence suggestive of a slight impairment of growth and development as measured by comparison of height and weight in the control and exposed children. No abnormalities of the eyes have been observed.

Shortening of Life Span

In animals the evidence for shortening of life span is quite good. It is

evident that the life shortening is some function of the dose of radiation. However, the extrapolation from mice to man is extremely difficulty. It is unlikely that any good statistical analysis can be made on the Marshallese because of the small numbers of individuals and the uncertainty of the precise birthdate in the older groups. There has been one death in the Rongelap group who at autopsy showed evidence of heart disease. In the larger group from Utirik there have been five deaths. The number of deaths is comparable in both groups one having received 175 r and the latter only 14 r. To date one must conclude that there has been no significant evidence for premature ageing or shortening of the life span of the Marshallese.

Leukemia and Cancer

Leukemia is one of the things that is know to have occurred in the Japanese and is prevalent in irradiated laboratory animals. To date no leukemia has occurred and there is no evidence of leukemic tendencies. This is being studied intensively by the use of alkaline phosphatase studies on the granulocytes and basophile counts on the blood. It has been shown by the studies of Moloney et al., in Japan that a basophilia and decrease in alkaline phosphatase precedes the development of leukemia.

Genetic Effects

The small number of individuals involved and the inadequate vital statistics make it difficult to determine genetic changes. It is certain that there have been no abnormalities in the first generation of babies. The undesireable aspects for genetic studies are in part offset by the tendency of consanguinous marriages that are prevalent among the Marshallese. From this standpoint genetic effects may develop and are being sought.

Long Term Effects of Internally Deposited Radionuclides

The very small amounts of radioactive materials that are deposited internally are by themselves inadequate to produce serious long term effects. However the subject is complicated by the fact that the individuals had a substantial initial insult from whole body radiation. In addition to the whole body radiation the thyroid gland

received approximately 100 to 150 rep from the short lived iodine family. It has been reported that irradiation of the thyroid area in early life increases the incidence of cancer of the thyroid. Accordingly thyroid function and the possilbity of thyroid cancer is being studied in the Marshallese children.

Before concluding I cannot refrain from expressing my personal opinion and conviction on two aspects of the fallout problem. First, the acute and long term hazards of fallout such as would occur following the use of thermonuclear devices in warfare is simply unthinkable. The wide spread contamination over continental areas from multiple detonations of thermonuclear devices over pupulated areas would produce radiation hazards for all living things and for generations to come. These hazards are understood. These bazards cannot be considered as the usual "calculated risk basis" of warfare in the past. One can only make a plea that an enlightened world, will demand that their representatives in government also appreciate these hazards and with this recognition bring every conceivable effort of diplomacy to solve the problems posed by differences in political and economic ideologies and thus prevent a type of warfare that cannot be considered in terms of "calculated risk".

Second the world wide low level radiation of today from diverse sources has been analyzed thoughtfully by competent people individually and in assembly. Note the sober and realistic reports of the National Academy of Sciences, the British Medical Research Council and the United Nations. These reports point out the multiple sources of radiation in our lives today and the necessity for continuous scrutiny. Let us not confuse unavoidable radiation exposure with radiation hazard. Let us not lose sight of the multiple sources by undue preoccupation with world wide fallout. Let us not be so preoccupied with radiation in general that we forget about industrial pollution of our environment in general by non radioactive but toxic substances. Lastly the incidence of leukemia was apparently increasing prior to the development of atomic energy. Why?

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