Late Effects of Radioactive Fallout on the Thyroid Gland in a Marshallese Population

During the past four years cases of thyroid abnormalities have developed in a Marshallese population who were accidentally exposed to radioactive fallout in 1954. Before discussing this development, I would like to briefly review the background of the accident and some of the other effects noted in this population which are believed to have been associated with their radiation exposure.

The accident occurred on March 1st, 1954 when a thermonuclear device was detonated at Bikini in the Pacific proving grounds. The yield was larger than expected and since the fireball touched the ground, large amounts of incinerated coral and debris were mixed with the radioactive cloud. An unpredicted shift in winds occurred high aloft and instead of the cloud going in a northerly direction over the open sea, it veered to the east dropping radioactive fallout on several inhabited islands.

The first slide shows the fallout pattern and location of the exposed islands as related to Bikini. The 64 Marshallese on Rongelap atoll received the heaviest exposure and it is this group that has shown the major radiation effects. The island groups with their exposure status are shown in the following table.

Summary of Fallout Effects

Group*	Composition	Fallout observed	Estimated gamma dose (rads)	Skin Lesions
Rongelap	64 Marshallese	Heavy(snowlike)	175	Numerous
Ailingnae	18 Marshallese	Moderate(mistlike)	69	Less Numerous
Rongerik	28 Americans	Moderate(mistlike)	78	Slight
Utirik	157 Marshallese	None	14	No skin lesions or epilation

*Also exposed were 23 Japanese fishermen aboard their vessel "Lucky Dragon" who received a sublethal dose.

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The next few slides show the village of Rongelap at that time and some of the people. All of these island groups were evacuated about two days after the accident and taken to a Naval base to the south where extensive medical examinations and personnel decontamination were carried out over a three month period. The next slide shows a group of Marshallese bathing in the lagoon to remove radioactive contamination from their bodies.

Examinations showed fewer radiation effects in the American servicemen and the Utirik people, and the former were returned to their duty station and the latter to their home island. However, Rongelap island was too contaminated and the people lived in a temporary village in a southern atoll of the Marshalls for three years. In 1957 a fine new village was built at Rongelap by the Atomic Energy Commission. The radiation levels on the island at this time were considered acceptable and the people were returned. The next several slides show pictures of the new village.

Annual examinations by medical specialists from the United States and medical personnel from the Trust Territory of the Pacific Islands have been conducted under the auspices of the Atomic Energy Commission and Brookhaven National Laboratory with the accumulation and publication of much valuable data. Some 200 unexposed Rongelap people, away from the island at the time of the accident, have since moved back with the exposed people and afford a most satisfactory comparison population.

The early or acute effects of the exposure of the Rongelap people will now be briefly reviewed. The penetrating gamma radiation dose of 175 rads resulted in temporary anorexia and nausea in the majority of people with vomiting and diarrhea in a few, during the first two days after exposure.

Depression of blood elements was the most notable subsequent finding. White blood cells dropped to levels of about one fourth to one half normal by about six weeks followed by slow recovery. Platelet levels dropped to one eighth to one third normal levels by 30 days. In spite of the significant hematological depression no evidence of increase in infections or frank bleeding was noted. No special therapy was necessary.

No deaths have occurred to date that could be unequivocally related to the radiation exposure.

The next slide shows the percent depression of blood levels compared to the comparison population. It can be seen that a slightly incomplete recovery of blood levels in the exposed people was noted for about 11 years after exposure. This may represent a slight residual damage to the bone marrow.

Let us now review the acute effects of their exposure on the skin. The deposition of fallout material on exposed areas of the skin not covered by clothing resulted in itching and burning sensations during the first two days. Further symptomatology was not noted until about two weeks after the accident when skin lesions, so called "beta burns" appeared. The next few slides show examples of these burns and demonstrate the sequence of pigmentation, desquamation and repigmentation that occurred. About 90% of the people had these burns of the skin. All but about 15% were superficial in nature and healed rapidly. The deeper burns left some scarring and pigment aberrations which are still present today. Though a few benign moles have appeared recently in the areas of more severe burns, no evidence of any skin malignancy has been apparent.

Internal absorption of radioactive material occurred in the Rongelap people as a result of their living in a contaminated environment for the two

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days before their evacuation. They absorbed radioactive fission products in the food and water that they consumed. Radiochemical urine analysis revealed the presence of various isotopes. As seen in the following table the isotopes of strontium and iodine contributed the largest dose.

Estimated Body Burden of Rongelap People (μCi)

Isotope	Activity at Day 1	Activity at Day 82
^{89}Sr	1.6-2.2	0.19
^{140}Ba	0.34-2.7	0.021
Rare Earths	0.12	0.03
^{131}I(in thyroid gland)	6.4-11.2	0.0
^{103}Ru	0-0.013	-
^{45}Ca	0-0.019	0.0
Fossile Material	0-0.16 (μgm)	0.0

More will be said shortly about the radioiodine dose to the thyroid gland. No acute effects of this internal exposure were apparent in the people and by six months the urinary excretions indicated greatly reduced body burdens. When the people were returned to Rongelap in 1957 a slight residual radioactive contamination of the island resulted in the accumulation of detectable but low body burdens of ^{137}Cs, ^{65}Zn and ^{90}Sr.

Before discussing the thyroid effects in the exposed people, let us examine certain other late findings, some of which, appear to have been related to their radiation exposure. During the years after the accident the exposed people have remained generally in good health with no greater incidence of

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illnesses or degenerative diseases than seen in the unexposed populations examined. During the 14 years since exposure fifteen deaths among the 82 exposed people of Rongelap have occurred. This death rate was somewhat greater in the exposed people but in no case was there definite relation of cause of death with radiation exposure. It should be mentioned that there have been a greater number of older people in the exposed group.

No leukemia has been seen. The occurence of three cases of cancer in the exposed group(one of the thyroid gland) presents a higher incidence in this exposed group but due to the small numbers of people involved, final decision on this point must await the results of future observations.

Based on birth rates, fertility has been about equal in the exposed group as compared with the unexposed population. However about twice the number of miscarriages and stillbirths occurred in the exposed women during the first four years after exposure. Fetal abnormalities do not appear to have been more numerous in the exposed group. No specific genetic studies have been carried out.

A low level of persisting chromosomal aberrations, of the type induced by radiation, have been noted as late as ten years postexposure in the Rongelap people.

Frequent slit-lamp observations have revealed no opacities of the lens characteristic of radiation exposure.

Evidence for premature aging or shortened life span in the exposed population compared with the unexposed population have not been apparent as a result of studies quantifying a number of recognized aging parameters.

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Growth and development studies of children using anthropometric measurements and bone age radiographic studies have revealed a slight retardation in growth and development of some of the boys exposed at less than 12 years of age. The greatest retardation was noted in several children exposed between 12 and 18 months of age. Only slight immaturity has been noted in the female children. The next slide shows the relatively greater retardation in skeleton age in exposed boys than in girls. The next slide shows the statural growth retardation in exposed boys. The cause of the growth retardation was not known until the recent detection of thyroid abnormalities. This will be discussed below.

There were several isotopes of iodine absorbed from the fallout, ^{131}I, ^{132}I, ^{133}I, ^{135}I. Thyroid accumulation of these isotopes resulted from consumption of contaminated food and water and possibly to some extent from inhalation. Since no direct measurements of radiation in the thyroid gland were made it was necessary to use an indirect approach, that is, the radioiodine measured in the urine analyses which were collected at 15 days after exposure. By extrapolation it was estimated that about 11.2 μCi ^{131}I was accumulated in the thyroid gland during the exposure. The adult gland was estimated to have received about 160 rads from the iodine isotopes in addition to 175 rads from the gamma radiation. The dose to the much smaller glands of children was quite likely higher. It was estimated that the dose to thyroid glands of children less than 4 years of age was in the range of 700 - 1400 rads. "Beta burns" in the neck region over the thyroid, as shown in the next slide, were not considered to have added any significant dose to the thyroid gland because of the low energies of the beta activity.

Annual examinations had always included careful thyroid examinations

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including plasma protein bound iodine and cholesterol studies. Until recently these examinations had not revealed any apparent abnormality of the gland. In 1963 a thyroid nodule was first detected in a 12 year old exposed girl and in the following year two more teen age girls were discovered to have nodules. Since then the incidence of thyroid abnormalities has increased and at the present time 19 people with thyroid abnormalities have been noted, all of these occurring in the more heavily exposed group except one in an adult in the Ailingnae group. Only three such cases have been detected in adults, the remaining 16 cases having occurred in children exposed at less than 10 years of age. The following table shows the high incidence(84%) of these abnormalities in this younger group.

THYROID NODULES (INCLUDING HYPOTHYROIDISM)

IN MARSHALLESE POPULATIONS

(R=Rongelap; A=Ailingnae; UT=Utirik; C=Unexposed)

Group	Age At Exposure	No. in Group	Gamma Dose (rads)	Estimated Thyroid Dose (I*, rads)	% Thyroid Nodules
R	<10	19	175	700-1400	84.2
A	<10	6	69	275-550	0.0
UT	<10	40	14	55-110	0.0
C	<10	61	0	0	0.0
R	>10	36	175	160	5.5
A	>10	8	69	55	12.5
UT	>10	59	14	15	3.4
C	>10	133	0	0	2.3

*In estimating the thyroid doses to the Ailingnae and Utirik exposed group, it was assumed that such doses were proportional to the thyroid doses of the Rongelap exposed group, based on relative whole body gamma dose received.

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Note the absence of such findings in the less exposed 6 Ailingnae children that received an estimated thyroid dose of 345-620 rads, the 40 Utirik children who received an estimated thyroid dose of 69-124 rads and the 61 unexposed children of comparable age. Though these numbers are small they do give an idea of the dose-response relationship for these thyroid effects.

Thyroid surgery was performed on 9 children and 2 adults. All nodules were found to be benign in the children. One adult, a 41 year old woman in the higher exposure group had a cancer. In addition to those cases with thyroid nodules, 2 boys showed atrophy of the thyroid gland with signs of hypothyroidism. Interestingly enough these 2 boys were the ones who were the most retarded in growth and development. The next slide shows the gross appearance of the nodules at surgery. Note the varied size of the nodules from several millimeters to several centimeters, some being cystic, and some hemorrhagic. The next slide shows the microscopic characteristics of these benign nodules. They resemble closely adenomatous goiter usually seen with iodine deficiency and definite radiation effects were not identified in the glands by most pathologists. The next slides show the gross and microscopic appearance of the mixed papillary and follicular cancer with localized metastases that occurred in the woman referred to above.

It has become increasingly clear that the growth retardation noted in the children is probably associated with thyroid deficiency, even though a hypothyroid tendency was not detected in earlier years when the growth retardation was first noted. It has since been discovered that a high level of iodoprotein is normally present in the Marshallese people which gives a falsely high PBI level. This may have masked a low degree of hormone

deficiency. However in the past two years the 2 boys showing the greatest growth retardation have developed characteristics of frank hypothyroidism with atropy of the thyroid gland, drop in PBI level to less than 2 μg%, development of coarse facial features, dry skin and Achilles reflex with sluggish return and bone disgenesis. High pituitary TSH levels indicated a primary hypothyroidism. Several other children with less degree of growth retardation have recently shown some degree of thyroid deficiency also.

In view of the seriousness of these findings it was decided to initiate thyroid hormone therapy on the exposed people. The rational now for this form of therapy was that by furnishing normal levels of exogenous thyroid hormone, pituitary TSH levels would be repressed and remove the thyroid gland from stimulation of that hormone. It is thus hoped that further development of nodules and possible malignancy might be prevented and of equal importance enhancement of growth and development in the children might result. Conclusive results of this treatment must await further observations and a stricter treatment regimen. However it does appear that several nodules have reduced on this treatment and some children may be showing increased growth. The next slide shows the results of hormone treatment on the 2 boys who had shown growth retardation, referred to before. It can be seen that there has been a spurt in skeletal development coincident with the institution of the thyroid therapy.

The exclusive development of these thyroid abnormalities in the irradiated Marshallese children seems clearly to indicate the radiation etiology. The development of such abnormalities is consistent with the known etiological relationship of irradiation of the thyroid gland and the development of such lesions. The high incidence in the children is probably related to the larger

dose of radiation received by their smaller glands. Though the pathological changes in the nodules are similar to those seen in iodine deficiency goiter there is no reason to suspect such causal relationship in the Marshallese cases since dietary iodine is normal, urinary excretion of iodine is in the normal range and there are no known goitrogenic foods.

The radiation induction of such changes in the thyroid could conceivably result from injury to the thyroid gland reducing the hormone output and thus calling on the pituitary to secrete a greater amount of TSH. This would give the thyroid picture of hypertrophy in those follicles capable of responding to such hormone and the presence also of atrophic follicles incapable of responding. In addition the occurrence of radiation induced mutations would enhance the possible development of malignancy in these glands. Such a possible development in the Marshallese subjects must be borne in mind. This is particularly true in the case of the children since many retrospective and prospective studies have shown a casual relationship of irradiation of the neck region in infants with the later development of thyroid cancer. It is of course not possible to prove the causal relationship of irradiation in the case of cancer of the thyroid in the exposed Marshallese woman but in view of the low incidence of such malignancies in the Marshallese this possibility must be seriously considered.

The causal relationship of thyroid deficiency and growth retardation in the children in the more heavily exposed group seems reasonably well established and it is hoped that thyroid hormone treatment will enhance their growth and development.

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