# Medical Survey of Japanese Exposed to Fall-out Radiation in 1954

## A Report after 10 Years

by

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### I. Introduction

On 1 March 1954 a thermo-nuclear test explosion was performed at Bikini lagoon by U.S. authorities. At that time, one Japanese fishing boat, the 5th "Fukuryu-maru" (Lucky Dragon) was about 90 miles east of the explosion centre. The twentythree Japanese fishermen on board, aged 18-39, saw a huge red light in the west and heard a detonation sound several minutes later while they were fishing for tunas. After this explosion, a large amount of radio-active substance fell on the neighbouring area. At about 7:00 a. m. white matter began to fall, which continued for approximately 5 hours. They gave up fishing and returned to their harbour on 14 March 1954.

After landing, all the fishermen were found to have been injured by the radioactive materials. Seven of them were hospitalized to the Tokyo University Hospital, and the other sixteen to the First National Hospital of Tokyo by 28 March. They were discharged from both hospitals in May 1955, except one fatal case who died on 23 September 1954.

After being discharged, they took rest at their home for some period. Although some of them continued to work as fishermen, most of them gave up fishery and got new jobs. Because of their varied status in occupations, financial situations and of the widely distributed addresses, it was not always possible to get all of them together for the annual examinations as planned.

### II. Summary of the Past Findings

We have reported medical data of these people several times[1)-7)]. The following is a brief summary of the past findings.

A. State of Irradiation and the Estimated Dose

The persons were irradiated in the following three ways:

(1) From the radioactive materials adhering to the body surface.
(2) Externally from the radioactive materials deposited in the cabins, on the deck, etc.
(3) Internally from the radioactive materials entering various organs.

The diameter of the fall-out materials ranged 19-460 $\mu$, mainly 100-400 $\mu$[8)]. The radiochemical analysis of the materials was performed at several laboratories. According to data from Prof. Kimura's laboratory[9)], on 26 March rare-earth elements contributed about 50% of the total radioactivity and uranium contributed about 20%. The specific activity of the material was 0.37 mCi/g on 23 April. By extrapolation of this data, a value of 1.4 Ci/g was obtained as the specific activity at 7:00 a. m. on 1 March. The estimation of irradiation dose, especially that from body surface and internally deposited radioactive materials, was difficult. However, externally irradiated dose for 14 days was estimated as 170-700 R, about half or more being irradiated on the 1st day (Table 1). This estimation was based on the results of the experimental reproduction of ash-fall, and on detailed investigation of each patient's behaviour on the boat. The dose to each person differed depending on his behaviour and the position of his cabin.

The integrated dose to the thyroid from $^{131}$I was inferred as about 20-120 rad on 4 persons who were examined 2-3 times for external countings of radioactivity in the thyroid region during the 4-7 weeks after the initial exposure.

Urine samples of patients were collected and transferred to the Health and Safety Laboratory of U. S. A. E. C. for radiochemical analysis several times.[10)] Significant amounts of radioactivity were found in the urine samples collected at about 4 weeks after the explosion. Radiochemical analysis of these samples indicated that $^{89}$Sr and

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Table 1. Estimated Dose of Whole Body Gamma Radiation

| Subject No. | 1st Day | Total | |
|---|---|---|---|
| T- 1 | 240~290R | 450~500R | |
| T- 2 | 210~260 | 390~440 | |
| T- 3 | 150~200 | 260~310* | (360~410) |
| T- 5 | 400~430 | 660~690 | |
| T- 6 | 130~180 | 200~250 | |
| T- 7 | 140~190 | 220~270 | |
| T- 8 | 310~360 | 520~570 | |
| K- 1 | 190~220 | 310~340 | |
| K- 2 | 130~180 | 200~250 | |
| K- 3 | 140~190 | 230~280 | |
| K- 4 | 120~170 | 190~240 | |
| K- 5 | 140~190 | 220~270 | |
| K- 6 | 180~230 | 300~350 | |
| K- 7 | 230~280 | 340~390 | |
| K- 8 | 220~270 | 380~430 | |
| K- 9 | 310~360 | 550~600 | |
| K-10 | 140~190 | 230~280 | |
| K-11 | 120~170 | 170~220 | |
| K-12 | 100~150 | 170~220 | |
| K-13 | 250~300 | 370~420 | |
| K-14 | 420~500 | 510~590 | |
| K-15 | 140~190 | 210~260 | |
| K-16 | 120~170 | 190~240 | |

* T-3 put the fall-out material close to his bed. Therefore, about 100 R should be added in total.

$^{140}$Ba contributed 4-20% of radioactivity at that time. The radioactivity decreased extremely rapidly, e. g. at about 6 months after the detonation, the activity in the urine was barely detectable. After 8½ years, the levels of $^{137}$Cs in urine/24 hrs. were the same to that of normal persons.

Radiochemical analysis of several organs from the fatal case, which died on 23 September 1954, showed that, comparing with the controls, radioactivity of these organs was clearly higher, although it was not extremely high.[11]

Whole body counting was performed on three persons 8½ years after the initial exposure. No significant difference was found between the curves of the three irradiated persons and the curve of the control.

B. Clinical Observations

1. Symptoms and Signs

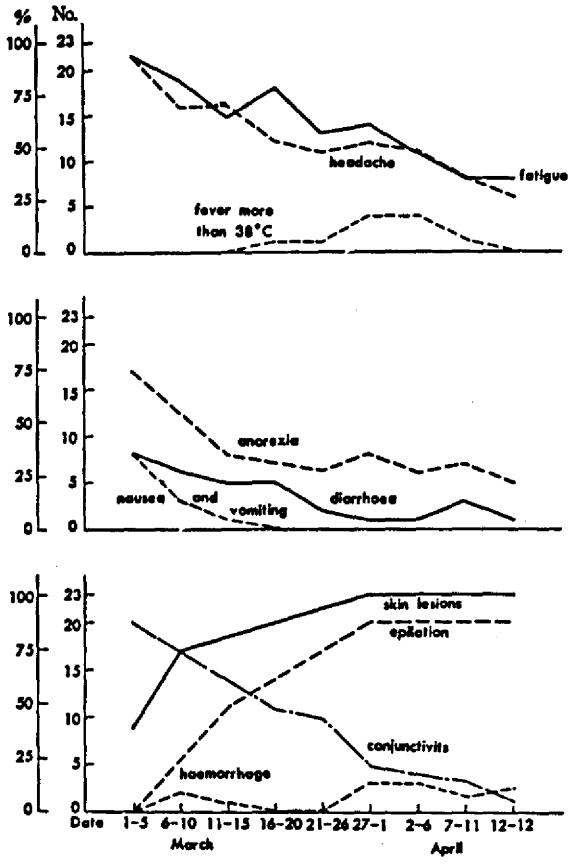


Fig. 1. Symptons and Signs in the Early Stage

Soon after the initial exposure most of the patients experienced anorexia, fatigue and lachrymation, etc. These symptoms and their changes are illustrated in Fig. 1.

The diseases occurred between 1955 and 1963 are listed in the following.

T- 3 eczema (1957-1960), pneumonia (1963)
K- 4 erosion of r. external ear (1962), impetigo (1963)
K- 8 r. pulmonary phthisis (1955)*
K-10 r. exsudative pleuritis (1959)*, Furunculosis (1960)
K-16 acute appendicitis (1957)

2. Skin Lesions

Skin lesions occurred due to beta radiation. An estimate of the radiation dose to the skin was difficult. Shortly after the exposure, they suffered from erythema which was followed by edema, vesicle, erosion, ulceration or necrosis.

* These were diagnosed by Dr. Kumatori. The others were due to complaints of the patients.

These signs reached the peak in about the 3rd-4th week and subsided gradually. These skin lesions including epilation were observed on parts of the body not covered by clothing and on the navel region where radioactive dusts from neck were deposited. Histologically, these skins were similar to ordinary radiodermatitis. Remarkable epilation was observed in 20 patients. Two patients who did not wear hats at the time of the accident revealed complete epilational necrosis. Microscopically, coagulation necrosis and cell infiltration in the necrotic scalp was observed at about the 4th week. These skin lesions recovered gradually. Thin and delicate hairs began to grow again at the beginning of May, and in 2-3 months they grew back almost completely. But, T-2 and T-7 have alopecia even now. In some persons, capillary dilatation, depigmentation and pigmentation of skin are still observed in the navel region. For the skin lesions every possible treatment was applied.

For decontamination, mechanical washings with Na-EDTA or warm water were done. The hair of head, axilla and pubes was shaved off. The nails were cut off. In one and half months superficial contamination was almost removed. The distribution of surface radioactivity and skin lesions is shown in Fig. 2.[12]

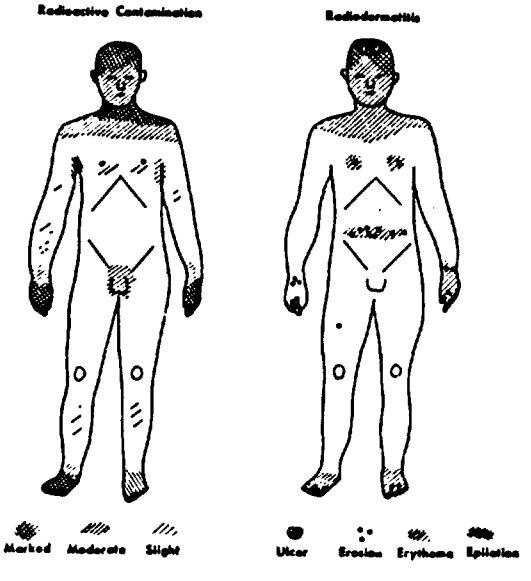


Fig. 2. Distribution of Radiodermatitis[12]

3. Haematological Observations

*Leucocytes*

Total number of leucocytes decreased gradually, showing minimum count at about 4-8 weeks after the exposure. Five cases revealed a count of less than 2,000/mm³, thirteen less than 3,000, and five less than 4,000. In one case, the leucocyte level depressed to 800. A correlation was found between these minimum count and the doses of individual external irradiation.

Neutrophil level also depressed. Between the 4th-8th weeks all of the cases got minimum values, which were proportional to the dose of radiation received (Fig. 3). In most cases a shift to the left of the nucleus was observed.

Lymphopenia was noted between the 2nd-8th weeks in all cases.

Leucocyte count began to increase since 8th week. At that time, metamyelocytes and myelocytes appeared in peripheral blood of some cases.

In most cases eosinophilia and in some cases monocytosis were remarkable, especially with the indication of recovery. Eosinophilia continued in some cases for several years without proof of parasite.

Neutrophil and lymphocyte levels recovered gradually. However, cumulative distribution curve of total leucocyte count at the 6th year was still slightly displaced to the left of normal Japanese, and in several cases, number of lymphocytes was below 2,000/mm³.

Motility and phagocytosis of neutrophils depressed remarkably. Although they recovered gradually, after one year these functions in some cases were still lower than in normal persons.

*Erythrocytes*

At the time of hospitalization, a few patients were slightly anaemic (RBC 3,000,000/mm³). No reticulocyte was observed in them at the critical stage. The cumulative percentage curves changed as in Fig. 4.

Colour index was higher than 1.0. The Price-Jones curves of erythrocytes diameter were displaced to the right of normal one at first, and returned to almost normal after one year. These changes corresponded to changes of erythroblasts diameter in bone marrow.

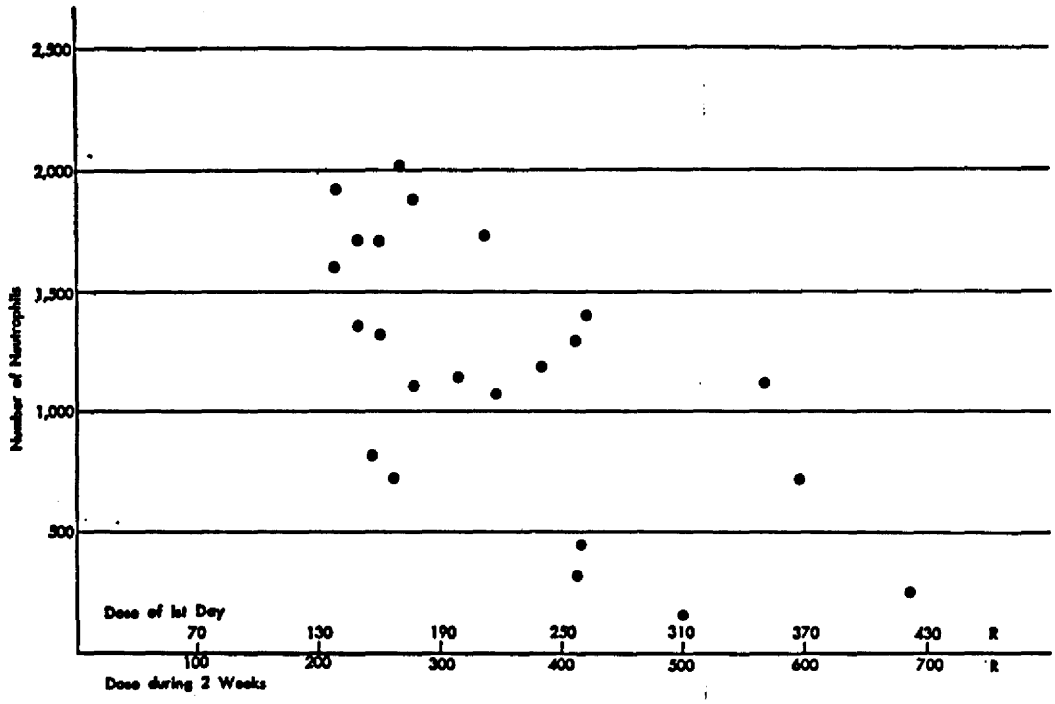


Fig. 3. Correlation between Minimal Neutrophils Count and Dose of Gamma Radiation

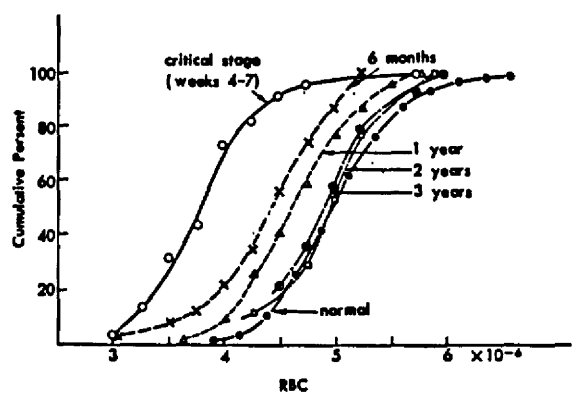


Fig. 4. Cumulative Distribution Curves (RBC)

*Platelets*

Platelets counts showed increasing depression, reaching minimum at the 4th-7th weeks. The recovery began during the following several weeks. The cumulative percentage curve still displaced to the left of normal curve after one year.

The results of other tests related to haemorrhage showed depression at the early stage in general and recovered by the 10th week.

*Bone marrow*

The bone marrow was aplastic at the critical stage in severe cases, which showed remaining and proliferation of plasma cells and reticulum cells. With the beginning of recovery, aplastic marrow changed to hypoplastic and then turned into a type of maturation arrest. Recovery was not complete even after one year. In the cases not so severe as these, the bone marrow was not 'astic but hypoplastic or a type of maturation arrest even at the critical stage.

*Morphological abnormalities*

Several morphological abnormalities, e.g. abnormal granules in lymphocytes or neutrophils, vacuoles in various leucocytes and megakaryocytes, giant nuclei and hyper-segmentation of neutrophils, binucleated lymphocytes, abnormal mitosis of erythroblasts, etc. were observed for about one year, especially at the critical and the recovering stages.

*Erythrocyte sedimentation rate* was accelerated in the early stage in some cases.

4. Spermatopoiesis

The examinations of spermatopoiesis were performed on 18 patients several times.

Number of spermatozoa decreased about 2 months after the initial exposure, and azoo-

spermia was found in 16 cases in November 1954, e.g. about 8 months after the detonation. Both lowering of motility and morphological abnormalities of spermatozoa were also observed.

The testicle of the fatal case, which died 206 days after the explosion, was remarkably atrophic, possessing the interstitial tissue composed of loosely arranged connective tissue. Spermatogonia were greatly decreased in number, and in some areas they were completely lacking. No sperm was encountered within the lumen of either seminiferous tubules or epididymis.

Indications of recovery were observed at about one year after the explosion in some patients, but number of spermatozoa was still far below normal value in all the cases. Most of them began to reveal a sign of regeneration about 2 years after the exposure, and got children (Fig. 5 and Table 2).

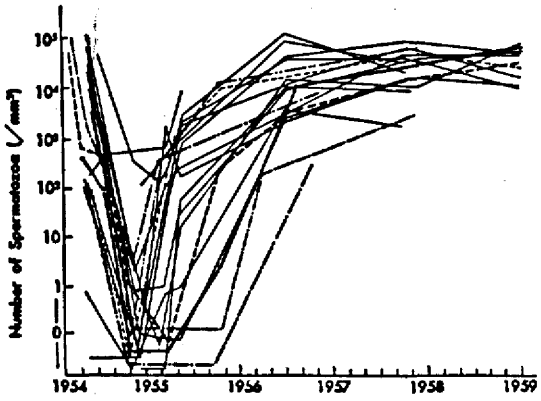


Fig. 5. Changes in the Number of Spermatozoa

5. Liver Function

Slight disturbances of the liver function were found in a few cases about 4 weeks after the initial exposure. Later it became more obvious, *i.e.* the repeated appearance of jaundice in several cases, an increase of serum gamma-globulin con-

Table 2. Marriage and Childbirth of the Patients

| Case \ Date | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963 | Age in March 1954 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| T- 1 | M (2) | | A | f | | | | | | | 27 |
| 2 | M (3) | | | | | | | | | | 38 |
| 3 | M (2) | | | | | | | | | | 28 |
| 5 | M (4) | | | | | | | | | | 30 |
| 6 | M (3) | | | | f | | | | | | 28 |
| 7 | | M | | | | | | f | | | 27 |
| 8 | | | | | | M | | | | | 26 |
| K- 1 | | M | m | | m | | | | | | 22 |
| 2 | | | | M | | | | f | | | 25 |
| 3 | | | | | M | f | | m | | m | 25 |
| 4 | | M | | | m | | | f | | | 24 |
| 5 | | | | | | M | | | m | | 22 |
| 6 | | M | m | | f | | f | | f | | 26 |
| 7 | | | | | | | | | | M | 18 |
| 8 | | | | M | | | | | | m | 23 |
| 9 | | | | | | | M | f | | m | 22 |
| 10 | | | M | m | | f | | | | | 24 |
| 11 | | | | M | m | | | | | f | 23 |
| 12 | | | | | | | M | | | | 18 |
| 13 | | | M | | | f | | f | | | 22 |
| +14 | M (3) | | | | | | | | | | 39 |
| 15 | M (2) | | | | f | | | | | | 27 |
| 16 | | | | | | M A | | f | | m | 20 |

M……Marriage ( )……No. of children at the time of exposure
m……Male f……Female A……Abortus +……Fatal case

tent, and increased retention of BSP, etc. were observed in most cases. One of the patients, who was pancytopenic at about the 4–7th week, died from liver damage 206 days after the exposure. In other patients, liver function gradually recovered, and clinically significant liver disturbances have not been found. For example, CCF test was positive in most of the patients in 1955 survey (1½ years), while CCF test in 1957 examinations was negative in all the cases.

6. Other Studies

The study of leucocyte chromosomes was made with peripheral blood culture method. The results of the study, however, were not sufficient enough to be presented.

Ophthalmological examinations showed slight lenticular opacities in several cases, but, these have not been related to the former exposure yet.

Content of Na, K, P and Ca in serum was normal.

## III. 1964 Medical Survey

As already mentioned, we have tried to perform medical survey on these irradiated persons on an annual basis. However, sufficient examination was impossible by several reasons.

This 1964 survey was carried out as follows:

1) Thirteen persons were examined at the National Institute of Radiological Sciences, and one person at the Tokushima University Hospital, under hospitalization.
2) Four persons were examined by Dr. Kumatori, *et al.* at the Yaizu City Hospital as outpatients.

The period of hospitalization was 3–6 days. The 1964 survey was performed from the end of January and finished at the beginning of May. During this period, Dr. R. A. Conard from Brookhaven National Laboratory, the Head of U. S. A. E. C. Medical Survey Team on Marshallese exposed to fallout on 1 March 1954, visited Japan to be on hand for the examinations of Japanese fishermen. Dr. T. Kumatori, National Institute of Radiological Sciences, went to the Marshall Islands with Dr. Conard, and cooperated with U. S. Medical Survey Team for about 3 weeks. This exchange visit was valuable for understanding of radiation effects on both Japanese and Marshallese exposed people.

A. Interval Histories

Their occupations in 1964 were as follows:

| | |
|---|---|
| Fisheries, including pelagic fisheries | 5 |
| Seaman | 1 |
| Labourers | 8 |
| Farmer | 1 |
| Personal business | 4 |
| Telegraph operator | 1 |
| Technical official | 1 |
| Occupation unknown | 1 |

The interval medical histories were summarized in page 2 and Table 2. Several diseases contracted after the release from the hospitals did not seem to be late effects. Since the 1963 survey no significant disease has occurred. Their children are healthy, but detailed medical examinations of the children have not been carried out yet.

B. Physical Examinations

The routine physical examinations revealed the following:

In 10 cases among the 18 examined, livers were palpable ½–2 finger breadth below r. costal margin at mid-clavicular line, but they were soft and not cirrhotic.

Case K-8 developed r. pulmonary phthisis in 1955 and received chemotherapy. At present, only small fibrotic foci are observed in r. subclavicular area on chest X-ray film.

Systolic murmurs were heard at the apex of heart in K-10, and r. bundle-branch block was proved by ECG. No medical treatment was required.

Case T-7 was proved glucosuria. Detailed medical examinations are to be done at Yaizu City Hospital.

Cases T-2, K-1, and K-6 showed slightly elevated minimum blood pressure (94, 98, 98, respectively).

C. Skin Lesions

Residual skin changes in areas previously exhibiting beta burns were still observed in some cases.

Most remarkable residual changes were shown in abdominal wall (T-6, K-2, 4, 5, 7, 11, 12, 13). Pigmentation, depigmentation and teleangiectasia were observed macroscopically (Plate 1). His-

tological section of these area revealed patchy loss of pigment cells at the base of the epidermis and slightly edematous upper dermis and papillae. The blood vessels showed slight vacuolation of the media of the muscular arteries, but no evidence of inflammation or neoplasm was found as well as chronic dermatitis (Drs. M. Seki and T. Yoneyama) (Plates 2 and 3). These findings are similar to those observed in the Marshallese[13].

In two cases who showed complete epilation, small alopecias were still observed (T-2 and 7). Thin hairs grew in the area. In T-7, grey hairs seemed to be much comparing with age.

Besides those area, residual beta burns were observed in small area of wrists (T-6 and K-7), external ears (T-2, 7, 8 and K-6), foot and leg (K-8).

D. Ophthalmological Examinations

Ophthalmological examinations were carried out on 14 hospitalized persons and 3 outpatients by Dr. S. Kubota, National Hospital of Chiba, and Dr. N. Hirota, Yaizu City Hospital, respectively. The results are presented in Table 3.

Table 3. Ophthalmological Examinations

| | | |
|---|---|---|
| Pterygium and pinguecula | 9 | (T-3, T-8, K-2, K-4, K-5, K-8, K-11, K-13, K-16) |
| Corneal pigment | 3 | (K-2, K-4, K-10) |
| Vasculalisation | 2 | (K-4, K-13) |
| Keratitis diffusa | 2 | (T-3, K-5) |
| Arcus senilis | 1 | (K-11) |
| Lenticularopacities | 7 | (T-2, T-3, T-6, T-7, K-5, K-11, K-16) |
| Vitreus opacities | 1 | (K-8) |
| Macular degeneration | 3 | (T-3, K-2, K-5) |
| Retinal arteriosclerosis | 5 | (T-2, K-4, K-5, K-6, K-9) |
| Strabismus | 2 | (K-4, K-10) |

Pterygium and pinguecula were observed in 9 persons. Corneal pigmentation was proved in 3 cases.

Lenticular opacities were noted in 7 cases; *i. e.* Cases T-2 and T-7 showed slight opacity of posterior capsule, cases T-3, K-5 and K-11 had opacities of [illegible]rtices. Case K-16 showed slight opacities [illegible] posterior cortex. Cataracta punctata was noted in T-6 who was examined in Tokushima University Hospital.

As to the neuroretinal findings, slight opacities and pigmentation of macula were found in 3 cases, and slight arterio-sclerosis were observed in 4 cases.

In general, it is still early to decide whether these abnormalities in the exposed persons were late effects of the exposure in 1954 or not. Precise observations should be continued.

E. Haematological Examinations

The results of haematological examinations are presented in Table 4.

a. Peripheral blood

*Leucocytes:* Leucocyte numbers were distributed between 4,200 and 9,400.

*Neutrophils:* Numbers of neutrophils were in normal range in all the cases except Case T-3. Obvious shift to the left of nuclei was not found.

*Lymphocytes:* Numbers of lymphocytes were over 2,000 in all the cases except Case T-6 which showed lymphocyte level below 2,000 in every examination.

*Eosinophils:* Case K-2 showed eosinophilia which had continued since acute stage. No sign of parasite was proved.

*Basophils:* As to basophils, the rate to 3,000 leucocytes was calculated (Table 5). Comparing with that of normal persons, slightly high percentage of basophils was observed in Case K-2 and Case K-9. The latter showed similar rate in 1961 survey.

*Monocytes:* No pathological data was obtained on these cells.

T-3, K-5 and K-4 were chosen as representing cases at the acute stage with signs and symptoms of marked degree, of moderate degree, and of minimal degree, respectively. The changes of WBC, neutrophils and lymphocytes are illustrated in Fig. 6-A, B and C. T-3 showed slightly decreased values. Considering the myelogram of T-3, a slight maturation arrest of myeloid cells might exist.

*Platelets:* Platelets counts ($130 \sim 510 \times 10^3$) were normal.

*Erythropoietic elements:* Between the exposed

Table 4. Individual Haematological Findings

| Subject No. | Hb g/dl | RBC ×10⁻⁴ | C. I | Retc ‰ | Pl. ×10⁻⁴ | WBC | Ht | Haemogram % | | | | | | Score of N. Ap-ase | Bleeding Time | Coagulation Time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | N | | E | B | Mon | Ly | | | |
| | | | | | | | | St | Seg | | | | | | | |
| T- 2 | 13.3 | 482 | 0.92 | 4 | 29 | 9,400 | 43 | 3 | 45 | 2 | 0 | 6 | 44 | 80 | | |
| 3 | 15.3 | 491 | 1.04 | 3 | 30 | 4,200 | 42 | 4 | 29 | 4 | 0 | 4 | 59 | 48 | 1'30" | 9'30"～15'00" |
| 6 | 16.8 | 533 | 0.98 | 8 | 13 | 5,200 | | 10 | 50 | 6 | 0 | 2 | 32 | | 2'30" | 9'00" |
| 7 | 15.3 | 477 | 1.08 | 6 | 27 | 6,500 | 45 | 11 | 40 | 2 | 0 | 1 | 46 | 93 | | |
| 8 | 16.6 | 571 | 0.9 | 14 | 45 | 6,200 | 48 | 5 | 49 | 2 | 0 | 8 | 36 | 30 | 2'20" | 10'00"～12'40" |
| K- 1 | 15.2 | 488 | 1.0 | 6 | 44 | 7,100 | 47 | 7 | 42 | 3 | 0 | 3 | 45 | 15 | 3'00" | 14'00"～16'50" |
| 2 | 13.4 | 457 | 1.0 | 7 | 45 | 6,600 | 44 | 7 | 40 | 17 | 1 | 3 | 32 | 57 | 2'30" | 3'00"～10'15" |
| 4 | 14.9 | 485 | 1.0 | 11 | 44 | 7,100 | 45 | 5 | 38 | 2 | 0 | 5 | 50 | 60 | 2'10" | 6'30"～15'00" |
| 5 | 13.6 | 438 | 1.05 | 6 | 22 | 8,000 | 41.4 | 1 | 68 | 1 | 1 | 4 | 25 | 38 | 2'00" | 9'20"～13'00" |
| 6 | 17.4 | 517 | 1.1 | 11 | 40 | 5,900 | 47 | 4 | 51 | 5 | 0 | 6 | 34 | 69 | 2'00" | 6'00"～17'00" |
| 7 | 15.7 | 523 | 1.0 | 11 | 34 | 5,600 | 49 | 7 | 52 | 0 | 0 | 2 | 39 | 53 | | |
| 8 | 16.1 | 515 | 1.05 | 7 | 30 | 6,100 | 49 | 9 | 49 | 3 | 0 | 4 | 35 | 42 | 3'00" | 7'20"～13'00" |
| 9 | 15.3 | 498 | 1.0 | 19 | 47 | 7,100 | 45 | 9 | 45 | 6 | 0 | 2 | 38 | 99 | 2'30" | 7'30"～16'00" |
| 10 | 15.4 | 533 | 0.9 | 5 | 51 | 6,800 | 50 | 7 | 49 | 2 | 0 | 7 | 35 | 40 | 3'00" | 6'30"～11'00" |
| 11 | 16.4 | 477 | 1.1 | 10 | 39 | 8,600 | 46 | 7 | 51 | 4 | 0 | 0 | 38 | 42 | 2'30" | 7'00"～12'00" |
| 12 | 12.9 | 457 | 0.9 | 7 | 42 | 5,100 | 44 | 3 | 43 | 7 | 0 | 4 | 43 | 73 | 2'30" | 7'00"～12'30" |
| 13 | 16.5 | 526 | 1.05 | 8 | 36 | 9,800 | 48 | 5 | 68 | 1 | 0 | 1 | 25 | 60 | 3'00" | 5'40"～ 9'30" |
| 16 | 14.9 | 498 | 1.0 | 6 | 31 | 5,900 | 47 | 3 | 48 | 2 | 0 | 2 | 45 | 56 | 2'40" | 8'30"～10'20" |

Table 5. Basophil Determinations

| Subject No. | % Baso./3,000 Cell Count | |
|---|---|---|
| | 1961 | 1964 |
| T— 2 | 0.30 | 0.48 |
| T— 3 | 0.30 | 0.12 |
| T— 7 | 0.50 | 0.39 |
| T— 8 | | 0.24 |
| K— 1 | | 0.04 |
| K— 2 | 0.27 | 0.80 |
| K— 4 | 0.10 | 0.36 |
| K— 5 | 0.37 | 0.55 |
| K— 6 | | 0.13 |
| K— 7 | | 0.22 |
| K— 8 | 0.13 | 0.12 |
| K— 9 | 0.90 | 0.89 |
| K—10 | 0.50 | 0.09 |
| K—11 | | 0.16 |
| K—12 | | 0.47 |
| K—13 | | 0.12 |
| K—15 | 0.90 | |
| K—16 | 0.63 | 0.08 |
| 9 normal persons | | 0～0.63 |

persons and the corresponding normal persons, no difference was shown in the levels of erythrocyte, haemoglobin, and haematocrit. Colour indices were nearly 1.0.

*Alkaline phosphatase of neutrophils:*

N. AP-ase score of WBC was slightly low in Case K-1. Other cases showed normal scores.

It is necessary to continue this study periodically.

b. Bone marrow

Bone marrow punctures of sterna were carried out on 14 exposed and 4 normal persons. Bone marrow smears, histological sections, were observed.

Case T-3 revealed slight increased percentage of myeloblast (6%). High M/E ratio was observed in Case K-12 (M/E=5.5). "Mitotically Connected Abnormalities (M. C. Abn.)"[4] were examined. The results are summarized in the Table 6. In Cases T-3, K-4 and K-9, karyomeres were increased, comparing with normal and other exposed persons.

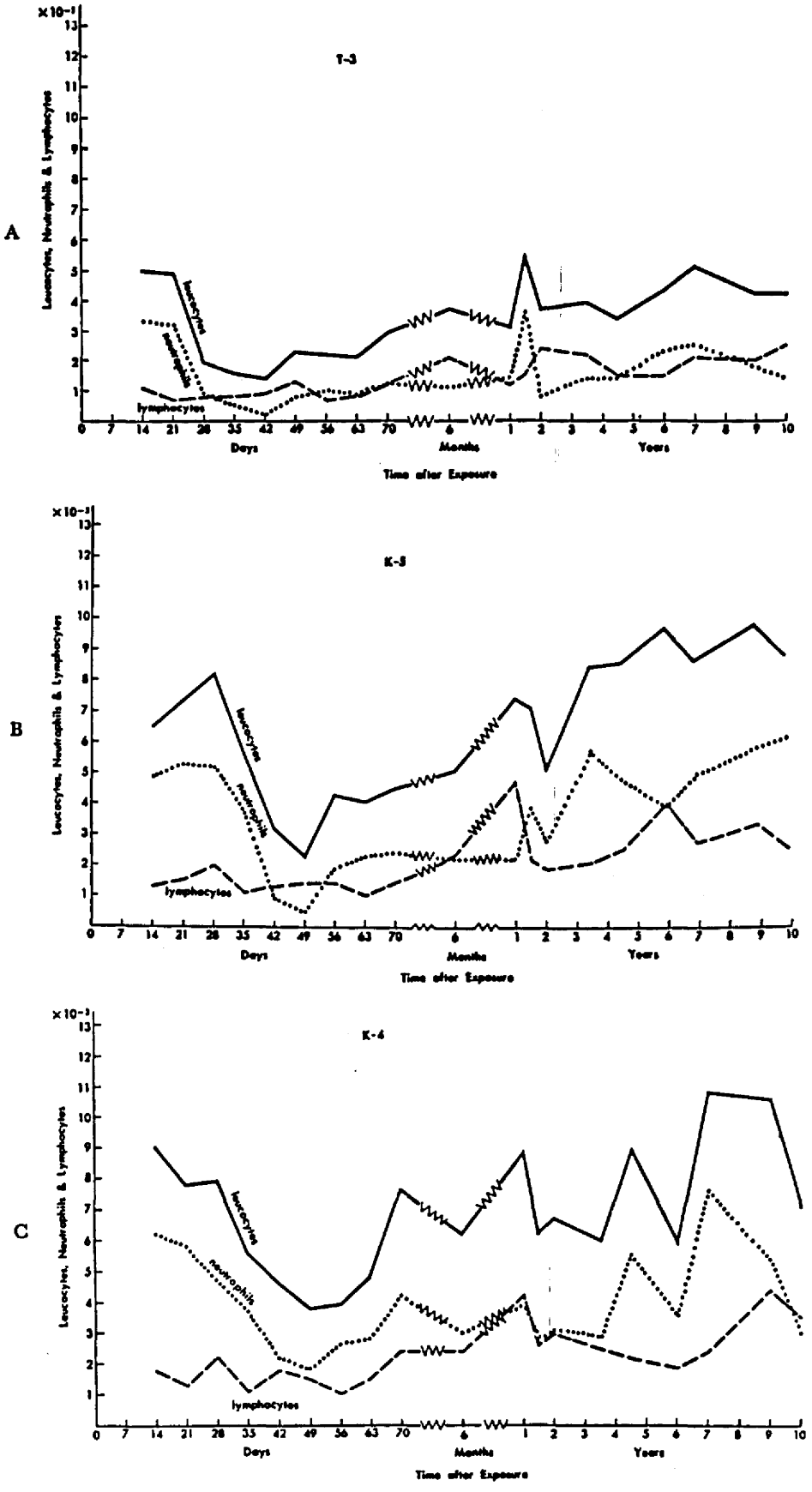


Fig. 6. Changes in the Number of Leucocytes, Neutrophils and Lymphocytes

Table 6. Mitotically Connected Abnormalities (per 1,000 Erythroblasts)

| Subject No. | Binucleated Erbl. | Karyomere | Aberrant Chromosome in Mitosis | Giant Neutrophils |
|---|---|---|---|---|
| T— 3 | 4 | 11.3 | 0.67 | + |
| T— 8 | 4 | 0 | 0 | — |
| K— 1 | 3.3 | 2 | 0 | — |
| K— 2 | 1.3 | 2 | 0 | — |
| K— 4 | 0.67 | 7.3 | 2 | — |
| K— 5 | 1.3 | 5.3 | 1.3 | — |
| K— 6 | 1.3 | 0 | 0 | — |
| K— 8 | 0 | 2 | 0 | — |
| K— 9 | 2 | 11.3 | 4 | — |
| K—10 | 1.3 | 0 | 1.3 | — |
| K—11 | 4 | 0 | 0.67 | + |
| K—12 | 0.67 | 0 | 0 | — |
| K—13 | 2 | 0.67 | 0 | — |
| K—16 | 2.7 | 0.67 | 1.3 | — |
| Normal | | | | |
| 1 | 2 | 4 | 2 | — |
| 2 | 4 | 0 | 0 | — |
| 3 | 0 | 0 | 0 | — |
| 4 | 0 | 0 | 0 | — |
| 5 | 2 | 0 | 0 | — |

In the histological sections, all showed normal cellular marrow.

c. Haemorrhagic diathesis

As to the haemorrhagic diathesis, no abnormalities were found.

F. Chromosome Studies

Chromosome studies succeeded on 13 of the exposed persons. The observation of chromosomes was made by cultures of peripheral leucocytes prepared in accordance with the method by Moorhead, *et al.* with a slight modification. Samples were obtained 72 hours after initiation of culture, and 200 metaphases were examined in each culture for all the cases except one case. The control observations were based on 11 normal males, aged 28-53. The results of the observations are shown in Table 7.

As shown in the table, frequencies of chromosome aberrations in the exposed persons were much higher than those in the normal. Further, dicentric chromosomes and monocentric abnormal chromosomes, chromosome-type abnormalities which have never been observed in normal persons, occurred in them. Dicentrics were found in 7 cases, and monocentric abnormal chromosomes were present in all of the cases examined. Also, aneuploid cells occurred in a high frequency.

In view of the importance of these findings, long term observations are to be made. The chromosome abnormalities of these patients were reported elsewhere together with those of other radiation-exposed people, *i.e.* atomic bomb survivors, Thorotrast-injected patients, etc.[1)]

G. Other Laboratory Studies

Several laboratory studies were made on the subjects. The results of these examinations were mostly within normal range. However, some of them indicated slight abnormalities.

*ZTT*: Normal.

*Thymol turbidity test*:
Cases K-5, 6, 8 and 9 revealed high values (7～10).

*Icteric index*: Cases K-8, 11, 13 and 16 showed slight increase (nearly 9).

*Serum alkaline phosphatase*:
Cases K-6, 7, 10 and 11 indicated increased values (12～18 King-Armstrong unit).

*GOT*: No pathological data was obtained except for T-7 (70 Frankel unit).

*GPT*: All data were within normal range.

*Paper electrophoresis*: No abnormal findings were obtained.

*Total cholesterol*: All were normal.

*BSP test*: Cases T-6 (12.5%), K-6 (5-7.5%) and K-13 (5-7.5%) revealed slight high retention (45 min.).

*Erythrocytes sedimentation rate*:
All were normal.

*Tests for syphylis*: All were negative.

*Routine urine analyses*:
A sample from Case T-7 was positive for sugar (1/10～1/4%). Others were normal.

*Feces*: No parasites were observed.

*PBI*: Five cases were measured for PBI content by courtesy of Dr. Tachibana (St.

Table 7. Chromosome Aberrations

| Case | Age | No. of Cells Examined | Chromatid Aberrations** % | Aneuploid Cells*** % | Acentric Fragments % | Dicentrics % | Rings % | Others % | Total Chromosome Abnormalities % | Cells with Chromosome Abnormalities % |
|---|---|---|---|---|---|---|---|---|---|---|
| Control* | 28~53 | 2,300 | 3.14 (0~6.0) | 2.14 (0~4.5) | 0.18 (0~0.5) | 0 | 0 | 0 | 2.32 (1.0~5.0) | 2.32 (1.0~5.0) |
| T— 3 | 39 | 200 | 4.0 | 3.5 | 1.5 | 0.5 | 0 | 0.5 | 6.0 | 5.5 |
| T— 8 | 37 | 100 | 2.0 | 2.0 | 0 | 0 | 0 | 2.0 | 4.0 | 4.0 |
| K— 1 | 32 | 200 | 4.0 | 3.0 | 0.5 | 0 | 0 | 0.5 | 4.0 | 4.0 |
| K— 2 | 35 | 200 | 3.5 | 6.0 | 0 | 0 | 0 | 0.5 | 6.5 | 6.5 |
| K— 4 | 35 | 200 | 4.5 | 4.5 | 0 | 0.5 | 0 | 1.5 | 6.5 | 6.0 |
| K— 5 | 33 | 200 | 2.5 | 3.5 | 0.5 | 0.5 | 0 | 2.0 | 6.5 | 4.5 |
| K— 6 | 36 | 200 | 2.0 | 3.5 | 0.5 | 0.5 | 0 | 2.0 | 6.5 | 6.5 |
| K— 9 | 32 | 200 | 9.0 | 3.0 | 0.5 | 0.5 | 0 | 1.5 | 5.5 | 5.5 |
| K—10 | 35 | 200 | 3.0 | 4.5 | 0 | 0.5 | 0 | 2.0 | 7.0 | 7.0 |
| K—11 | 33 | 200 | 4.5 | 3.0 | 1.0 | 0 | 0 | 1.0 | 5.0 | 5.0 |
| K—12 | 29 | 200 | 4.5 | 2.0 | 1.0 | 0 | 0 | 0.5 | 3.5 | 3.5 |
| K—13 | 28 | 200 | 2.0 | 2.0 | 0.5 | 0 | 0 | 1.0 | 3.5 | 3.5 |
| K—16 | 30 | 200 | 5.5 | 2.0 | 0.5 | 1.0 | 0 | 1.5 | 5.0 | 5.0 |
| Total | | 2,500 | 3.9 | 3.3 | 0.5 | 0.3 | 0 | 1.3 | 5.3 | 5.1 |

* Consisting of eleven healthy male.
** Not being included in "Total chromosome abnormalities" and "Cells with chromosome abnormalities".
*** A chromosome or chromosomes being missing from or additional to one or more of the seven chromosome groups: the distribution in the remaing groups being normal.

Luke's Hospital). No abnormal value was obtained.

*BMR*: Cases T-8, K-2 and K-12 were measured. Data were +9%, −2%, and −2%, respectively. As Case K-2 was suspected of a slight enlargement of thyroid, $^{131}$I uptake, PBI conversion rate and Triosorb tests were added. No abnormal result was obtained.

H. Internal Exposure

a. $^{137}$Cs

1) Whole Body Counting

Gammaspectrometric analyses by whole body counting on the 13 exposed people indicated no significant increase of $^{137}$Cs. No difference was recognized between the curves from the exposed persons and those from the controls.

2) Radiochemical Analyses of Urine

$^{137}$Cs analyses were carried out on 24-hour urine samples from 10 exposed people and 14 normal persons. The $^{137}$Cs content of urines from the exposed people was distributed between 23.3±0.6 and 129.6±2.3 pCi/24 hrs. and the mean $^{137}$Cs contents were 79 pCi/24 hrs. urine. On the other hand, the $^{137}$Cs content from normal urine samples was distributed between 57.8±1.7 and 191.1±2.6 pCi/24 hrs. and the mean $^{137}$Cs contents were 112 pCi/24 hrs.

Considering the results of whole body counting and urine analyses, $^{137}$Cs content of the exposed people is not different from that of the present normal Japanese.

b. $^{90}$Sr+$^{90}$Y

$^{90}$Sr analyses were done on the pooled urine samples collected from 3–5 exposed persons. As the control, 3 normal samples were analysed. No significant increase was found on the samples from the exposed persons.

## Summary

Medical examinations were carried out from middle of January to middle of May 1964 on 18 persons exposed to fall-out in the middle Pacific

Ocean in 1954. Fourteen of them were examined under hospitalization, and the other four were treated as outpatients. At first we planned to examine all the exposed persons (twenty-two in total), however, mainly for reasons of their own, we could not include four of them in the 1964 survey.

In general, these persons had been in good health during the past years. Although several diseases occurred in some of them, there was no definite reason to relate the radiation exposure to such diseases. Since most of them got children after being discharged from hospitals, it would seem evident that permanent sterility did not occur in them.

The routine physical examinations of 1964 revealed that liver was palpable in ten cases. However, it was not cirrhotic, and did not seem to be related to liver disturbances. The routine physical examination had no observation to be relatable to the radiation exposure.

Residual beta burns of the skin were noted in 13 people of the 18 examined. The burns were observed in wrists, external ears, abdominal walls, foot and leg. Most remarkable ones were those seen in abdominal walls. Skin biopsies of the abdominal walls were performed in six cases. Histological diagnosis as well as macroscopic examination of these lesions indicated no malignant change. In two cases that showed complete epilation at the time of the accident, a small alopecic area was still noted in each scalp.

Ophthalmological studies revealed lens opacities in 7 cases, in which 2 cases showed opacities of posterior capsules. However, these changes had not characteristic features described about progressed cataracts of atomic bomb survivors in Hiroshima, although lens opacities of 2 cases were found in posterior. Further ophthalmological survey should be needed.

Haematological survey showed that the results of peripheral blood examinations were almost normal, although neutropenia, lymphopenia, eosinophilia and slight basophilias were observed in one or two cases respectively. N. AP-ase-score decreased in one case. Bone marrow examinations revealed slight increase of myeloblasts and M/E ratio in Cases T-3 and K-12 respectively. "Mitotically Connected Abnormalities" were found in a few cases. In view of these findings, it could be indicated that there is some residual effect of radiation exposure on haematopoiesis on these persons.

Chromosome observations of peripheral leucocytes were made in 13 cases. The average rate of chromosome aberrations was much higher than that in the normal. The frequency of aneuploid cells was higher, and chromosome-type abnormalities such as dicentric chromosomes and monocentric abnormal chromosomes were frequently observed. Cells with dicentric chromosomes occurred in 7 cases, and those with monocentric abnormal chromosomes were present in all of the cases. To trace the fate of such cells with chromosome abnormalities persisting in them seems to be necessary in the succeeding annual investigations.

There were some abnormal findings in different laboratory studies. However, it was not proved that radiation exposure was related to these results.

Whole body counting and determination of urinary excretion of $^{137}Cs$ and $^{90}Sr$ were carried out. No significant increase of $^{137}Cs$ or $^{90}Sr$ was found on the exposed persons by the examinations.

In general, the results of 1964 medical survey on Japanese fishermen did not indicate clinically significant late effects of the fall-out exposure in 1954. However, it seems to be very important as well as necessary to conduct further medical survey to detect the significance of subtle changes such as observed in haematological, chromosomal or ophthalmological examinations.

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## Explanation of Plates

Plate 1. Residual "beta burn" on abdominal wall of Case K-5 in 1964.

Plate 2. Section of skin from "beta burn" area shown in Plate 1 (100×).

Plate 3. Section of skin from "beta burn" area of abnominal wall of Case K-12 in 1964 (100×).

Plate 4. Section of skin from non-exposed area of abdominal wall of Case K-12 in 1964 (100×).

Compared with Plate 4, Plate 2 and 3 reveal atrophy of epidermis with narrowed stratum granulosum and elongation of rete pegs. Fibrosis and collapsed blood capillaries are seen subepidermally.

Plate 5. A metaphase from Case K-4. A dicentric chromosome is observed.

Plate 6. A karyotype from Case K-16. It reveals an unusual acrocentric chromosome.

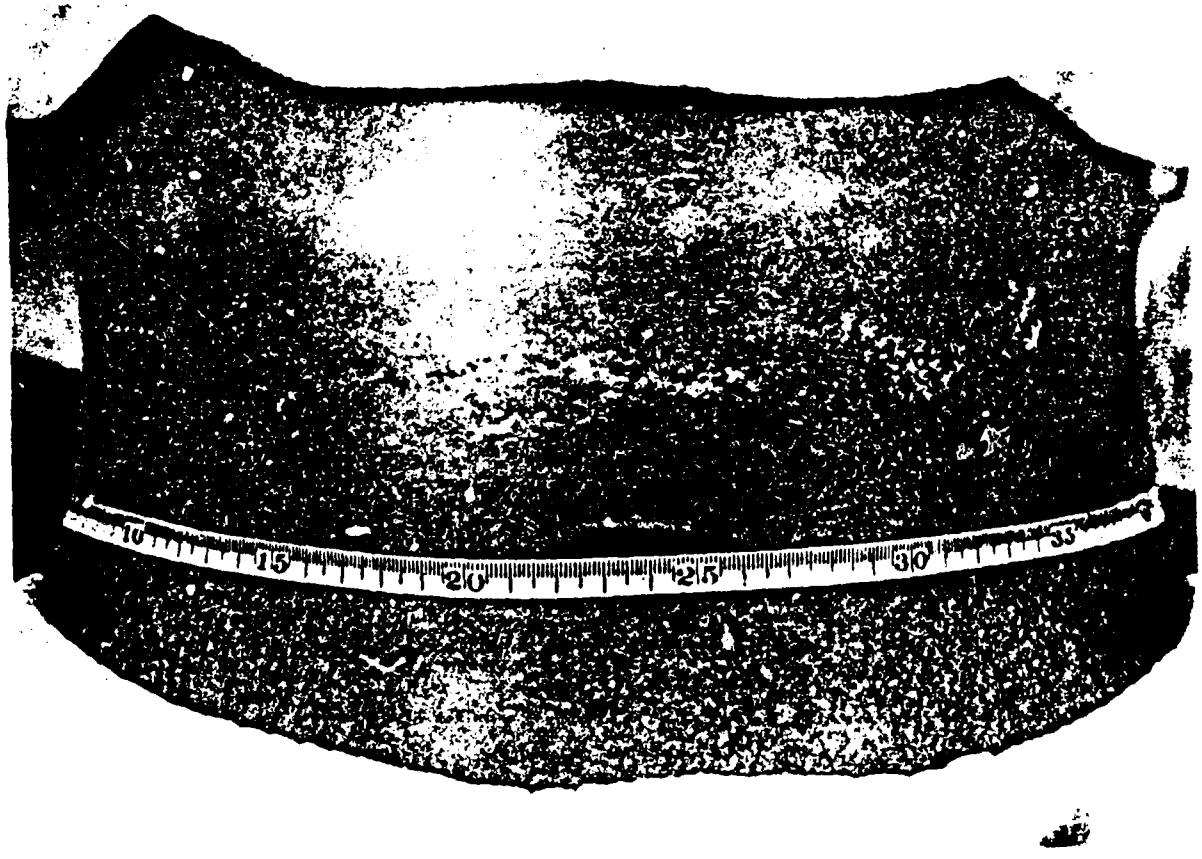


Plate 1.

Plate 2.

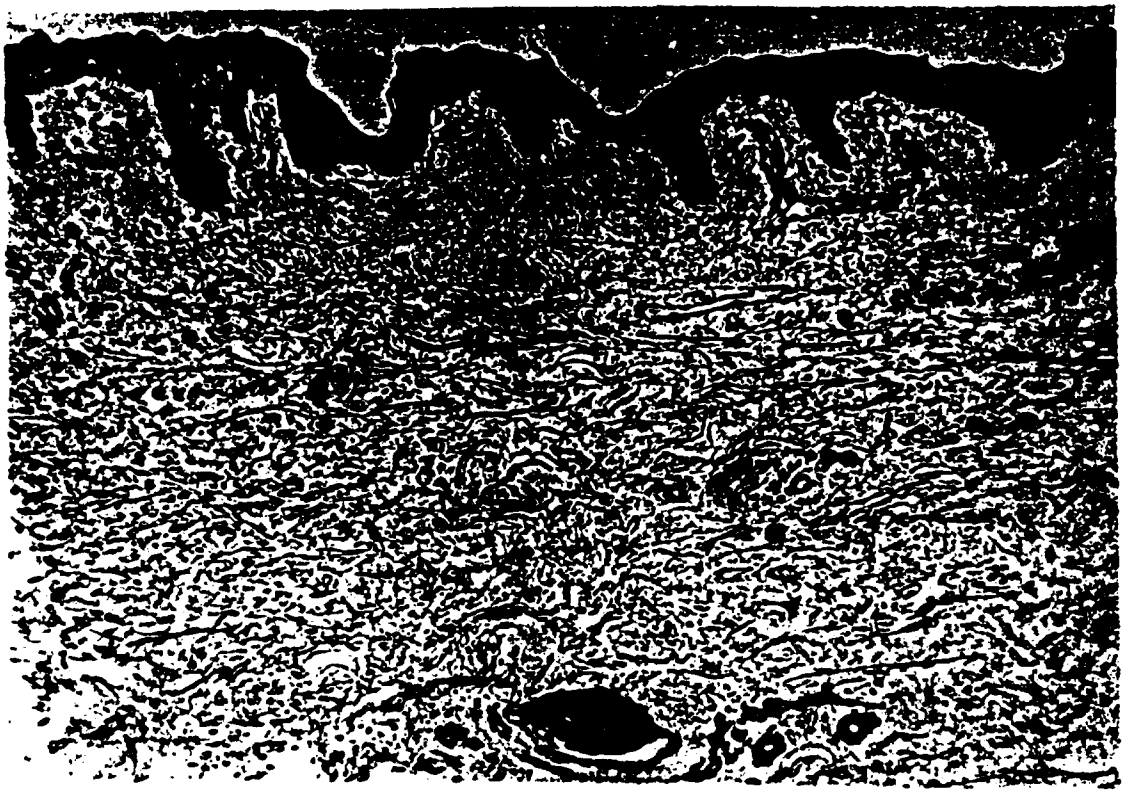

Plate 3.

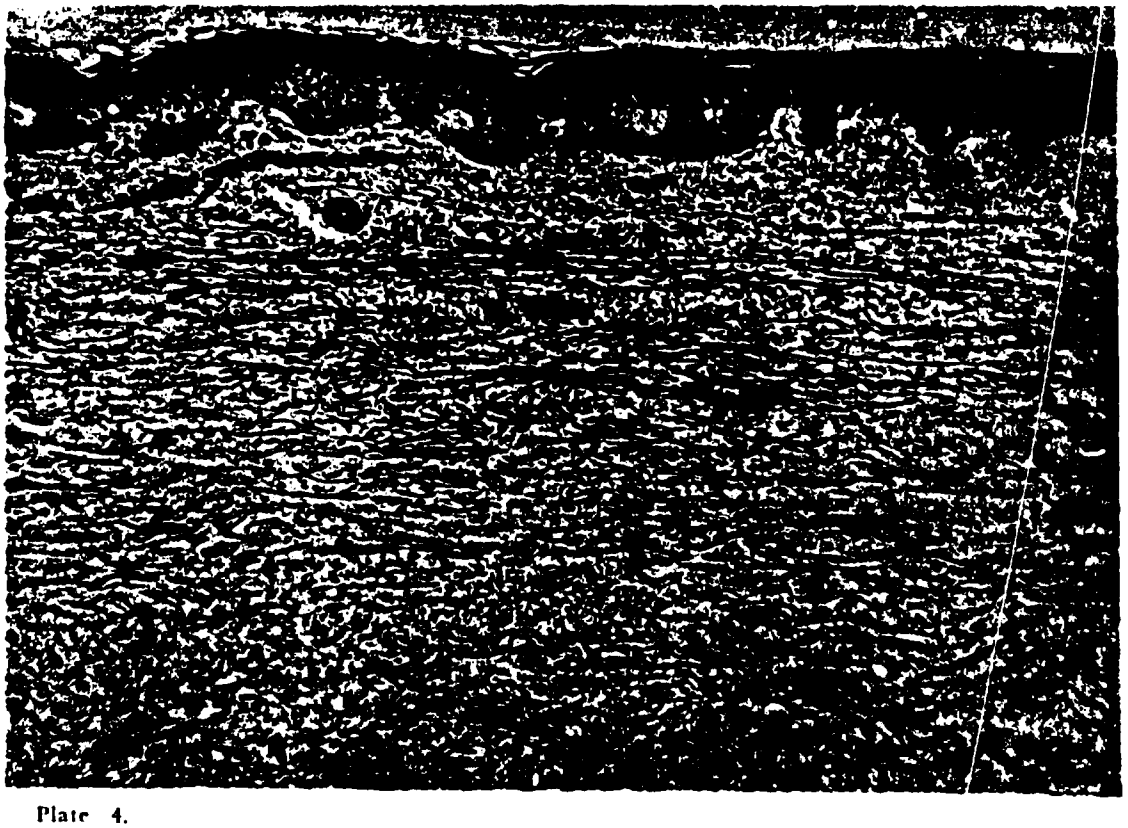

Plate 4.

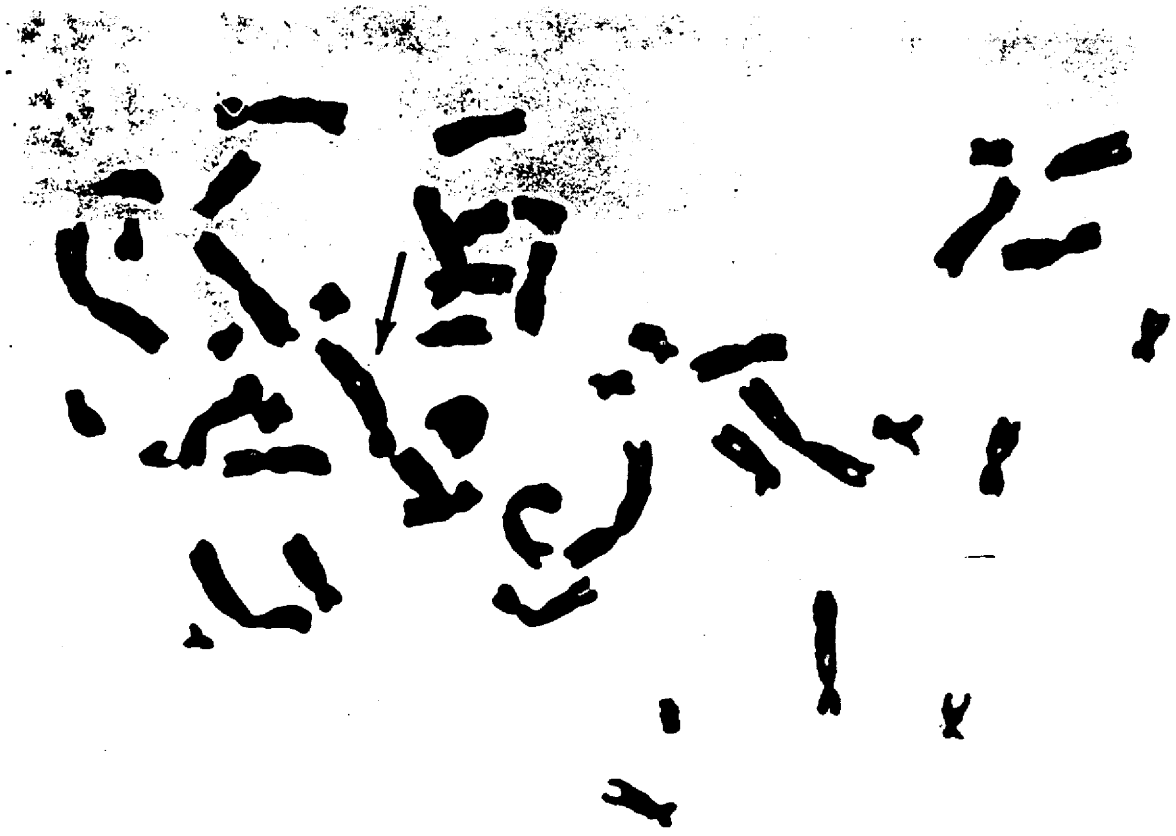

Plate 5.

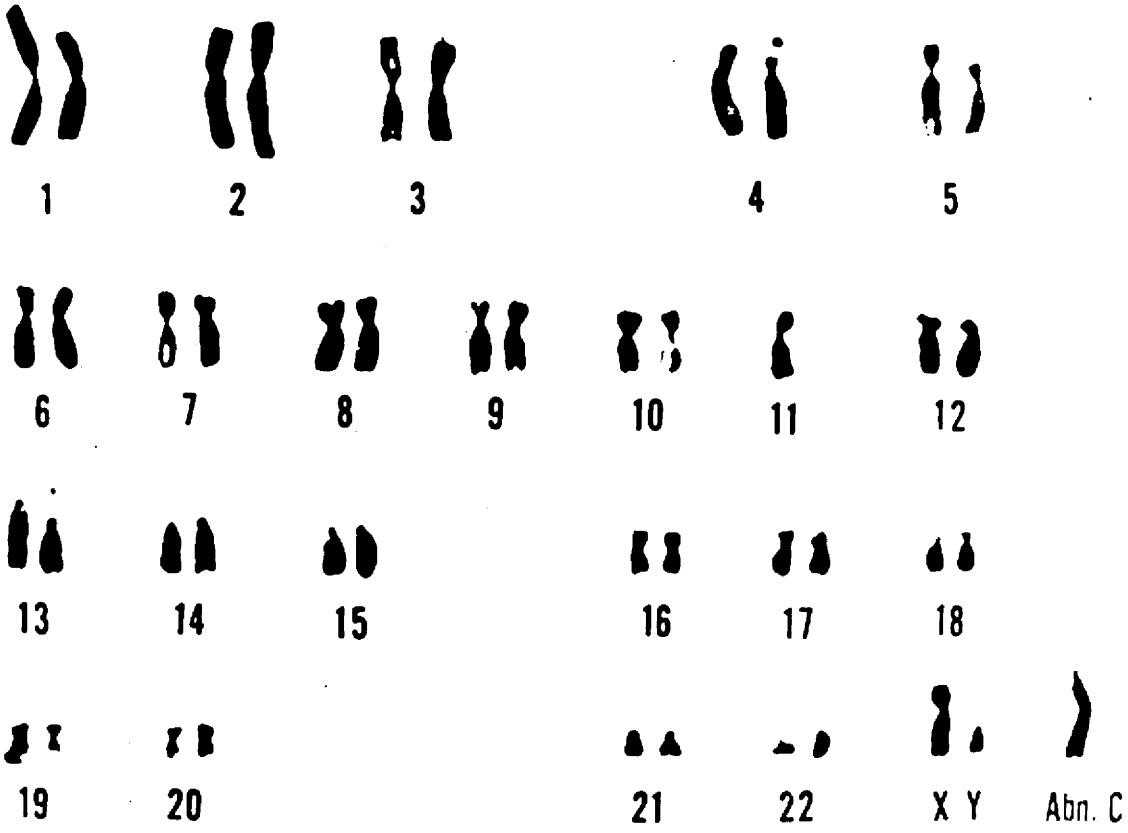


Plate 6.

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