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Operation CASTLE

PACIFIC PROVING GROUNDS

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Addendum Report 4.1A

MEDICAL EXAMINATION OF RONGELAP PEOPLE SIX MONTHS AFTER EXPOSURE TO FALLOUT

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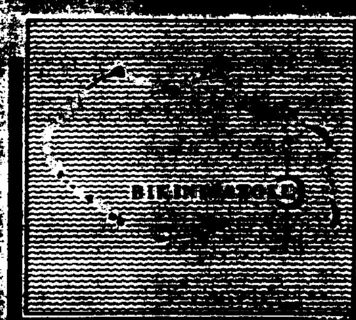

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WT-937

Report to the Scientific Director

OPERATION CASTLE - ADDENDUM REPORT PROJECT 4.1A

MEDICAL EXAMINATION OF RONGELAP PEOPLE SIX MONTHS AFTER EXPOSURE TO FALLOUT

by

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ABSTRACT

Follow-up medical examinations were made of the Marshallese inhabitants of Rongelap Atoll 6 months after they had been exposed to atomic bomb fallout radiation during the Operation CASTLE test series in March, 1954. During the early acute period following exposure, these people had shown systemic effects and marked hematological changes resulting from penetrating gamma radiation; extensive superficial skin lesions and epilation associated principally with beta and soft gamma radiation from fallout material deposited on uncovered skin areas; and minimal internal contamination with fission products, resulting principally from ingestion of fallout material. At the time of the 6-month resurvey the individuals, in general, appeared healthy and normally active, and no deaths had occurred in the interim period. Three babies had been born since exposure, none of whom displayed detectable abnormalities. One miscarriage at 3 months occurred during the interim period. No specimen was available for study. The skin lesions previously prominent had healed completely, and only occasional hyperpigmentation of depigmented scars was seen in a few individuals who had severe early skin damage. Regrowth of hair had commenced during the third month following exposure and was essentially complete at the 6-month examination. Residual of the fingernail discoloration previously noted was found in three individuals. No additional findings on physical examination could be ascribed to radiation exposure, and most had gained weight during the interim period. A measles epidemic was in progress during the examinations. The severity of the disease in the Rongelap people was no greater than in a control unexposed population, and the incidence was no higher. Chest X-rays of all individuals revealed no abnormalities ascribable to the fallout radiation. Analysis of hematological data obtained failed to demonstrate a significant effect of measles on the peripheral blood count. Neutrophile, lymphocyte, and platelet counts were not significantly different from counts taken on the 74th post-exposure day, and none of these values had returned to control levels. Studies of bone marrow specimens obtained on 20 adult individuals revealed no significant abnormalities. Minimal amounts of residual radioactivity were detectable in the urine of approximately one-third of the exposed individuals.

ACKNOWLEDGMENTS

The authors are indebted to a number of individuals at a number of administrative levels for their extensive aid and willing cooperation, so necessary for the success of a field mission of this type. Drs. John Bugher and Charles Dunham of the Division of Biology and Medicine, Atomic Energy Commission, coordinated and expedited all necessary arrangements among the State Department, the Department of the Interior, the Navy Department, and the Trust Territories. The Chief of Naval Operations arranged all necessary transportation. Commander Harry Etter of the Bureau of Medicine and Surgery was instrumental in completing arrangements so that the resurvey team could proceed on schedule. CAPT R. A. Hinners, Director, U.S. Naval Radiological Defense Laboratory (NRDL), and CAPT W. E. Kellum, Commanding Officer, Naval Medical Research Institute (NMRI), placed all necessary facilities of the two laboratories involved at the disposal of the medical team, as did CAPT A. R. Behnke, Radiological Medical Director, NRDL; CAPT T. L. Willmon, Executive Officer, NMRI; and Drs. P. C. Tompkins and E. P. Cooper, Scientific and Associate Scientific Director, respectively, of the NRDL. The authors are particularly indebted to CDR. E. P. Cronkite, NMRI, in charge of the original observations on the exposed people, for his extensive efforts in organizing the resurvey and for his support throughout all phases of the endeavor.

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CHAPTER 1

INTRODUCTION

1.1 OBJECTIVES

The present medical resurvey was organized as the first of a contemplated series designed to provide long-term medical examinations of the Marshallese people exposed to radiation from fallout during Operation CASTLE.

1.2 BACKGROUND

Following the detonation of a thermonuclear device on Bikini Atoll on 1 March, 1954, 28 Americans on Rongerik Atoll and 239 Marshallese (64 on Rongelap, 18 on Ailinginae, and 157 on Utirik) were exposed to significant amounts of radiation from fallout. These individuals were evacuated to Kwajalein, where they were cared for during the acute period following exposure by a special medical team composed of individuals from the Naval Medical Research Institute (NMRI) in Bethesda and in the U.S. Naval Radiological Defense Laboratory (NRDL) in San Francisco. A report of medical findings has been issued as an Operation CASTLE report.[1] The present report is concerned with the medical status 6 months later of the Marshallese people who received the highest estimated dose of gamma radiation, the Rongelap and Ailinginae groups.*

The Rongelap group was exposed to an estimated 175 r of gamma radiation, calculated from dose rates measured free in air, over a period of approximately 46 hr. The Ailinginae group received an estimated 69 r of gamma radiation over approximately 54 hr. Both groups received additional beta radiation to exposed skin areas. All findings were more severe in the Rongelap than in the Ailinginae group. These findings are reviewed later in the report.

Because of the continuing hazard from radiation on their home atolls, the Rongelap and Ailinginae people were not returned to their homes after observation at Kwajalein. Instead, they were moved to Majuro Atoll, the Trust Territory Headquarters for the Marshall Islands. Housing was furnished them on Ijij Island (pronounced "edgit"), 10 minutes by boat from the Trust Territory Headquarters, where they were residing at the time of the present examinations.

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* The Utirik people, who received comparatively slight exposure, were returned to their home atoll following observation at Kwajalein and were not examined during the present resurvey. The exposed Americans had been returned to their duty stations in the United States.

1.3 GENERAL METHODS; CONTROL POPULATION

The facilities of the Marshall Island Memorial Hospital in the Trust Territory Headquarters were made available for the clinical and laboratory examinations. The resurvey included the establishment of a control group of unexposed Marshallese, in addition to obtaining interval histories, complete physical examinations, hematological studies, and radioactivity excretion studies on all the exposed individuals. Similar examinations were conducted on this control group for immediate comparison of findings and to serve as a base line for comparing growth and other future changes in the two groups.

The control patients were obtained principally from among the residents of the village of Rita, located about 2 miles from the hospital. This population was chosen on the basis of its similarity with respect to the living conditions of the exposed people, its relative permanence, and its accessibility to the Memorial Hospital. The individuals were selected on the basis of age and sex to be paired with the members of the exposed group. Thus, each individual of the exposed group was assigned a control individual of the same sex and approximately the same age. The age distribution of the exposed and control populations is given with the hematological results in Chap. 4. The age distribution of the exposed and control groups was the same, except that suitable controls were not found for two women of reported ages 60 and 100, nor were controls established for the three babies born to members of the exposed group since March, 1954. Numbers were assigned to the controls by adding 1000 to the number of the corresponding member of the exposed group. For example, Labnir, number 1011, was the control for Antak, number 11.

REFERENCE

1. E. P. Cronkite et al., Study of Response of Human Beings Accidentally Exposed to Significant Fallout Radiation, Operation Castle final report of Project 4.1.

CHAPTER 2

CLINICAL EXAMINATION

2.1 PREVIOUS FINDINGS

Within hours of exposure to radiation, approximately two-thirds of the Rongelap people felt nauseated and one-tenth of the group had vomiting and diarrhea. One Ailinginae individual reported nausea. Itching and burning of the skin and eyes during this period occurred in over one-quarter of the Rongelap residents and in a smaller number of the Ailinginae population. With the exception of skin lesions and epilation reported in Chap. 3, there were no further symptoms nor findings on physical examination that could be attributed with certainty to radiation exposure. All individuals were normally active throughout the period of observation. The various clinical conditions encountered in the highest exposed Rongelap and Ailinginae groups were not remarkably different in type or extent from those seen in the least exposed Utirik group. Although a number of individuals were markedly neutropenic, no infections attributable to neutropenia *per se* were observed. No external evidence of hemorrhage was observed, although platelet counts in 20 per cent of the Rongelap group fell to 90,000/mm^3 or lower at the time of maximum depression. Antibiotics were used in a few individuals where indicated for incidental infections. However, no prophylactic or therapeutic drugs were necessary or given because of whole-body radiation exposure alone.

2.2 PROCEDURES

The following procedures were carried out routinely on both exposed and control groups: (1) brief past history,* (2) complete interval history, (3) skin examination (including biopsies and photographs in selected cases), (4) complete physical examination (including ophthalmoscopic, rectal, and pelvic examinations), (5) chest X-ray, and (6) hematological studies (including bone marrow aspirations in selected cases). Serology was done on some of the exposed individuals. Special measurements were taken on children to provide a base line for future growth and development studies.

2.3 CLINICAL FINDINGS

Past histories revealed little of note, with the exception of a high incidence of yaws (exposed group, 23; control group, 17) and gonorrhea (exposed group, 21; control group, 19). One

* Interval and past histories were taken by Dr. John Iaman, a Gilbertese physician who spoke excellent English as well as Marshallese. English-speaking Marshallese nurses aided in the physical examinations.

control patient gave a history of syphilis for which she had been treated twice. Interval histories were essentially negative. No deaths had occurred in the exposed population, and three apparently healthy infants had been born in the interim period. Their *in utero* ages at the time of exposure were approximately 3, 6, and 7 months. Three other pregnancies were noted during the present examinations, in one of which conception had occurred at about the time of exposure and in the remaining two, 2 to 4 months after exposure.

TABLE 2.1—Positive Findings on Physical Examination of Exposed and Control Populations

Diagnosis	No. of exposed group	No. of Rita control group
Cardiovascular system:		
Generalized arteriosclerosis	1	3
with heart disease	1	0
Hypertension	2	0
with heart disease	1	0
Luetic heart disease (?)	1	0
Heart disease, etiology unknown	0	1
Arthritis:		
Hypertrophic	0	2
Rheumatic	0	1
Parkinsonism	0	1
Diabetes mellitus	1	1
Gynecological system:		
Pregnancy	3	1
Fibromyoma of uterus (?)	0	1
Cervical erosion	1	7
Cervical cyst	0	2
Cervical polyp	0	1
Urethral curuncle	2	0
Furuncle of labium	1	0
Syphilis (clinical diagnosis), activity (?)	0	1
Tuberculosis, pulmonary, arrested	0	1
Leprosy, arrested (?)	1	0
Impetigo	6	1
Bronchitis	0	1
Otitis externa	1	0
Otitis media	0	1
Pyorrhea	7	2
Blindness, traumatic	0	1
Hernia, inguinal, direct	0	1

Table 2.1 summarizes the principal findings from history and physical examinations, and additional data on individuals are given in Appendices A and B. Dermatological findings are reported in detail in Chap. 3. There appeared to be no significant difference in disease incidence between exposed and control populations, and no findings, with the exception of those reported in Chap. 3, could be ascribed to radiation effects. A measles epidemic, in progress in both populations during the examinations, had begun to decline in the control group but was still at its peak in the exposed group at the completion of this study. The time interval between the peak incidence of measles in the two populations was probably due to the relative isolation of the exposed group.

Body weights of the exposed patients were compared with their weights in March, 1954. Although there were a few instances of significant weight loss in individuals, the over-all popu-

lation showed an increase. This was probably because of relative inactivity in addition to having ample supplies of food. Weight changes are shown in Appendices A and B. The special measurements taken on children age 19 or less showed no significant abnormalities.

Chest X-ray examinations revealed only long-standing changes ascribable to previous disease.* Estimates of bone age from wrist X-rays[1] were in keeping with the stated age. X-rays of long bones showed no abnormalities ascribable to radiation effects. Of 40 Kahn tests given to exposed individuals, three were 3+. Two of these gave a history of, or had physical findings consistent with, late syphilis. Previous yaws *per se* did not result in a positive Kahn test.

REFERENCE

1. John Caffey, Pediatric X-ray Diagnosis, Year Book Publishers, 1950.

* The authors are indebted to CDR C. D. Burroughs for interpreting the X-ray films.

CHAPTER 3

SKIN LESIONS, EPILATION, AND NAIL PIGMENTATION

3.1 PREVIOUS FINDINGS

The Rongelap and Ailinginae groups observed the fallout as a powdery material that fell for several hours and clung to their skin and hair.

Thorough decontamination was not accomplished until evacuation occurred one to two days later. The dosage to the skin, resulting from soft beta and soft gamma radiation, could not be calculated due to the complex make-up of the fallout material. Initial symptomatology related to the skin consisted of burning and itching in a large number of people, and irritation of the eyes with lacrimation in a small number, the first two days after exposure. The early symptoms were followed by pronounced lesions of the skin and epilation of the head, which first appeared about the 12th to the 14th day post-exposure in the Rongelap group and after the 20th day in the less-exposed Ailinginae group; the lesions occurred primarily on the exposed parts of the body which were not protected by clothing. Those persons who remained under shelter in their homes developed less severe lesions or no lesions. Also, there was some protection to those who bathed or remained in their homes during the fallout.

The development of the skin lesions did not conform in all respects to beta skin lesions described in the literature. No primary or secondary erythema was observed; however, the dark skins of these people may have obscured this phenomenon. The lesions showed differences in the latent period and appeared on different parts of the body in roughly the following sequential order: scalp, neck, axillary region, antecubital fossae, feet, arms, legs, and trunk. Epilation and scalp and neck lesions were observed in 60 to 70 per cent of the Rongelap group, and foot lesions were also common.

The first indication of a developing skin lesion was the appearance of pigmented macules, papules, and raised plaques. Usually, these dark pigmented lesions had a dry, thickened, leathery feel. However, some areas developed only simple hyperpigmentation of the skin over extended areas. The majority of lesions were superficial without vesicle formation, which, after several days, showed dry, scaly desquamation of the pigmented skin from the center of the lesion outward. Desquamation left depigmented pink-to-white epithelium not remarkedly different in texture from the surrounding skin. During the next few weeks the lesions gradually became repigmented, resulting in a relatively normal appearance.

Approximately 20 per cent of the Rongelap people developed lesions of a deeper nature, which occurred primarily on the feet, to some extent on the neck and scalp, and, in one case, on the ear. These lesions also began with hyperpigmentation, followed in a few days by wet desquamation with weeping and crusting ulcer formation. In some of the foot lesions bullae formation occurred, followed by a breaking of the bullae with ulceration. Many of the lesions were accompanied by symptoms of pruritus and a burning sensation, and some of the deeper lesions were painful during the acute stage. The application of bland antipruritic lotions and

ointments was the only treatment necessary, except in a few lesions which became secondarily infected and which were treated with antibiotic ointments.

Essentially, all lesions healed rapidly and re-epithelialized in a week or 10 days. Repigmentation gradually took place in most of the lesions, and in some, notably on the neck, hyperpigmentation of a grayish, dusky color developed with thickening, resulting in an "orange-peel" appearance. The deeper foot lesions, however, did not show repigmentation.

An unexpected finding in nearly all the Rongelap and Ailinginae people was the development of a bluish-brown semicircular band of pigmentation of the fingernails and toenails which was first noted about the 23rd day. The pigmentation band started in the semilunar area and progressed distally with growth of the nail. Since all the American Negroes but none of the white Americans exposed developed this pigmentation, it appeared that this phenomenon was characteristic of dark skinned races. It also was probably due to whole-body irradiation and not local skin irradiation, since some individuals without skin lesions developed the pigmentation and vice versa.

Biopsies taken from active lesions showed spotty transepidermal damage with atrophy and flattening of the retepegs. Areas of relatively normal skin intervened, emphasizing the particulate nature of the radioactive material. Cells of the malpighian layer showed pleomorphic nuclei, pyknosis, and cytoplasmic halos. Focal disorganization of the malpighian and basal layers was present in extensively damaged areas. In the dermis, telangiectatic vessels were noted in areas where the overlying epidermis showed greatest damage, and there was considerable lymphocytic infiltration surrounding these telangiectatic spaces. An outstanding feature of the early histological changes was the pronounced damage to the epithelium, with relatively minimal damage in the dermis.

Biopsies taken at six weeks post-exposure showed, in general, that the epidermis had made a definite recovery, except for a few persistent areas of atrophy and finger-like downgrowths of stratum malpighii, with cells showing rather prominent pigment content. There were many outward epidermal excrescences covered by thickened stratum corneum. The dermis showed less cellular infiltration of the papillary layer but still some slight degree of telangiectasis of the capillaries.

3.2 PROCEDURES

In addition to an examination of the skin and its appendages of the exposed people, 80 control Marshallese living on Majuro Atoll were also examined. Color pictures were taken of the skin where indicated, and attempts were made to take pictures of lesions magnified 20 times. Biopsies were taken at the site of former lesions in 12 exposed individuals. Most were repeat biopsies from individuals who had been studied in this manner during the initial examinations. Several skin biopsies from control individuals were also taken.

3.3 PRESENT FINDINGS

Healing of all the early superficial lesions was essentially complete. The skin had repigmented to normal color, appeared to be of normal texture, and gave no remaining gross evidence of previous injury. Plates 1, 2, 8, and 9 show the early lesions as compared with their appearance at 6 months. Those lesions which had been deeper, and particularly those which showed evidence of transepidermal injury, continued to show slight evidence of previous damage, largely in the form of pigment alterations. Most of the neck lesions, which at 10 to 11 weeks after exposure had shown the thickened skin with grayish, dusky pigmentation, showed much less thickening and less marked pigmentation at 6 months. It was observed that the skin of the necks of many of the control population, particularly of the women, showed slightly increased pigmentation. Hence it was frequently difficult to determine whether there was remaining hyperpigmentation in this area or whether the degree of pigmentation was in the normal range. There were, however, 10 cases out of an original 16 in which the amount of pigmenta-

tion of the neck appeared to be definitely increased at the site of previous lesions. However, little thickening, if any, was apparent and the skin appeared otherwise normal. It is noteworthy that none of the neck lesions showed depigmentation. Small areas of hyperpigmentation persisted also at the site of two axillary, four antecubital fossae, one arm, and one back lesion.

In contrast to the neck and other lesions mentioned, the deepest foot lesions showed no hyperpigmentation but, on the contrary, persisting depigmentation. Plates 3 and 4 show deeper foot lesions early and at 6 months post-exposure. The skin texture in these depigmented lesions appeared essentially normal on a gross scale. However, pictures magnified 20 times showed that there was scattered, blotchy, faded pigmentation with some slight atrophy (flattening of skin ridges). Depigmented foot lesions were observed in six cases. One antecubital fossae lesion also showed a small area of depigmentation.

The persistent lesion of the ear, noted in the initial examination, had gradually healed with considerable scarring and atrophy and some scaling of the epidermis. Plates 5, 6, and 7 show this lesion early and at 6 months post-exposure. Telangiectatic vessels can also be seen in Plate 7 (magnified 20 times).

In every case, there appeared to be a complete regrowth of hair, with normal color, texture, and distribution. Plates 5, 6, 8, and 9 show epilation and regrowth of hair.

The bluish-brown pigmentation of the nails, noted in most of the Marshallese in the initial examinations, had disappeared, apparently with growth of the nails, in all but three cases. The pigment in these individuals remained at the distal end of the nail (Plate 10). It was evident in these cases that the pigment was not in the nail plate but between it and the nail bed, closely adherent to the underside of the nail.

Biopsies showed some residual damage to the epidermis, as well as to the dermis. In the epidermis the following changes were present: (1) focal atrophy of the stratum granulosum; (2) slight focal pigmentary disturbances in cells of the basal layers; (3) slight-to-moderate hyperheratinization; and (4) in some cases persistent, but minimum cellular, changes as manifested by the presence of paranuclear cytoplasmic halos and slight disturbances in polarity of epithelial cells in the basal capillary projections. In the dermis a slight-to-moderate degree of telangiectasis was evident. Some of these changes are shown in Plates 11 and 12.

NOTE

Color plates (Plates 1 through 12) numbered with letters *a*, *b*, *c*, and *d* are considered to be pages 17 through 24.

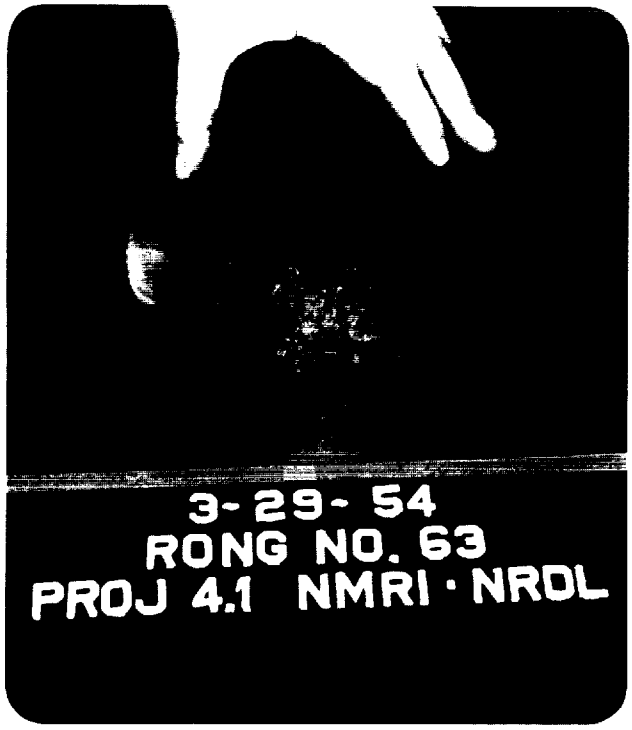

Plate 1. Neck lesions 28 days post exposure. Note pigmented and desquamated, depigmented areas. Case 63, age 38, F.

Plate 2. Same case as in Plate 1, six months after exposure. Neck has healed completely.

Plate 3. Hyperpigmented raised plaques and bullae on dorsum of feet and toes at 28 days. One lesion on left foot shows deeper involvement. Case 67, age 14, F.

Plate 4. Same case as in Plate 3, six months later. Foot lesions have healed with repigmentation, except depigmented spots persist in small areas where deeper lesions were.

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Plate 5. Epilation back of head at 46 days. Note persistent ulceration of left ear. Case 79, age 41, M.

Plate 6. Same case as in Plate 5 showing complete regrowth of hair of normal color and texture at six months after exposure. Ear lesion has healed with considerable scarring. See Plate 7.

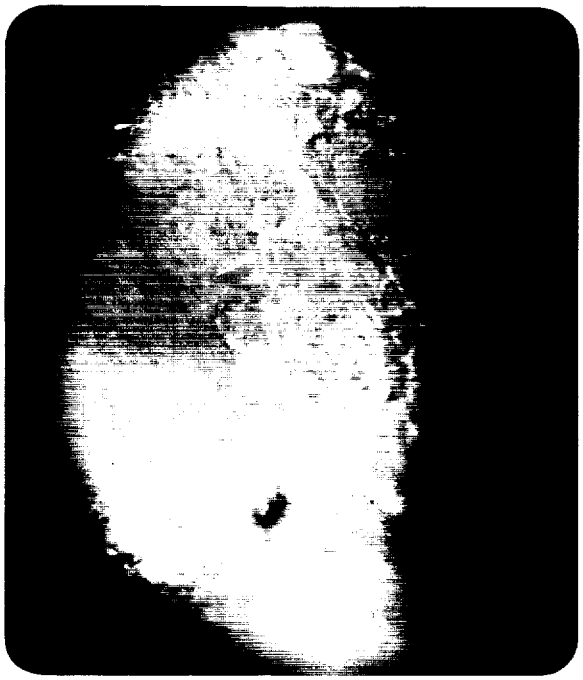
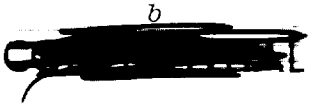


Plate 7. Ear lesion shown in Plate 6 magnified 20 times. Note atrophy and scaling of scar tissue. Telangiectatic vessels can be seen in the upper part of the picture.



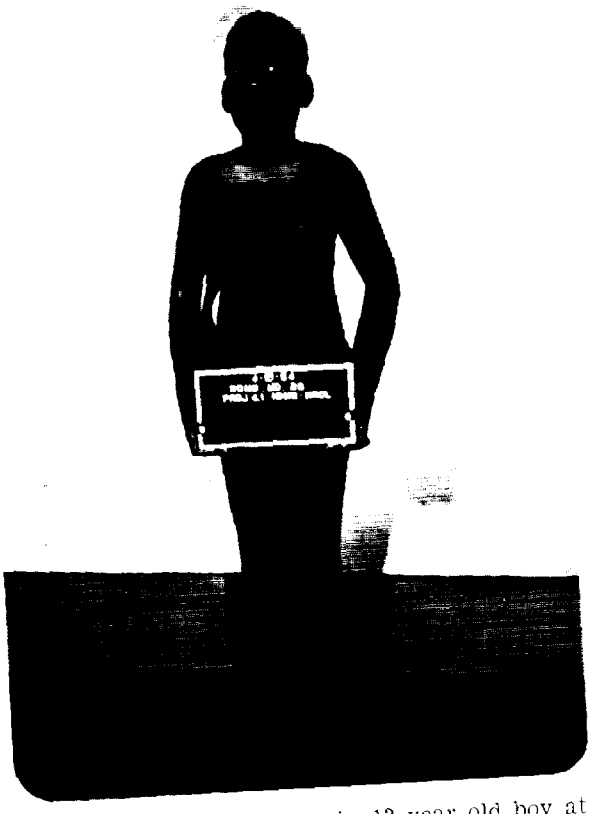


Plate 8. Extensive lesions in 13 year old boy at 45 days post exposure. Case 26.

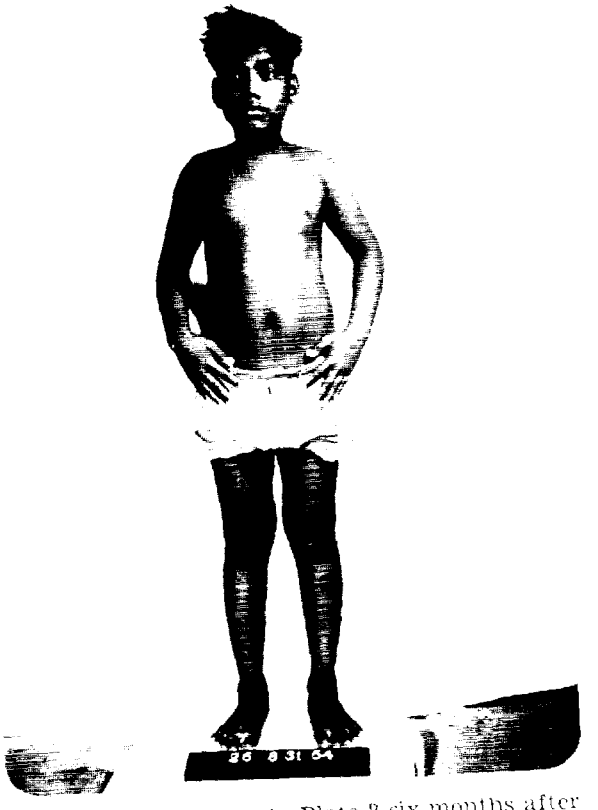


Plate 9. Same boy as in Plate 8 six months after exposure showing healed lesions and regrowth of hair.

Plate 10. Pigmentation associated with thumbnail at end of nail bed at six months. Note pigment is beneath nail, not in nail plate.

Plate 11 (X100, H&E) (Case #39). Six months post-exposure. Note the marked diffuse atrophy of the stratum granulosum accompanied by narrow downward prolongations of the basal papillae. Moderate disturbance of keratinization and moderate telangiectasis are also seen.

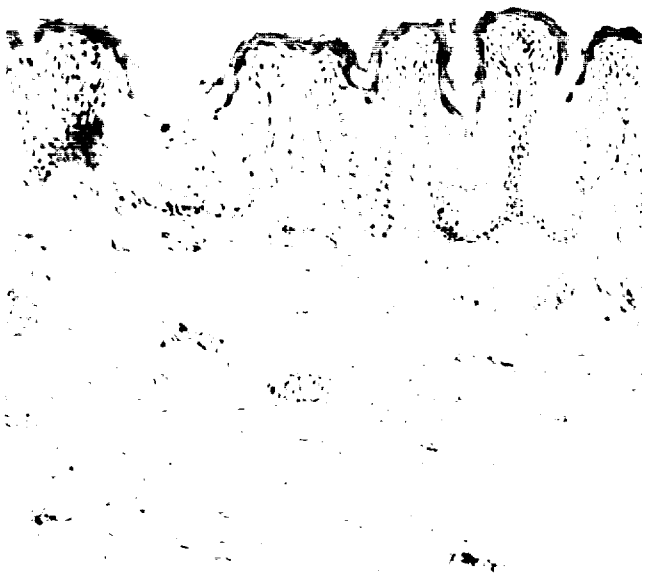


Plate 12 (X100, H&E) (Case #24). Six months post-exposure. Moderate focal atrophy of stratum corneum. Paranuclear halos are present and areas of depigmentation are prominent. In the dermis a moderate uniformly distributed telangiectasis is seen. There is also a perivascular distribution of cellular infiltrate.

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CHAPTER 4

HEMATOLOGY

4.1 PREVIOUS FINDINGS

Hematological determinations employed in the initial post-exposure period included total leukocyte, neutrophile, lymphocyte, and platelet counts and hematocrit determinations. Whenever possible, an entire exposure group was studied in a single day. In order to estimate the severity of the hematological response, findings were comparable to a phase of a control group similar, where possible, with respect to race, age, sex, background, and habits.

Depression of the total white, neutrophile, lymphocyte, and platelet counts was marked in the Rongelap group and less severe in the Ailinginae group. The total white count was consistently lowest during the sixth and seventh post-exposure weeks, followed by an upward trend with levels remaining below that of the control population at the end of the observation period. The drop in lymphocytes was early and profound, with little or no evidence of recovery during the period of observation. Fluctuations in the total white count were due to changes in the neutrophile count. Neutrophile counts in 10 per cent of the Rongelap group fell to below 1000 cells/mm^3 at the time of maximum depression. Platelet counts showed less fluctuation than did the total white and neutrophile counts and reached lowest values on the 30th post-irradiation day. At this time, counts in 20 per cent of the Rongelap group were below 90,000/mm^3. A secondary fall in platelets, with greatest depression on the 55th day, was observed, and recovery to control levels was not complete at 6 months.

4.2 METHODS

Determinations made on peripheral blood included total white, neutrophile, lymphocyte, and platelet counts, as well as hematocrit determinations. Techniques employed were identical with those used during the initial observation period.[1] Two determinations were made on each individual approximately one week apart (date of all counts taken as the 185th post-irradiation day). In addition to peripheral blood, bone marrow from the anterior or posterior iliac crest was obtained on 21 exposed and 20 control individuals. Approximately 1 ml was aspirated, and cover slip preparations were made from the small particles of marrow thus obtained. Differential counts were taken on these preparations. Part of the marrow was allowed to clot on a glass slide and was then fixed in formalin-sublimate solution for later examination of histological structure and degree of cellularity.

4.3 PRESENT FINDINGS

Peripheral blood count data for the exposed and control populations are given in Tables 4.1 to 4.3, Figs. 4.1 to 4.4, and in Appendices A and B. To obtain valid comparisons within

TABLE 4.1 — Hematological Data for Control Populations by Age and by Sex

	No. of individuals				WBC × 10^3				Neutrophile × 10^3				Lymphocyte × 10^3				Platelet × 10^4				Hematocrit, %			
	Majuro		Rita		Majuro		Rita		Majuro		Rita		Majuro		Rita		Majuro		Rita		Majuro		Rita	
Age	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
5	10	14	9	7	13.9	12.8	12.2	8.8	4.3	4.8	6.4	4.0	8.4	6.6	5.0	4.3	42.2	35.9	35.0	31.7	38.5	37.4	35.9	37.8
6-10	6	4	4	6	11.8	9.6	12.8	9.3	5.5	3.9	6.6	5.2	5.1	5.1	4.3	3.9	39.7	38.7	35.0	36.2	41.2	39.2	38.5	37.7
11-15	1	3	2	4													28.0	38.3	24.5	33.7	42.0	42.3	38.0	39.2
11-20					10.8	8.9	9.6	9.3	5.1	4.6	5.6	5.2	4.7	3.8	3.4	3.4								
16-20	5	3	3	5													27.6	43.3	37.0	32.6	48.4	38.7	42.3	38.2
21-30	17	10	5	7	8.9	10.6	7.5	9.8	4.3	5.8	4.3	5.6	3.8	4.2	3.3	3.7	23.6	34.2	25.4	29.3	46.9	38.9	46.2	40.1
31-40	4	9	2	4	7.9	9.3	14.4	12.9	3.8	4.7	7.6	7.9	3.3	4.1	6.2	4.4	25.0	39.2	26.5	30.0	47.2	41.2	46.0	42.5
41-50	3	12	8	2	7.5	9.4	8.9	7.3	4.5	4.7	4.6	3.0	3.6	4.0	3.7	3.6	21.3	35.4	27.4	23.5	42.3	41.8	44.1	42.0
50	10	4	7	8	9.1	10.2	8.1	9.3	4.9	5.1	4.9	4.6	3.5	4.2	2.6	3.9	30.2	32.2	25.3	27.6	43.7	41.7	40.6	41.0

TABLE 4.2—Mean Values for Peripheral Blood Determinations on the Rongelap Group 185 Days Post-exposure

Determination	Sex	Age, years	Lowest counts*	185th day	Majuro control
WBC (in thousands)	Combined	<5	5.6	8.5	13.2
		>5	5.5	6.6	9.7
Neutrophiles (in thousands)	Combined	<5	2.3	4.6	4.8
		>5	2.4	4.2	4.8
Lymphocytes (in thousands)	Combined	<5	2.5	3.6	7.4
		>5	2.2	2.2	4.1
Platelets (in thousands)	Male	<10	136	244	412
		>10	126	203	258
	Female	All ages	114	232	365
Monocytes (in thousands)	Combined	<5	1.2	1.4	2.0
		>5	1.2	1.1	2.0
Eosinophiles (in thousands)	Combined	<5	0.9	2.5	9.5
		>5	0.7	1.6	4.7
Hematocrit, %	Male	<15	36.3	38.0	39.6
		>15	41.6	41.7	46.0
	Female	All ages	36.8	38.2	39.9

*Approximately post-exposure days 39 to 51 for WBC, neutrophiles, lymphocytes, monocytes, and eosinophiles; days 26 to 30 for platelets; and days 26 to 33 for hematocrit.

TABLE 4.3—Mean Values for Peripheral Blood Determinations on the Ailinginae Group 185 Days Post-exposure

Determination	Sex	Age, years	Approx. lowest counts*	185th day	Majuro control
WBC (in thousands)	Combined	<5	7.5	7.7	13.2
		>5	6.4	6.5	9.7
Neutrophiles (in thousands)	Combined	<5	3.2	4.8	4.8
		>5	3.8	3.9	4.8
Lymphocytes (in thousands)	Combined	<5	4.0	2.7	7.4
		>5	2.4	2.2	4.1
Platelets (in thousands)	Male	<10	198	252	412
		>10	133	142	258
	Female	All ages	178	239	365
Monocytes (in thousands)	Combined	<5	2.2	1.1	2.0
		>5	1.9	1.4	2.0
Eosinophiles (in thousands)	Combined	<5	2.3	1.5	9.5
		>5	1.0	2.2	4.7
Hematocrit, %	Male	<15	35.5	37.5	39.6
		>15	43.8	40.1	46.0
	Female	All ages	36.8	37.3	39.9

*Approximately post-exposure days 39 to 51 for WBC, neutrophiles, lymphocytes, monocytes, and eosinophiles; days 26 to 30 for platelets; and days 33 to 39 for hematocrit.

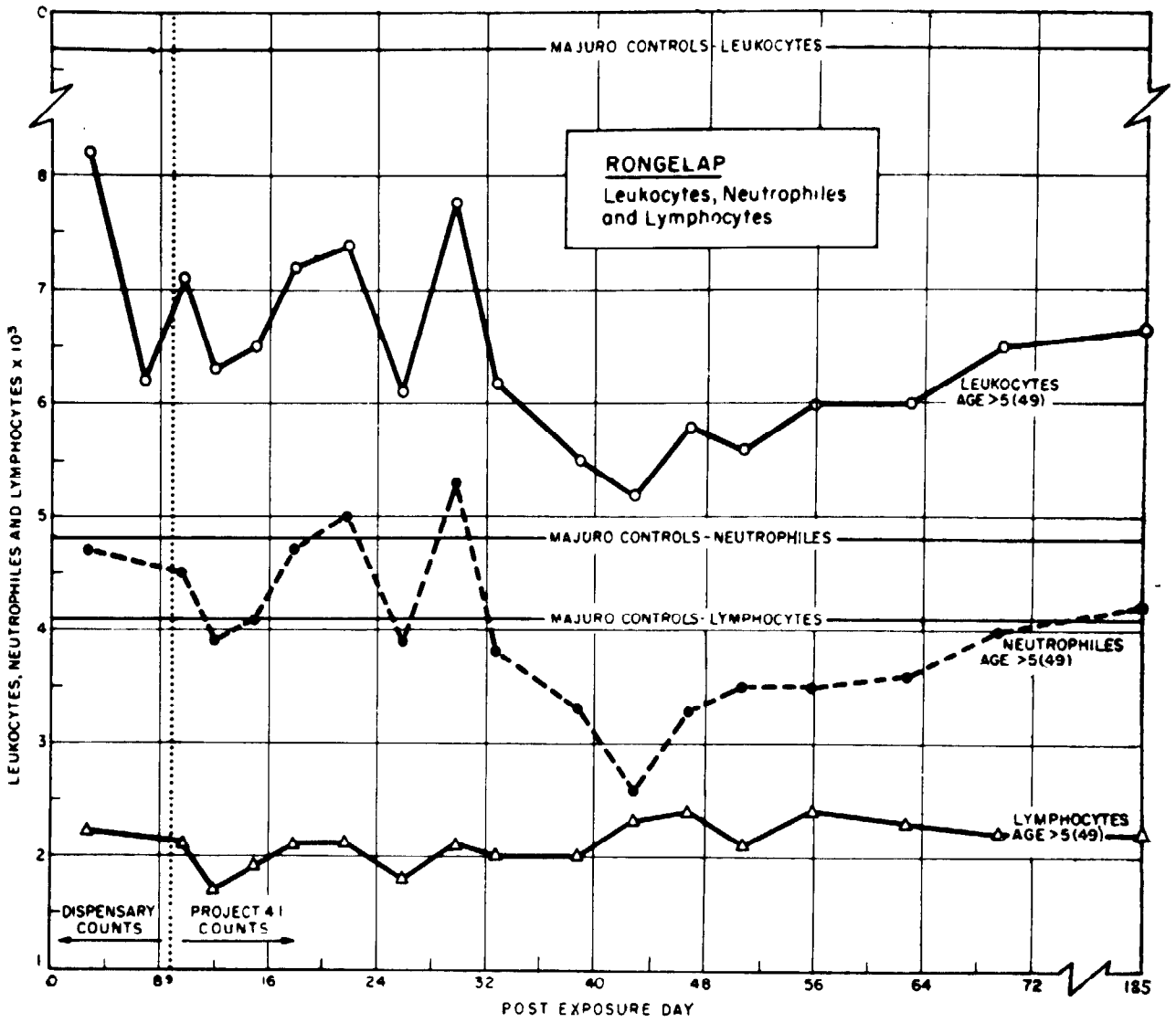

Fig. 4.1 — Serial Post-exposure Changes in the Mean Total Leukocyte, Neutrophile, and Lymphocyte Counts for the Rongelap Group.

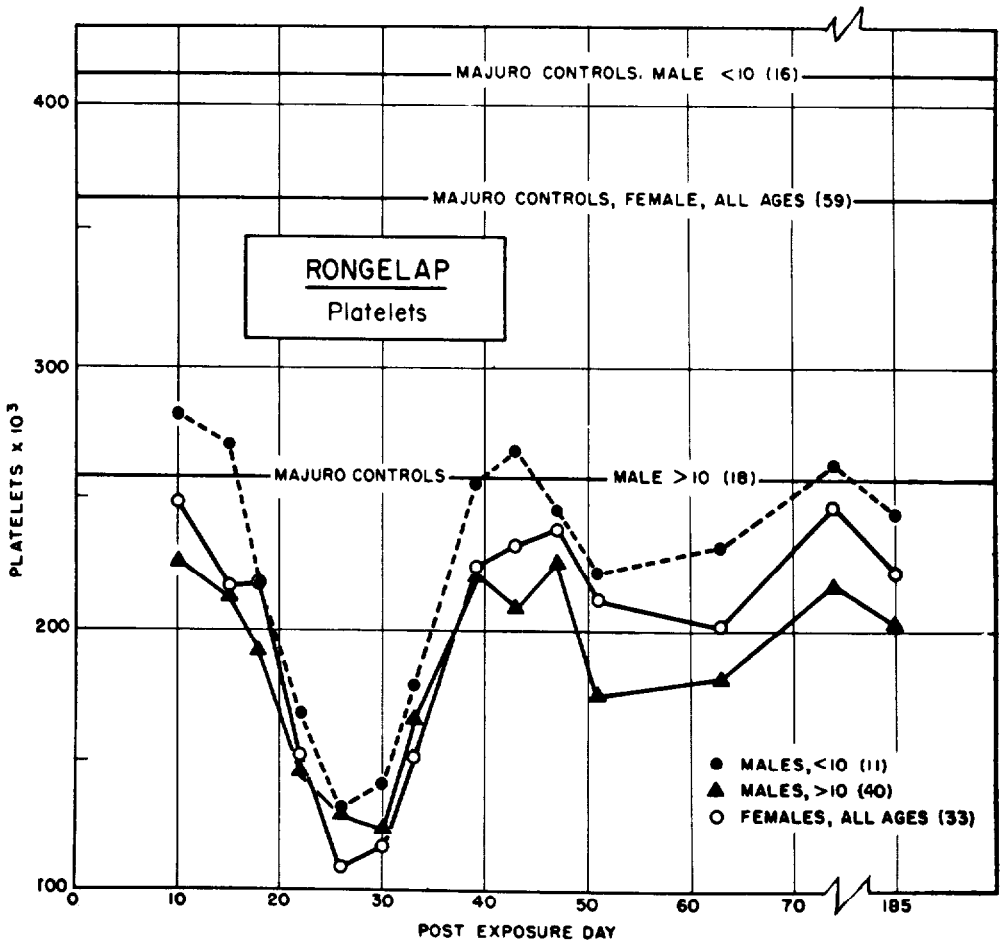

Fig. 4.2—Serial Post-exposure Changes in the Mean Platelet Counts for the Rongelap Group.

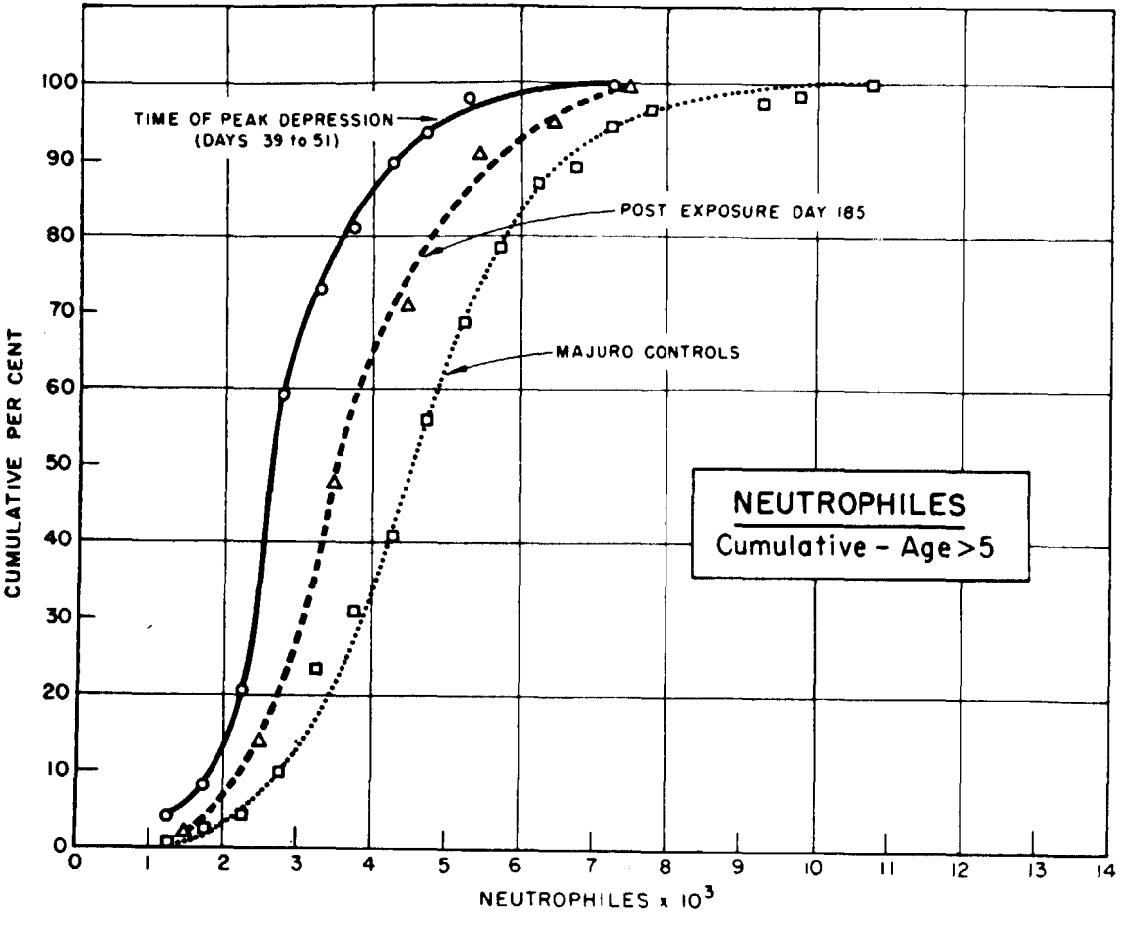

Fig. 4.3—Cumulative Neutrophile Counts for the Rongelap Group at the Time of Maximum Depression and 6 Months After Exposure.

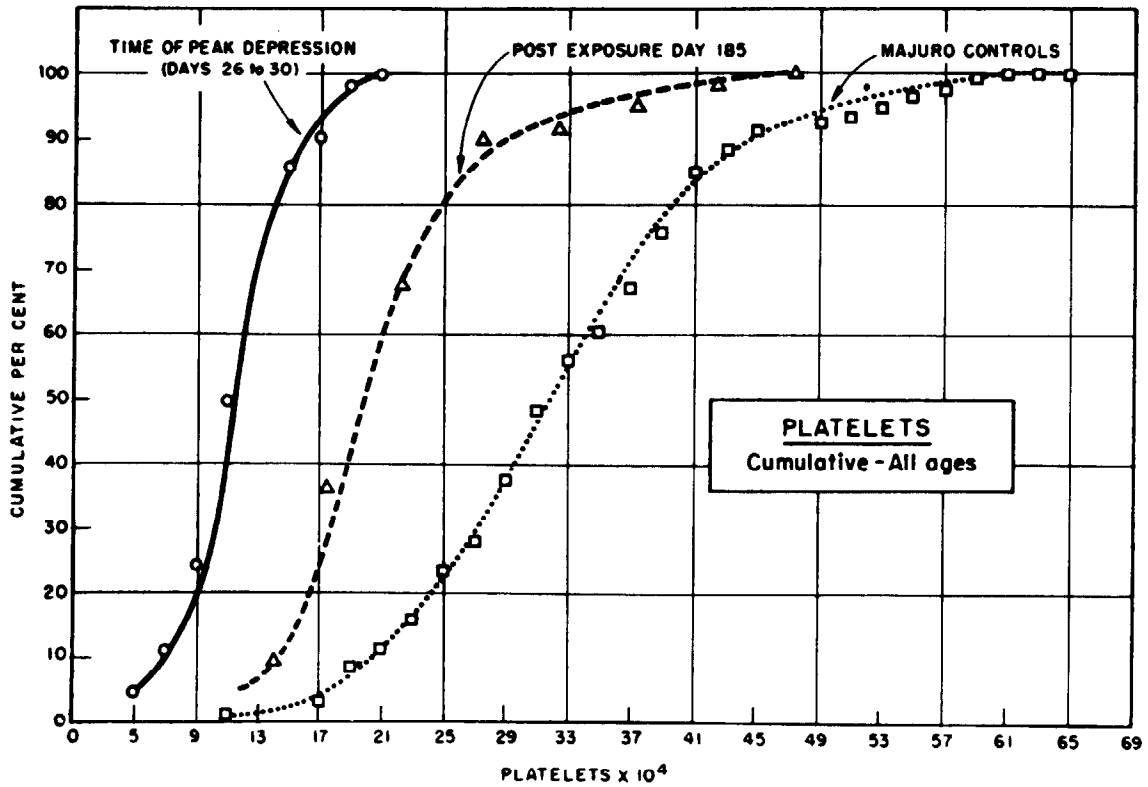

Fig. 4.4 — Cumulative Platelet Counts for the Rongelap Group at the Time of Maximum Depression and 6 Months After Exposure.

and among the exposure groups, the groups were subdivided as to age and sex as was done in the initial report.[1] Control data for both the Rita group and for the Majuro control group obtained during the initial period of observation are shown in Table 4.1. The Rita control values did not differ appreciably from the Majuro levels and were used for some comparisons with the exposed population. However, because of the possible effect of the measles epidemic, the values for the two control groups were not combined. Instead, the Majuro control values alone were taken as the "normal" for the population in most considerations throughout the report.

From the control data given in Table 4.1, it is seen that the total white and neutrophile counts were independent of age and sex, that the lymphocyte count was dependent on age but not on sex, and that the platelet count and hematocrit were dependent on both age and sex. The values given in Tables 4.2 and 4.3 are presented in accordance with this dependency to allow valid comparisons. In addition, the total white, neutrophile, monocyte, and eosinophile counts are presented for ages less than, and greater than, five to allow a comparison of response in children and adults.

TABLE 4.4—Mean Blood Counts for the Exposed and Control Populations, with and without Measles

Determination	Rongelap		Control	
	With measles	Without measles	With measles	Without measles
WBC (in thousands)	6.7	7.3	10.7	9.1
Neutrophiles (in thousands)	4.1	4.5	5.6	5.0
Lymphocytes (in thousands)	2.2	2.5	4.3	3.5
Monocytes (in thousands)	0.2	0.1	0.2	0.2
Eosinophiles (in thousands)	0.2	0.2	0.6	0.4
Platelets (in thousands)	246	206	332	274
Hematocrit, %	38.3	38.9	39.2	41.5

It is apparent from the tables and figures that, while all peripheral blood elements had shown definite recovery from the peak depression observed earlier, none of the values had returned to control levels at 6 months.

In order to investigate the possible effects of the measles epidemic on the peripheral blood count, values for those individuals with and without measles were averaged separately (Table 4.4). No significant effect of measles on any of the determinations could be demonstrated in this manner. Since these averages were taken without regard to the time relation between onset of symptoms and the date of the determination, counts were tabulated with relation to onset of symptoms and averaged. It was not possible, however, to demonstrate changes in any of the peripheral elements at the time of onset of the disease by this approach.

The results of bone marrow differential counts on exposed and control individuals are given in Table 4.5. No consistent significant abnormalities were found in the control and exposed groups in the character of the differential count nor in the degree of cellularity or histological structure. In a few instances in both groups of patients, variations in cellular distribution were found which were consistent with systemic infections, such as rubella. These marrows are indicated in the table. Considerable variability in the degree of cellularity was observed, attributable in a large measure to inherent variability in the amount of peripheral blood in the aspirated marrow specimen.

REFERENCE

1. E. P. Cronkite et al., Study of Response of Human Beings Accidentally Exposed to Significant Fallout Radiation, Operation Castle final report of Project 4.1.

TABLE 4.5 — Bone Marrow Differential Counts on Exposed and Control Marshallese*

Cell type	Patient No.																																	
	1001†	1010	1022†	1018	1082	1077‡	1071†	1046	1069†	1024†	1090	1073	1079	1066	1011	1014	1009	1025†	10488	1055	561	82	75	67	63	52	38	73‡	14	111†	40‡	96	78**	88††	9	7	13	39†	22	35
Myeloblast				0.2		0.5							0.7											0.3												
Promyelocyte		2.5	0.2	0.5	1.3	0.5	0.2	0.5					0.3			0.3			0.3				0.3	1.0		9.7				0.5		0.2	0.2		0.2	0.7	0.2	0.2	0.3
Myelocyte:																																							
Neutrophilic	5.3	5.5	6.5	3.5	5.0	2.3		1.3			1.0	4.0	2.7	2.3	1.7	2.3	2.7	0.7	4.3	1.0			6.7	4.0	1.7	1.3	7.7	3.0	2.3	2.0	2.5	6.3	4.3	3.8	3.0	3.8	3.0	2.3	2.8	6.6
Eosinophilic	1.0	2.3	0.5	2.5	0.5	1.0	0.5	3.5			0.7	1.0	0.7	0.3	0.7	1.0	0.7		0.7	0.7			1.3	1.0	0.7	0.3	2.0	0.7			0.7	0.7	1.0	1.3	0.2	0.3	1.8	0.5	1.0	0.3
Basophilic																																							
Metamyelocyte:																																							
Neutrophilic	5.0	5.5	10.5	10.0		3.0	4.3	2.0		4.5	4.3	8.0	8.0	5.3	8.3	5.7	5.0	2.7	7.7	2.3	1.0	3.0	11.3	11.7	7.3	3.0	5.7	6.7	7.0	8.3	7.8	5.5	8.0	4.5	3.5	7.5	3.3	4.5	5.5	7.3
Eosinophilic	2.6	2.0	1.0	1.3		1.3	0.5	3.0		1.5	2.3	0.3		0.7	2.0	1.3	1.3		0.7	1.7		0.5	1.7	2.0	0.3		0.3	1.0	0.7	0.3	0.2	0.7	0.2	1.5	0.2	0.5	0.2	0.2	0.7	1.0
Basophilic																																							
Polymorphonuclear																																							
band	10.6	12.0	17.0	20.0	8.8	15.5	10.5	12.3	61.0	8.0	5.7	16.0	11.0	14.7	7.3	9.0	9.3	9.3	8.7	10.3	6.0	9.0	25.0	16.0	7.3	6.7	18.0	13.7	15.0	6.3	10.0	19.0	9.8	6.8	16.0	6.5	11.5	17.5	12.8	8.0
Mature	33.3	31.8	30.3	20.0	28.5	17.5	37.8	35.0		36.5	28.0	18.3	29.7	26.7	28.0	31.7	19.3	37.5	29.0	30.0	25.0	44.5	26.7	25.7	44.3	36.3	19.0	36.0	32.3	70.7	38.5	19.3	40.5	42.8	37.0	36.5	15.8	18.3	31.0	33.3
Eosinophilic	3.6	3.5	2.3		2.5	1.3	2.8	9.5	1.0	1.0	6.3	0.7	1.7	2.7	4.3	3.7	0.7	0.7	3.0	7.7	2.0	2.5	2.3	3.7	3.3	6.7	1.7	1.7	2.7	1.7	2.5	1.0		2.8	3.3	1.3	1.5	2.5	3.3	1.0
Basophilic	0.3		0.2		0.7	0.5	0.2			0.5	0.7		0.3	0.3	0.3	0.3				0.3	1.0	0.5					0.3	0.3			0.2	0.5		0.2	0.7	0.1		0.7	0.2	
Lymphoblast																								0.3																
Prolymphocyte							0.5				0.7	0.3	1.0		0.3	1.0	0.3		0.3	1.7			0.3	1.7																
Lymphocytes	29.0	14.5	23.7	12.0	14.5	9.5	29.2	3.5	28.0	31.0	32.3	9.0	19.3	20.3	19.3	15.0	11.3	27.7	9.3	21.3	53.0	20.0	6.7	17.3	17.3	32.7	11.0	11.0	16.7	5.7	21.0	18.0	10.5	13.5	16.0	25.0	16.3	21.3	17.0	13.3
Plasma cells	3.3	0.7	0.2	4.5	3.3	4.0	1.5	1.3		1.0	0.7	2.3	4.0	1.3	3.0	3.3	2.7	1.0	2.7	1.0	3.0	1.0	2.7	4.0	0.7		3.0	7.0	0.7		1.0	1.3	1.3		0.7	1.5	12.3	4.8	3.0	9.0
Monocytes	0.6	1.3	0.7	1.0	1.8		2.2	1.3	6.0	6.5	2.3	4.0	5.3	1.0	3.0	3.0	3.3	6.0	3.3	5.3	2.0	3.5	2.0	2.0	4.0	1.7	3.7	6.3	2.0	0.3	2.0	1.8	1.8		3.0	4.5	1.3	1.0	6.5	2.3
Proerythroblast	1.0	0.7	0.2		0.5	2.3		1.3			2.0		0.7	0.3	0.3		2.8			1.3		0.5			0.7	0.3		0.3			0.5	1.5	0.7	1.0	0.7	0.7	0.2	1.0	4.5	0.5
Erythroblast	4.0	5.3	0.7	4.0	3.8	9.8	2.0	4.8		3.5	13.7	5.0	1.7	4.7	6.0	2.7	6.7	2.7	7.7	2.0	1.0	2.0	2.0	2.3	1.7	2.7	4.0	0.7		0.3	3.3	4.8	3.3	3.3	6.3	3.3	4.5	6.0	4.3	3.0
Normoblast	1.3	12.3	5.5	16.3	22.3	28.5	7.8	17.8	3.0	7.0		31.3	13.0	18.3	15.0	19.0	34.3	14.3	28.7	12.7	7.0	13.0	10.0	6.7	11.7	6.3	19.7	11.7	2.3	7.3	7.0	19.5	12.8	18.0	12.0	6.3	22.0	18.5	11.0	12.3
Megakaryocytes	0.3		0.2	0.5		1.0		0.2		0.5		0.3		0.3	0.7	0.7	0.3		1.7	0.3				0.3			0.3	0.3	18.3		0.5	0.2	0.5	0.7		0.2	0.2	0.5		0.3
Unclassified	14/1	3/1	10/1	3/1	2/1	1/1	5/1	3/1			3/1	13/1	2/1	2/1	2.5/1	25/1	1/1	3/1	1/1	3/1	4/1	4/1	7/1	6/1	4.5/1	5/1	2.5/1	4/1	3/1	10/1	3.5/1	2/1	3/1	3/1	3/1	5/1	1.5/1	1.7/1	3.6/1	3/1
Myeloid-erythroid ratio		0.2	0.2	0.2	1.3	1.2		0.2		0.5					0.3		1.3		0.3	0.3							1.0				0.5		0.2		0.2	0.1	2.3	0.2	0.2	

* Numbers below 100 indicate exposed individuals; numbers above 100, controls.

† Diluted with blood (?).

‡ Measles; patient 1077 developed measles in August 1954.

§ Rectal bleeding (?).

¶ Hypocellular smear.

** Palpable liver.

†† Mast cells, 1.5 per cent.

CHAPTER 5

INTERNAL RADIOACTIVE CONTAMINATION

5.1 PREVIOUS FINDINGS

Following the contaminating event, high levels of activity were found in drinking water and on the external surface of plants on the contaminated atolls. Gross beta activity was found in the urine of the majority of Rongelap and Ailinginae inhabitants, with an average of 1208 dis/min/24 hr for the Rongelap and 553 dis/min/24 hr for the Ailinginae groups 6 weeks after exposure. The excretion rate of radioactivity was found to be three times as great in adults as was found in the 0 to 5 year old age group. Strontium, barium, and the rare earth group together contributed 75 per cent of the total beta activity of the urine at this time. The degree of internal radiation hazard was considered too low to have contributed significantly to the acute effects observed following exposure.

5.2 METHODS

Twenty-four hour urine specimens were obtained for analysis by the U.S. Naval Radiological Defense Laboratory (NRDL), Chemical Technology Division, and by the New York Operations Office of the Atomic Energy Commission. Methods of analysis have been described previously.[1]

5.3 RESULTS

Of 53 urine specimens obtained from the Rongelap and Ailinginae groups and analyzed by the NRDL Chemical Technology Division, detectable gross beta activity was found only in six patients, all of whom were in the Rongelap group, and only one of whom was over 12 years of age. Counts ranged from 6 to 90 dis/min/24 hr. Barely detectable radioactivity was found in 23 urine specimens analyzed by the New York Operations Office.

REFERENCE

1. E. P. Cronkite et al., Study of Response of Human Beings Accidentally Exposed to Significant Fallout Radiation, Operation Castle final report of Project 4.1.

CHAPTER 6

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

6.1 DISCUSSION

It would not have been possible, from physical examination alone at the time of the resurvey, to conclude that the Rongelap and Ailinginae groups had been exposed to penetrating gamma and external beta radiation. The people were in average good health on physical examination. The residual pigment changes from previous skin lesions were not prominent. The mean peripheral blood counts were within the range of normal for individual counts, although definitely below the mean values for the control groups. The bone marrow findings were in no way diagnostic, and thus a diagnosis of previous exposure would be difficult, if not impossible, without a medical history.

The marked improvement in the appearance of the skin of most of the exposed individuals is in conformity with the superficial nature of the earlier lesions that resulted principally from exposure to soft radiation. Even the deeper skin lesions showed healing in all cases, with only minimal remaining evidence of damage in the form of scarring and pigment aberrations.

The contrasting residual change of hyperpigmentation in the neck lesions and depigmentation in the foot lesions is worthy of comment. In general, the foot lesions were more severe than the neck lesions. It might be assumed that the chromatophores were destroyed; consequently, repigmentation was impossible. On the other hand, the chromatophores of the neck apparently were not completely destroyed, and thus repigmentation resulted.

It is significant that no secondary breakdown of tissue had occurred in either the superficial or deep lesions, although there was suggestive evidence of atrophy in the deep foot lesions and of atrophy and telangiectasis in the persistent ear lesion. It is possible that the deep lesions, particularly that on the ear of one individual, may still break down, requiring consideration of excision and repair. With regard to prognosis over the next several years, there are factors for and against the future development of further lesions, or cancer of the skin in these people. A favorable prognosis is suggested by (1) the superficial nature of most of the lesions with rapid healing and little scarring, (2) lack of gross telangiectasis or extensive vascular changes that would portend chronic radiodermatitis, (3) the lack of marked histologic changes after 6 months, and (4) the fact that the Negroid skin is reported to be less prone to develop malignancy. The prognosis still must be guarded, however, when one considers that (1) the large number of young people exposed with long life expectancy probably exceed the induction period of cancer development, (2) the continuous exposure to tropical sunlight, (3) the possible influence of the sublethal whole-body exposure, and (4) the persistent aberrations in pigmentation.

The apparent delay in recovery of mean peripheral blood counts to normal values has been discussed[1] in Chap. 4 and, apparently, is in keeping with previous experience on human exposures. Depression appears more protracted in human beings than in large animals.

The radioactivity in the urine of the exposed individuals had decreased rapidly with time and was barely detectable at 6 months. This rate of elimination, coupled with the initial estimates of a low degree of internal contamination,[1] minimizes the possibility that chronic irradiation effects from this source will occur.

6.2 CONCLUSIONS

Re-examination of the Rongelap and Ailinginae people 6 months after exposure to fallout radiation revealed the following:

1. Skin lesions were completely healed, and only a few hyperpigmented or depigmented scarred areas remained at the sites of the most severe early lesions. There was no evidence of secondary breakdown of any lesions.
2. Regrowth of hair was essentially complete. No changes in hair color or texture were noted.
3. Residual bluish-brown discoloration of the fingernails was observed in three individuals.
4. No other findings on physical examination or X-ray examination of the chest were ascribable to radiation exposure.
5. The total white, neutrophile, lymphocyte, and platelet counts remained depressed below control levels.
6. No significant abnormalities were detected in bone marrow samples aspirated from 22 exposed and 20 control individuals.
7. Minimal amounts of residual gross beta activity were detectable in the urine of approximately one-third of the exposed individuals.

6.3 RECOMMENDATIONS

It is recommended that the following procedures be considered for future medical resurveys: (1) complete serological studies on all exposed and control individuals, (2) stool examinations for parasites, and (3) complete ophthalmological examinations with photographs of lenses.

Also, when additional X-ray pictures are contemplated, consideration should be given to including a portable X-ray machine in the equipment. The machine at the Majuro hospital at present is old and badly in need of repairs.

In summary, information of considerable importance can be obtained by continued observation of the exposed Marshallese people; however, possible late effects cannot be properly evaluated in the absence of an adequate control population. The lack of suitable controls in the Nagasaki-Hiroshima data has been a most serious difficulty in evaluating changes that have appeared. During the present resurvey a control population thought to be adequate was established and examined. It is strongly recommended that consideration be given to the adequacy of this population and, if it is felt to be adequate, that measures be taken to ensure continued observation of the control individuals. Consultation with Dr. Hardin Jones in relation to radiation and longevity is recommended.

REFERENCE

1. E. P. Cronkite et al., Study of Response of Human Beings Accidentally Exposed to Significant Fallout Radiation, Operation Castle final report of Project 4.1.

APPENDIX A

TABLE A.1 — Exposed Population: Comparison with Initial Findings of Individual Weights and Hematological Values

Case No.	Age, years	Sex	Weight, lb		Peripheral blood counts, in thousands						Hematocrit, %		Date of Measles
					Neutrophiles		Lymphocytes		Platelets				
			March	Sept	April	Sept	April	Sept	March	Sept	March	Sept	
2	1.8	M	22	26	2.9	3.4	4.1	3.7	110	240	37	37	
3	1	M	22	25	2.8	5.7	4.2	5.6	155	380	38	38	
4	38	M	148	152	2.7	3.1	3.6	4.5	130	285	46	42	
5	1.8	M	20	25	2.6	5.6	2.7	3.8	115	247	35	37	9/4
7	37	M	120	128	2.5	3.5	2.5	1.5	195	280	41	40	
9	23	M	134	137	2.7	6.6	2.4	2.3	125	190	43	43	
10	30	M	124	131	2.8	4.2	1.6	1.6	105	202	45	46	
11	50	M	123	114	1.6	5.5	1.4	1.5	85	215	41	37	5/54*
12	19	F	96	112	3.3	5.0	1.3	1.8	150	285	32	38	9/3†
13	62	F	91	91	2.4	5.1	1.5	2.3	105	275	38	37	
14	26	F	118	122	2.8	5.8	1.7	1.1	55	160	36	36	†
15	7	F	37	37	1.5	4.7	2.3	2.1	200	270	36	37	9/1
17	4	F	30	32	3.4	4.0	2.7	3.0	105	170	39	35	
18	24	F	101	105	4.3	6.0	1.7	1.2	45	155	34	30	†
19	5	M	32	32	3.1	5.0	2.4	2.3	115	262	34	40	
20	7	M	43	43	3.2	2.9	2.0	1.5	120	230	39	39	9/1
21	3.5	F	29	30	2.7	6.5	2.0	2.2	85	355	35	41	
22	17	F	120	116	2.5	4.8	1.9	1.7	130	235	41	40	
23	4	M	37	37	4.1	4.8	2.8	2.9	195	250	37	38	9/2
24	15	F	96	100	3.5	3.8	2.0	1.5	195	165	38	41	9/2
25	43	M	152	151	4.1	4.2	2.1	1.4	110	275	39	36	
26	12	M	86	104	3.5	3.9	2.3	1.8	145	228	39	37	9/3
27	28	M	145	132	3.6	5.1	1.9	3.8	110	182	44	43	
30	59	F	115		3.9	4.1	1.6	1.7	85	142	42	41	
32	4.5	M	29	29	2.6	4.5	2.7	3.0	95	260	36	39	
33	1	F	22	25	1.7	4.2	3.6	6.5	85	260	33	35	
34	15	F	113	120	3.7	3.7	2.4	2.6	125	210	38	36	
35	14	M	98	94	2.7	5.4	2.2	2.1	140	187	39	40	
36	6	M	50	51	2.5	4.3	2.5	3.3	130	205	36	38	9/1
37	19	M	128	132	3.1	3.7	2.6	1.2	130	167	34	40	
38	70	M	132	138		3.0		1.5		162	38	42	
39	15	F	104	102	2.9	3.8	1.6	1.4	165	237	33	38	9/3
40	30	M		122	2.5	5.2	2.9	2.1	140	270	42	37	8/15
42	3	F	25	27	2.5	6.0	2.9	3.7	80	195	33	38	
46	76	M	132	132	2.4	2.1	2.1	1.8	135	145	33	35	
47	8	M	55	54	4.7	6.1	2.3	2.5	120	205	32	35	
49	16	F	120	123	4.1	3.6	2.2	2.0	180	267	39	39	9/2
52	56	F	114	116	3.0	3.6	2.5	2.1	160	220	38	39	
54	1.6	M	22	22	2.6	2.6	2.0	4.2	145	160	36	34	
55	75	M	149	145	1.5	1.9	2.7	3.2	135	152	37	34	

TABLE A.1 — (Continued)

Case No.	Age, years	Sex	Weight, lb		Peripheral blood counts, in thousands						Hematocrit, %		Date of measles
					Neutrophiles		Lymphocytes		Platelets				
			March	Sept	April	Sept	April	Sept	March	Sept	March	Sept	
56	78	F	108		3.5	5.4	2.6	1.2	125	295	38	37	9/5
57	100	F	104	102	2.0	3.2	2.7	3.8	55	202	34	32	
58	50	F	100	107	2.6	3.3	1.9	2.2	80	160	38	37	
60	63	F	160	170	4.1	5.2	2.5	3.0	160	225	38	38	
61	6	F	66	70	2.5	7.9	3.0	3.2	105	235	39	40	9/3
62	30	F			5.2	3.8	2.8	2.8	110	467	41	39	
63	38	F	113	118	2.6	3.7	1.5	1.9	65	262	41	41	
64	28	F	122	123	3.2	2.8	2.1	2.5	70	190	37	39	
65	1	F	21	23	2.5	4.0	2.4	3.3	105	200	38	34	
66	30	F	116	116	2.8	3.7	3.1	3.1	145	175	38	40	
67	14	F	115	117	3.0	4.3	1.9	2.2	115	250	41	41	9/1
68	49	M	146	150	2.4	2.7	2.0	1.8	120	127	43	41	
69	3	F	33	35	1.4	3.0	3.2	2.2	115	130	36	36	
71	25	F	100	109	5.0	7.5	2.7	2.0	105	200	41	38	
72	7	F	44	40	1.8	4.2	2.0	2.2	185	430	33	41	9/1
73	18	M	160	158	2.6	2.7	1.3	1.4	60	127	49	46	8/31
74	18	F	128	134	7.3	3.5	2.6	2.0	155	262	35	38	
75	12	F	79	82	2.3	4.4	1.7	1.2	110	337	38	40	8/31
76	9	M	63	64	2.8	4.2	2.9	2.5	150	235	38	38	
77	22	M	117			4.2		1.5		180	51	47	
78	37	F	125	135	3.4	3.5	2.0	1.3	95	250	39	38	
79	45	M	138	133	5.1	5.4	2.5	3.1	70	140	47	40	
80	46	M		132	2.9	4.0	2.5	2.7	100	250	44	43	
82	60	M	132		2.6	3.2	2.5	2.1	130	235	40	40	
83	0.25	M		15		2.5		3.0		87			
84	0.33	M		14		2.6		6.5		440			
85													
					Allinginae								
1	54	F	144	166	3.6	6.7	2.4	2.2	175	185	41	38	
6	1	M	24		3.5	3.5	5.6	3.5	215	235	37	37	9/2
8	2	F	22	35	3.5	7.1	4.1	3.0	185	250	35	37	9/2
16	38	M	124	125	2.2	1.8	2.3	1.5	195	212	47	43	
28	69	F	99	107	3.7	3.2	2.3	3.8	115	187	39	39	
29	65	M	124	124	4.1	3.9	2.2	2.4	115	177	42	39	
31	32	M			3.0	3.7	2.5	2.4	145	245	45	42	9/4
41	44	M	126	125	3.1	3.8	2.3	2.6	110	175	44	40	
43	66	F	99		3.7	4.1	2.0	2.0	215	180	41	38	
44	4	M	32	32	2.4	3.5	2.1	1.6	180	270	35	38	9/5
45	33	F	116	107	4.2	3.1	1.5	1.6	180	217	32	35	
48	6	F	41	43	3.0	1.2	3.2	2.0	210	205	36	38	8/30
50	39	M	164	166	4.0	4.5	2.9	1.5	95	152	41	43	
51	23	F	101	98	4.6	5.2	3.0	2.0	170	230	40	38	
53	8	F	48	46	3.7	4.5	2.5	3.4	240	502	36	37	8/25
59	34	F	92	92	8.1	5.6	3.7	2.1	105	197	37	33	
70	17	F	96	104	3.0	3.3	1.8	1.6	187	207	28	32	
81	8	F	43	48	2.3	3.7	2.2	1.6	240	265	36	37	

* Delivered.
† Pregnant.

APPENDIX B

TABLE B.1—Control Population: Individual Weights and Hematological Values

Case No.	Age, years	Sex	Weight, lb	Peripheral blood counts, in thousands			Hematocrit, %	Date of measles
				Neutrophiles	Lymphocytes	Platelets		
1001	54	F	113	2.8	3.8	170		
1002	1	M	16	9.2	9.5	362	32	8/23
1003	2.6	M	26	6.0	7.5	377	35	8/17
1004	52	M		4.2	4.3	250	40	
1005	1	M	19	6.4	5.4	372	31	8/27
1006	1	M	22	9.6	3.1	310	38	
1007	36	M	148	7.2	6.2	307	46	
1008	2.9	F	27	2.9	3.1	445	41	8/17
1009	26	M	160	3.8	3.2	320	46	
1010	30	M	130	4.5	4.0	235	49	
1011	50	M	143	5.6	3.5	200	46	
1012	19	F	114	4.9	2.4	377	42	8/23
1013	62	F	133	4.7	2.7	265	39	
1014	25	F	116	4.0	3.3	310	35	
1015	7	F	44	4.9	3.4	275	36	8/24
1016	42	M	140	4.2	1.7	240	47	
1017	4	F	31	7.3	3.5	360	36	8/19
1018	24	F	146	3.7	3.9	385	38	
1019	5	M	42	8.2	3.1	397	39	8/25
1020	7	M	52	3.6	3.5	350	40	8/17
1021	3	F	32	3.6	4.4	262	34	8/30
1022	18	F	112	5.6	4.5	240	40	
1023	4	M	37	5.1	6.1	410	38	8/30
1024	15	F	107	5.3	4.3	375	39	8/26
1025	43	M	143	4.6	4.9	205	47	
1026	12	M	51	4.8	3.4	247	40	8/24
1027	28	M	130	3.3	2.4	265	42	
1028	70	F	86	8.0	4.5	265	38	
1029	65	M	135	3.6	3.8	302	42	
1030	59	F	131	2.1	2.8	220	42	
1031	35	M	155			215	47	
1032	4	M	32	5.1	3.2	300	38	
1033	1.8	F	20	2.1	4.4	265	40	
1034	50	F	139	2.0	3.5	287	42	
1035	14	M	113	3.8	3.8	240	36	8/15

TABLE B.1 — (Continued)

Case No.	Age, years	Sex	Weight, lb	Peripheral blood counts, in thousands: Neutrophiles	Lymphocytes	Platelets	Hematocrit, %	Date of measles
1036	7	M	58	5.7	4.3	440	35	8/17
1037	19	M	96	10.6	3.1	600	40	8/23
1038	60	M	134	3.1	1.9	242	40	
1039	15	F	95	4.6	3.8	367	38	
1040	19	M		4.3	3.8	227	44	8/15
1041	44	M	159	4.0	3.9	292	45	
1042	4	F	33	3.4	3.8	252	35	8/24
1043				5.3	5.4	305	45	
1044	4	M	31	4.4	3.1	285	34	9/2
1045	30	F	130	6.3	4.7	207	41	
1046	60	M	172	6.3	2.7	195	36	
1047	8	M	67	8.5	7.6	300	37	8/17
1048	6	F	41	6.1	5.0	370	39	8/17
1049	16	F	91	4.0	3.8	260	38	8/30
1050	35	M	162	9.2	5.9	340	48	
1051	25	F		8.5	4.5	295	37	8/27
1052	60	F		4.9	6.6	320	45	
1053	8	F	71	5.3	3.5	505	37	8/21
1054	1	M	19	4.1	4.1	340	36	9/5
1055	75	M	110	6.4	3.1	272	36	
1056	75	F		6.4	5.2	190	44	
1057				5.2	1.6	260	50	
1058	60	F		2.4	3.1	350	42	
1059	34	F	113	12.8	4.9	275	39	
1060	60	F	126	5.7	4.2	242	38	
1061	7	F	56	3.8	3.6	297	36	8/25
1062	47	F	179	4.2	3.7	195	42	
1063	38	F	100	5.3	3.5	305	40	
1064	28	F	101	9.4	3.8	312	44	
1065	1.3	F	17	5.6	7.4	390	37	
1066	30	F	136	3.3	2.8	232	43	
1067	14	F	81	6.2	3.8	315	39	8/15
1068	49	M	130	4.1	2.7	252	41	
1069	2.5	F	28	3.3	3.2	315	42	
1070	16	F	133	4.6	4.7	445	38	8/18
1071	29	F	98	4.1	3.2	425	43	
1072	7	F	48	5.5	3.6	425	36	8/27
1073	17	M		4.5	3.0	280	42	8/17
1074	15	F	118	8.6	1.7	350	33	8/19*
1075	13	F	86	3.5	2.1	305	41	
1076	9	M	72	8.6	3.7	310	42	8/25
1077	22	M	128	3.4	3.3	350	47	8/18
1078	37	F	234	4.4	3.5	275	43	
1079	45	M	108	5.3	4.1	275	41	
1080	46	M	125	3.6	3.7	245	41	
1081	9	F	58	5.8	4.9	310	41	8/24
1082	60	M	156	5.5	2.1	272	40	

* Pregnant.

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