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SYMPOSIUM ON RADIATION SICKNESS CAUSED BY BIKINI ASH

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(Tokyo, 27 October 1954)

Furukawa: Let us open our discussion on the radiation sickness caused by Bikini ash to which the crew of the Fukuryu [Fortunate Dragon] V was exposed.

Attending today's discussion are Dr. Koyama and Dr. Kumatori of the Department of Internal Medicine, First Tokyo National Hospital, who forsook bed and board to treat Mr. whose case is still fresh in our memory; Dr. Okamoto, of the Department of Radiology, same hospital; Dr. Ohashi, of the Department of Research, same hospital. We members of the Therapeutic Compilation Committee would like to proceed with this discussion and we invite your opinions. I have been asked to preside over this discussion by reason of seniority.

First of all, Dr. Kumatori, will you please tell us about the progress of the disease from the time the patients first were exposed to radiation until they were hospitalized?

From Exposure to Hospitalization

Kumatori: Let me discuss it briefly. These patients were engaged in tuna fishing on 1 March 1954 about 100 miles outside the so-called danger zone. A little before 0400 hours the western sky suddenly brightened. Some of the crew saw this and some did not. In any case, they rushed out onto the deck wondering what it might be. About 10 minutes after the flash they heard the dull sound of explosion so they decided to quit fishing and return home. They were wondering at the time whether it might be an atomic explosion. In any event, about 3 hours after they heard the explosion, the ash began to fall. This was about 0700, and the ash fell until the afternoon. The ash accumulated on the deck to such a degree that footprints were visible and the general appearance was like frost. Some of the ash penetrated even into the sleeping quarters. Certain crew members presented symptoms of roentgen intoxication and were nauseated. From this point on, their conditions differed individually. The ship entered port on 14 March. By that time, symptoms of roentgen burns were apparent. Loss of hair

was noted several days before entry into port. After entry into port the patients were treated at Yakizu, where Dr. Miyoshi and others of the treatment group of Tokyo University had been sent. On 28 March, 16 of the crew members were hospitalized at the First Tokyo National Hospital and five of them at the hospital attached to Tokyo University. The number of patients at the University Hospital then was seven, as two had been hospitalized already. I was mainly in charge of the 16 patients at the First Tokyo National Hospital. This is the summary of progress until the time of hospitalization.

Summary of the Conditions of the Disease and the Treatment

Furukawa: Now let us discuss clinical matters. As other medical journals have already reported the external wounds, I shall ask Dr. Kumatori to discuss chiefly the changes in internal organs, especially hematopoietic organs, and particularly the matter of liver dysfunction.

Kumatori: Let me speak about the manner in which the crew was attired at the time of exposure. Most were wearing round-neck shirts, under spring haori or similar garments, and caps; some wore head-bands. At the time of hospitalization, the burned areas were the head, neck, and wrist. As the men were wearing belts, blisters formed at the navel above the belts from ash which settled in the waist region. The skin showed red pigmentary deposits and desquamation. The depilation occurred chiefly in the occipital region. As impetigo followed where hair had fallen out, I treated it with unguent. Progress was comparatively favorable, but a few of the men still have impetigo in the occipital region. Generally speaking, new hair began to grow in from about June and the patients at the First Tokyo Hospital regained their normal hair distribution about July. The abdominal wounds left cicatrices and the pigmentation is gone; but pigments generally are thought to deposit very gradually.

Leaving the question of external wounds, let us discuss changes in the blood, which we considered an important problem. The men were hospitalized on 28 March, 4 weeks after the explosion. In the case of Hiroshima, this was the period after which changes in the blood grew more marked. The newspapers reported that the 16 patients at the First Tokyo National Hospital were mild cases; but in reality some of them were serious, as I shall describe later, and Mr. [redacted] was one of the most serious. Some of the more serious cases had anemia of about 3 million. The white cell count decreased gradually from the beginning of April; one patient at the First Tokyo National Hospital had a count as low as 1,500 and one at the Tokyo University Attached Hospital, as low as 800. The thrombocyte count also decreased. By removing bone marrow, we found that the number of cells had decreased; this condition is called panmyelophthisis. Examination of the cells showed some degree of nucleus disintegration in all cases, including those where the number of cells did not decrease, and some showed a tendency to slight hemorrhage. We gave blood transfusions in these cases. Thanks to transfusion, the red cell count increased to about 5 million but we switched to dry blood plasma to avoid excessive increase in red cells. The patients who were not anemic from the beginning did not receive blood transfusions but only dry blood plasma. In general, we stopped the transfusions after the 2-month period of April and May. As for antibiotics, we used interchangeably

penicillin, tetracyclin, and in some cases streptomycin. We stopped these antibiotics about the middle of May, and used them later as the occasion demanded. We also prescribed several kinds of vitamins. Of course, rest and nutrition were fundamental; and from the beginning we prescribed a diet which would favor the liver.

These were roughly the conditions at the beginning. Some of the serious cases showed gradual increase in peripheral white cell count from about the end of April and the beginning of May; the patient who showed a count of 1,500 began to return to normal. However, in some cases, although we tried puncturing the bone marrow at various spots, the number of cells was small and the number of peripheral white cells was 3,000 or 4,000 at the most. (See Figure 35 in the monograph by Dr. Koyama et al.)

Some of the patients at Tokyo University Hospital began to show symptoms of jaundice from the beginning of May and some of the patients at our hospital, from the middle of May. Up to now, seven patients at the First Tokyo National Hospital and three patients at Tokyo University Hospital have definitely been jaundice cases. Five or six patients had a lesser form of jaundice, in which the eyes were slightly yellow. Examination of the liver revealed that all of the patients had dysfunctions at one time or another. The BSP test (30 minute value), showed that all of the patients suffered liver dysfunction of more than 10 percent or in some cases more than 20 percent, at some point. One patient at the First Tokyo National Hospital still has jaundice; the white cell count is low and the myelocyte count is also low. This jaundice has recurred six times to date and the patient has not been cured since the end of May. In the case of four other patients jaundice recurred twice or three times. This is the rough summary of the conditions of disease and treatment.

The Progress of Mr. Case

Now let me discuss Mr. . The change in the blood picture in this case is shown in Figure 19 of the monograph by Koyama et al. The white cell count was 1,900 at the minimum during the middle of April. The myelocyte count was 19,000 on 2 April and 9,000 on 15 April. The number of thrombocytes remained between 50,000 and 60,000 until the middle of April. The red cell count was about 3 million, so we gave a blood transfusion immediately, using blood from the First Tokyo National Hospital blood bank. Eleven transfusions were given, 200 cc each, and dry blood plasma was given 51 times, 100 cc each time, until the beginning of June. The use of antibiotics has been described before. After this, the myelocyte count did not increase much, but the germ myelocytes, scarcely noticed earlier, began to appear and the number of peripheral white cells rose to between 5,000 and 6,000 at the end of May. The thrombocytes and red cells began to increase. However, from the middle of May, an anemic count of about 3 million was noted again. The liver was swollen from the time of hospitalization. The BSP was 50 percent in the latter part of June and definite symptoms of jaundice appeared a few days thereafter. The Maulengracht index was 60 early in July, and the jaundice was nearly cured toward the end of July when the Maulengracht index was 15, though it reached 30 around 29 July. Later, the jaundice was gradually clearing up and the BSP was lower than 20 percent on 1 August. At that time the patient

seemed to feel very pleasant and said that he might be able to go home sometime this fall; he asked me to come and visit him at his home. However, on 21 August the yellow pigmentation of the ocular conjunctiva increased somewhat and the patient lost his appetite. The color of urine grew deeper after 26 August. On 27 August the Moulengracht index was 105. From about 1100 hours on 29 August the patient's consciousness was hazy and he seemed to be in a state of excitement. On 31 August, he lapsed into coma. On 3 September, he appeared to have regained consciousness, and on the morning of 4 September he uttered a few words. His behavior showed signs of Korsakoff's syndrome from that time until 8 September. He almost recovered full consciousness on 9 September and was placed on a liquid diet. The Moulengracht index was 225 on 2 September and it continued as high as 140, or sometimes 160, after that. The patient's appetite was comparatively good; but edema was observed on 6 September and it was presumed to be an ascitic accumulation. After 17 September the patient lost his appetite and ate nothing after 20 September. From that time his blood pressure dropped, his pulse rate increased, and he developed symptoms of so-called heart prostration. The patient died on 23 September. This was in outline the progress of the disease.

Let me give you some additional data. Figure 38 in the monograph shows photomicrographs of the tissue patterns in the marrow taken when the patient was first hospitalized on 2 April. According to this figure the number of cells is very small, showing hematopoietic dysfunction. After the patient emerged from coma in September, the white cell count increased to 10,000 and 20,000. Leukemia was observed in the peripheral blood picture. In an x-ray plate of the chest taken on 17 September we discovered a shadow the size of a thumb in the lower part of the upper left lobe. In an x-ray plate taken on 22 September we discovered a shadow of the same size of a fist in the upper right lobe, indicating pneumonia.

I am following the wrong order, but let me read you Mr. Shimatani's opinions on the electrocardiogram of Mr. .

Right after the hospitalization: at the induction of the limbs, the P wave showed only extremely flat, low traces. At right precordial induction the S and T rose slightly and the P (+ -) showed diphase; at left precordial induction, the S and T were slightly lowered.

The aforementioned finding, regardless of causes, indicated some myocardiac dysfunction. But the P wave gradually rose and the findings of 10 August showed a picture which was nearly normal.

According to the findings of 31 August, at the second and third inductions of the limbs, and at the inductions of aVF and V_5, the S and T were lowered; every induction showed a completely flat T wave. This indicated damage to the entire myocardium. According to the EKG findings on 6 and 8 September, the S and T were lowered and the T wave was flat and low, showing the tendency to gradual aggravation of the patient's condition. According to the findings of 18 September, all induction voltages were prominently decreased.

The EKG of 21 September showed extreme aggravation and complex arrhythmia accompanying dysfunction of the atria and ventricles. The

heart was completely in a critical condition. The EKG of 23 September showed markedly rapid pulsation and was clearly a premortal EKG.

As for antibiotics, we gave a total of 18.3 grams of chlortetracyclin and tetracyclin and, later, one gram of chloranphenicol. When the patient was comatose we gave a total of 110 mg of ACTH but none was given after 9 September. We also gave 570 mg of cortisone.

A large quantity of Candida was found in the phlegm and saliva before death. Aspergillus was found in the urine.

Fujimori: I understand you made an electroencephalogram.

Kumatori: Yes. The electroencephalogram showed a comatose pattern.

Goto: I was in Hiroshima on an investigation for nearly one month after the atomic explosion. I found that the white cell count decreased considerably in 4 or 5 weeks. I also observed high fever as in typhoid fever and pseudomembranous ulcerative angina. Did such symptoms occur in these cases?

Kumatori: Those patients whose white count dropped considerably had a temperature between 38 and 39 degrees. But because we used antibiotics to a great extent, we did not note much septicemia as in the Hiroshima cases.

Goto: In the Hiroshima cases the white count began to rise from the sixth week and became normal from the ninth or tenth week. I understand that in this instance the white count returned to normal in many cases. Were there some cases in which it did not become normal?

Kumatori: There were more cases in which it did not become normal.

Goto: Was this the result of absorption of the radioactive material into the body?

Kumatori: Of course, that must be taken into consideration. Besides, investigators from Tokyo University who studied the actions of the crew on board ship computed the amount of radiation received externally. This and the symptoms must be compared.

Goto: In the Hiroshima cases the external exposure was momentary; but in this instance it lasted quite a long time. As this was a case of long external exposure, I think the progress of recovery might have been a bit more along normal lines, although treatment was somewhat delayed.

Kumatori: These persons received more radiation than those survivors of Hiroshima. We cannot say what might have happened to them if they had not been treated in time. For that reason, I think their recovery was slow. I wonder whether they were not so seriously injured as the survivors of Hiroshima.

Oshima: In the case of Hiroshima, in general, within a radius of one km from the center of the explosion, all died instantly; within a

radius of one to 2 km, the injury was serious; within a radius of 2 km or more, the damage was somewhat serious. Some who were within a radius of one km were saved, thanks to proper treatment.

Goto: In the case of Hiroshima, some persons who were injured by the explosion or the heat were saved, even though they were comparatively near the center of explosion. I am now treating the branch chief of the Bank of Japan, who was in a steel-concrete building about 500 km [sic] from the explosion. In his case, the hair fell out of his scalp within 4 or 5 weeks; the white count dropped and he had a fever. As a result of blood transfusions and other medications, he recovered in about 9 weeks.

Kumatori: In this case, the recovery was very late.

Ohashi: Mr. . died after a long period of illness, in spite of all the efforts of his physicians. Considering the Hiroshima cases, I believe he lived as long as he did only because of proper treatment.

Goto: I agree, in the light of my experiences at the time of the Hiroshima atomic blast.

Kumatori: Now, as for the urinary findings in Mr. case, from the time the patient fell into a critical condition (see Figure 40 in the monograph by Koyama et al) crystallized tyrosine was found in large quantities. This can be found in cases of acute yellow atrophy of the liver, phosphorous poisoning, etc. I think it is an interesting finding. And, from about 26 August, the potassium excretion increased suddenly. By that time, the progress of disease was good, considering the excretion of potassium.

Goto: Mr. has passed away, unfortunately; but was he not older than the others, or did he not receive a heavier exposure than the others?

Kumatori: Being in command, Mr. worried about the others as a responsible man would, and walked about the ship. He subsequently ordered the ship to enter any port, lest a member of the crew die at sea. His anxiety may have affected his health. We do not know as yet how much radiation he received. Mr. was 40 years old, and it is true that he was the oldest aboard. As for the medical history of his family, his older brother suffered from Salvarsan jaundice and his younger brother died of postmalarial jaundice in Shanghai during the war.

Furukawa: Did Mr. go to war?

Kumatori: He went to the South Seas aboard a mobilized ship. His medical history does not include malaria, etc; in childhood he suffered from periostitus of the right lower jaw. After hospitalization, his syphilis serum reaction was negative.

Fujimori: How great is the danger that this radiation sickness might become chronic cirrhosis of the liver?

Kumatori: Well, if the disease is prolonged, the possibilities are high, I'm afraid. Patients who suffer repeatedly from jaundice are prone to cirrhosis and I am concerned about this. (Dr. Koyama then appears.)

Furukawa: Diet, of course, is a part of the therapy. Did it require special attention, Dr. Koyama?

Koyama: At first, all the men had very hearty appetites and we found that the ordinary hospital diet was not enough for them. Besides, in Tokyo, it was impossible to furnish the patients with an all-rice diet for three meals every day. At the beginning, before we were prepared, we substituted bread for one meal but none of the patients ate it. They usually ate 5 go [one go equals 0.361 pint] of rice per day. So we asked the Ministry of Health and Welfare and the Tokyo Metropolitan Government for a ration of five go per day. Thus we were able to settle the problem of staple food for the patients. We paid close attention to the problem of supplementary foods and developed special diets for hematosis and nourishment of the liver: low in fats and rich in vitamins and protein. Although our cooks did their best to prepare good meals, the food was more suitable for the urban palate and was not welcomed by the patients. They disliked insufficiently salted food. They liked vegetables and fish, but would not eat fresh fish from the river. We were very much at a loss to accommodate them.

Radioactivity Tests

Furukawa: Dr. Okamoto, will you please discuss the matter of radioactivity?

Okamoto: We conducted several tests to obtain data which had been requested by Dr. Koyama and Dr. Kumatori from the time the patients were hospitalized on 28 March. We wished to test the degree of contamination on the surface of the body and the excrement and to dispose of such excrement as soon as possible. Dr. Hamada and Dr. Hayashi were very cooperative in the radioactivity tests.

As soon as the patients were hospitalized, we changed their clothing. We examined the clothing and the patients' belongings to see if they were contaminated. The surface of each patient's body was examined for contamination, and the excrement was sent daily for examination.

Since all the clothing had been changed at Yakisu, the clothing the patients wore to the hospital did not produce a reaction on the surveymeter; but the clothes, shoes, trousers, etc which some of the patients had with them proved to be radioactive. Mr. straw sandals particularly showed radioactivity. (See Figure 5a in the monograph by Dr. Koyama et al.) The radioautograph of the bottom of the sandals is shown in Figure 5b of the monograph by Dr. Koyama et al and the radioautograph of the sand is shown in Figure 6a and Figure 6b of the monograph.

As in the diagram the contamination was clearly evident and the partial decrement of the sand is shown in Figure 7 of the monograph. Of course, the sand is impure; but we have been surveying 0.3 g of it right up to the present. Here are the results: 1 April, 1,480

counts per minute; 10 April, 696 counts; 20 April, 671 counts; 30 April, 512 counts; the radioactivity decreased rapidly in this manner. On the other hand, we know that it was considerably stronger before 1 April. Since May it has gradually decreased.

Now let us consider the surface of body. The patients were thoroughly bathed at Yakizu; their hair was cut, their nails were trimmed, and all contaminated areas were scrubbed. For this reason, when they were hospitalized they showed very little contamination excepting at the finger and toe nails, where all of them showed reactions. By careful measurement some showed a count of 200, but generally the count was between 50 and 60. Decontamination of the nails was very difficult but was gradually accomplished by brushing; by the end of May the count had decreased considerably. The count at the hair was very low following haircuts: 44 at the maximum on 6 April; 7 or 8 in June; and 4 or 5 in August, for one gram of hair.

Since adequate blood supply was vital to the patients at that time, we made tests on drop samples ranging from 3 mg to 7 mg. As the amount was very small, we could not clearly determine the reaction. Measurements were taken on a 3-cc evaporation residue of medullar puncture fluid from three patients. The measurements seemed somewhat greater than the background /Big/.

A 10-gram fecal residue measured the same as the background in some cases and showed more counts in others. Some sputum samples and some dermal scrapings from burn cicatrices showed more counts than the background. It was found that the bile taken on 23 April had more counts than the background in 20-cc residue samples. Extracted decayed teeth may have more counts than the background, but a definite reaction was not perceptible.

Dr. Daiken Higashi of the Kimura Laboratory, Tokyo University, tested the urine samples taken on 28 March and 21 April and noted radioactivity. Since then, the body surfaces have shown little reaction, due to cleaning, and we have stopped making tests.

Tests for radioactive contamination were made roughly in this manner.

Goto: It is understandable that there would be more counts on the surface of body. But if the sputum, bile, and medullar puncture fluid of some patients showed more counts than the background, does this mean that radioactive substances were absorbed into the body by various routes?

Okamoto: Since the tests were conducted on meager samples, we must of course be cautious. Such substances, having entered the body through various routes, will be spread throughout the body by the blood. Tests on animals show that it is true of strontium -- which is thought to deposit in bone -- of phosphorus, and of calcium. This case however concerns the human body, and we have never dealt with these problems. We must also consider carefully potassium in the body.

Goto: How did the substances enter the blood?

Okamoto: The most common channels are supposed to be the alimentary canal (by contaminated food), the respiratory system, external wounds, or openings in the skin.

Goto: If there is a radioactive substance on the surface of body, would inductive radioactivity be produced inside the body?

Okamoto: I heard that in the bombing of Hiroshima, inductive radioactivity was produced by neutrons; but I did not hear anything of that nature in this case.

Goto: It must be difficult to determine how radioactive substances entered the body.

Okamoto: Yes, it is difficult under these conditions.

Fujimori: How long had Mr. been wearing his straw sandals?

Okamoto: I think he must have worn them after landing, and possibly when he returned to the ship to get something.

Fujimori: If we read the decrement curves of radioactivity in Figure 7 or the monograph by Koyama et al, we find that they are not clear exponential functions. Therefore we know that we are dealing not with a single element but with a mixture of several.

Okamoto: Radioactivity was gradually reduced in those which had a shorter halflife, and now it is found only in those which have a longer halflife. I suppose this will continue for quite a while.

Fujimori: You said that a good deal of contamination was found in the nails. Could this be removed by washing, just as you would wash your hands before an operation?

Okamoto: A considerable amount can be removed; but the nails were hard to decontaminate. The nails were badly worn; we noted many scratches in microscopic examination, and we found that it was hard to decontaminate the nails. Tests on animals show that such contamination penetrates into the marrow of the nails.

The Autopsy of Mr.

Furukawa: Now, Dr. Ohashi, will you tell us about your findings in the case of Mr. ? (I understand that Dr. Ohashi spent considerable time in performing the autopsy of Mr. , and I am sure we will all benefit from hearing his findings.)

Ohashi: I rushed to the hospital on the afternoon of 23 September, as soon as I was notified that Mr. had taken a sudden turn for the worse despite the great sacrifices made by his physicians. But I then learned that he had died before I arrived. I was not one of the doctors in charge, but I felt very discouraged and went directly to the proper doctors to ask what to do. Although I had once performed a partial autopsy on a person who had died as a result of the Hiroshima atomic explosion, I knew nothing about this new radiation

sickness. When I was told to perform the autopsy of Mr. , I could not help feeling the important responsibilities involved. However, I performed the autopsy, (as has been reported in the newspapers), thanks to the encouragement and assistance of the doctors in charge, the clinical study group of the Committee on Countermeasures, Professor Miyake of the Department of Pathology, and others. I entered the autopsy room at 1130 and heard a detailed report of the clinical progress from the doctors in charge, lasting nearly an hour. The autopsy began at 1230 and ended at 0630 the next morning. During the autopsy, Dr. Okamoto conducted radioactivity tests on various extracted organs. However Dr. Murakami of the Kimura Laboratory stressed the virus considerations so I performed the autopsy in the presence of Dr. Jo of the Virus Laboratory and Dr. Eto, Chief of the Pathology Department, to whom the data were furnished.

Macroscopic Findings

Dr. Kumatori, the doctor in charge, mentioned in connection with the clinical progress of Mr. , the patient died after 3 months of treatment. I think Mr. himself did his best to survive and the physicians in charge did their best to save him. If the treatment were improper, he might have died late in August when he was comatose for the first time. For the efforts of the physicians in charge, let me offer my respects. Despite his critical condition his nourishment was not too bad. His height was 1.57 meters and his weight, 52 kilograms. It should be remembered that this weight of 52 kilograms included ascites. His condition would not be so good if ascites were excluded. But the jaundice throughout his skin and mucosae was considerably strong. The abdominal region was extremely swollen. Macules of extravasation were seen here and there in the back and the upper frontal part of the chest. As Mr. Okamoto mentioned some time ago, there were traces of radiation dermatitis in the skin and there were pigmentary deposits and partially discolored areas on the neck, the legs, and the back of the feet. The partially discolored areas on the neck indicated strong external beta and gamma radiation.

Opening the abdominal cavity I found about 2.6 liters of yellow ascitic fluid. Ascitic accretion is a very bad symptom in radiation disease. The stomach was greatly enlarged, which is a sign observed when acute contagious diseases and toxicoses are aggravated. The liver was also atrophic. The rim of the liver was slightly thrust out at the arch of the rib and was so indurated that it was easily palpable without removing the rib.

There was a deposit of 115 cc of liquid in the pericardium; the liquid was dark brown and somewhat turbid. The quantity was probably somewhat increased. The heart was somewhat in transverse position, and the right atrium was considerably enlarged. At the front right part of the epicardium villi had begun to form as a result of the appearance of new fibrin, and this was strongly congested. The pleura had adhered fibrously to the upper parts. At the lower part was a residual cystiform membrane containing yellow exosmotic pleural fluid: 14 cc on the left and 17 cc on the right.

The heart weighed 320 grams and was about the size of the fist. Hemorrhage spots were observed here and there in the epicardium; at

the front of the right atrium was a tendinous formation. The myocardiac layer was very soft and diffusive extravasation was observed below the endocardium of the left ventricle. Turbidity was conspicuous in the myocardium. The valves and the lining membrane were tinted yellow.

The left lung weighed 540 grams and the right lung, 640 grms. In the S_3 area of the left lung we observed a fructified nidus of pneumonia the size of the tip of the thumb; this was later attributed largely to a mixed infection of aspergillus. The surrounding area was characteristically congested. At the lower lobe of the left lung was an old sarcotic nidus of pneumonia surrounded by interstitial pneumonia foci the size of a goose egg and occasional necrosis. The circumference was not very distinct. In the S_1 and S_2 areas of the right lung were occasional grey foci of hepatic degeneration larger than a goose egg. The area was prominently edematous. The lymph nodes at the lower basin of the lungs were not swollen despite the aggravated pneumonia. In section they were somewhat red and generally atrophic. In correlation with the autopsy which I performed on those who died following the Hiroshima atomic explosion, I thought this was a very important finding.

The weight of the spleen was 90 grams, which is not so great considering the extent of the changes in the liver. In section it was rich in blood; when I incised it I could get nothing substantial. The trabeculae lienis were conspicuous. The lymphatic follicles were few in number and only certain of them were visible; I think there was some involvement with the lymph nodes at the lower basin of the lungs.

Next, I shall discuss the liver, which is rather problematic. The weight of the liver was 860 grams; the size was not so far from normal. It was elastic and firm. The tapetum showed some soft wrinkles; the rim of the liver was comparatively thin and the surface was grey-brown; in section it was yellow-brown with varicolored areas. Macroscopically it was assumed to be the picture of advancing cirrhosis. The bile in the gall-bladder was yellow and brown. Calculi or other inflammatory obstructions which may cause jaundice were not found in the ducts.

The left suprarenal weighed 8 grams and the right, 7.5 grams. The left kidney weighed 220 grams and the right, 190 grams. The kidneys were soft; in section they appeared very turbid and edematous, brown-grey-green in color, which is characteristic of toxic obstruction of the liver. But this case suggests the advanced degeneration which follows serious hepatargia. I think that the changes in the kidneys and in the hematogenic system deserve careful study.

The pancreas weighed 170 grams, a bit heavier than normal, and was light yellow. It showed a large, rough, lobulated structure and was somewhat hard. On the surface and in section, the parts corresponding to the head and body regions showed some fat necrotic nidi here and there.

The gastric mucosae were atrophic and edematous, covered with rather abundant mucus. Near the cardiac and pyloric regions we observed some grey-white and green deposits caused by Eumycetes. The duodenum and the small intestines contained grey or light yellow mucus. The mucosae of the small intestine showed occasional hemorrhage points and were atrophic. The lymphatic system was hardly visible to the naked eye. I think this finding is worthy of note. The wall of the colon was generally similar to that of the small intestine but highly edematous; the colon contained light yellow,

muciform soft stool. Small drops of comparatively fresh blood were observed in the colon. The lymph nodes of the mesentery and lateral abdominal aorta were somewhat visible but all were small and flat. Even in section the picture of proliferation was not observed, which is similar to the Hiroshima cases.

The left testicle weighed 6 grams and the right, 7 grams; they were both atrophic. The scrotum was also edematous.

The esophagus showed extravasation and the mucosae were moderately yellow. In the veins of the lower esophagus we recognized some enlargement which was assumed to be a varix. The thyroid gland weighed 17.5 grams and was somewhat atrophic. The lymphatic tissue of the radix linguae was atrophied. The tonsils were the size of the tip of the little finger and red in color; the left crypt contained pus. The bronchi and mucosae of the trachea were bilaterally hemorrhagic.

The brain weighed 1,430 grams. The meninges were yellow; the matter was probably edematous; and the blood vessels of the mucosae of the spinal medulla were generally swollen. The pituitary gland weighed 0.75 gram, which I considered a bit heavier than the norm.

The marrow of the femur was red at the edge and tended to be fibrous. The center was medullar and occasionally gelatinous. The diaphysis marrow was strongly yellow and gelatinous; there were no signs of red maculate regeneration in the hematopoietic nidus. The marrow of lumbar bones, sternum, ilium, etc were red-brown and the cells were not very large. The cells were becoming fibrous and the nuclei were medullar in places. Whether the central gelatinous portions were nidi of regeneration will be determined through further study! Since it is most important to determine which portion of the marrow received the greatest injury and just how regeneration occurred, in our attempts to understand this disease, we shall conduct more tests.

Partial Histological Findings

One month has passed since I completed the autopsy. Our laboratory is very poorly equipped and we have been unable to work satisfactorily; but we are now preparing histological specimens in cooperation with all members of the laboratory. We are going to ask Dr. Okamoto to make radioautographs of the specimens. After the specimens are returned to our laboratory they will provide data for determining the pathological and histological changes. Of course, we will depend heavily upon the data of chemical analysis by the Kimura Laboratory and data prepared by Dr. Eto, the department chief, and Dr. Jo.

Now let me tell you what has been clarified by the histological tests. As the attending doctors recognized, after making partial tests, we also found that the condition of the marrow was similar to that of panmyelophthisis. Partial recovery was seen in the marrow at the center of the bone. Injury to the erythrocyte system was slight; but the leucocyte system and the giant marrow cells were not fully recovered.

As for the liver, which is a matter of controversy, there was no typical cirrhosis. The liver was in a state which might be called a sort of fibrosis. The liver cells had rather suddenly degenerated and

been destroyed. The condition resembled red atrophy. In the Glisson's sheath we observed cell infiltration typical of hepatitis. The liver cells which survived had somewhat regenerated, although only slightly. We also noted the formation of pseudolobules. Proliferation was comparatively prominent in the biliary ducts, which also revealed bile deposits. Hemosiderin deposits appeared in the liver cells and Kupffer's cells. Around the lobules the liver cells were becoming adipose. The findings indicate that radioactive or other toxic substances destroyed the liver and that the destruction was quite serious. Partial regeneration had occurred, but the restored portions were about to be destroyed again. These changes correspond to the clinical progress in which the same symptoms recurred. But we must wait until the data of Prof. Okamoto and the Kimura Laboratory of Tokyo University will be available before we can reach a conclusion. If it is found that radioactive elements were concentrated around the areas of change, or if any pertinent data on such elements are available, I think we will find them very helpful. A book by an American named Bloom discusses many experiments on animals, using radioactive elements. There should naturally be great differences between animals and humans; but Bloom made radioautographs of the liver, having injected radioactive isotopes into the animals, and demonstrated that the isotopes were diffused in the liver. Still, I hear that in some cases it does not bring about much change in the liver, morphologically speaking. I understand however that a serious change occurs when plutonium is used. Although radioactive elements were found in the liver according to the data of these experiments, I think there might be cases in which no morphological changes would occur and I feel that this point must be carefully watched and studied hereafter. The fact of active regeneration in the liver, marrow, testicles, and lymph nodes has greatly helped in analyzing the findings.

The spleen usually becomes edematous when there is degernation in the liver. But in the case of Mr. there seems to be no such tendency to edema and on the contrary the spleen was small. The blood vessels were considerably enlarged and the lymphatic follicles were atrophic; but some regeneration was observed. Hematogenic nidi were not demonstrable.

Cholemic nephrosis was severe in the kidneys. The tubules contained overcurrent with conspicuous bile pigment and siderin deposits were observed in the epithelium of the tubules, indicating some dysfunction in the metabolism of iron.

I think the liver degeneration fully explains Mr. death, but I think the heart also had something to do with it. Toward the end, the liver and the heart, as in the kidney degeneration, acted somewhat like the two wheels of a cart. The changes seen in the heart were very serious: the myocardium had atrophied, and it might be said that the myocardiac fiber was turned into connective tissue fiber. In the myocardium we observed indistinct extravasation. The hemorrhagic degeneration below the myocardium and the endocardium was very serious, which substantiates the findings of the EKG described by Dr. Kumatori. The atrophy and inflammatory changes of the gastrointestinal mucosae are probably connected with the hepatic dysfunction. Since direct influence by Bikini ash penetrating the body via the mouth is still a possibility, we shall conduct very careful investigations.

The atrophy of the lymphatic system may have been due to radiation sickness and we plan to study this matter very carefully. Although we have examined only the lymph nodes of the mesentery, the neck, and the armpit, we found that in the mesentery the lymphatic sinus was considerably expanded and the endothelial cells were prominently proliferated; mobilization was observed. Proliferated endothelial cells were gormandizing the nuclei in which red and white corpuscles had been destroyed. Owing to proliferation, the original lymphatic tissue was rather atrophied, resulting in a structure in which the cortex was difficult to distinguish and the center was hardly visible. The lymph nodes of the armpit were rather atrophic and the cortex contained glassy deposits. The lymph nodes of the neck showed atrophy, endothelial degeneration, and development of polynuclear giant cells. It was very difficult to grasp the meaning of these findings; but I shall study them further.

The testicles appeared somewhat atrophied to the naked eye. Histologically speaking, spermatogonia were scarcely in evidence and mature spermatozoa were not seen. The basal membrane of the spermatic tubules was prominently swollen. On the other hand Sertoli's cells and Leydig's cells were observed without difficulty. Degeneration in the testes, together with hematopoietic dysfunction, is very highly characteristic of radiation sickness.

Other matters which I am now studying and which are not ready for today's discussion will be furnished to the Medical Group of the Council on Countermeasures for further guidance and advice.

Summary

Thus far, I have discussed the pathological changes in Mr. case; now let me summarize. First of all, the changes are caused by radiation sickness. I believe they occurred in two ways: from external radiation and from internal radiation. One would suppose that the degeneration from beta radiation burns would appear in the ectodermal skin or the mesodermal or mesenchyme organs and tissues. But the problem was to determine the forms and their scope and we must grasp the characteristic morphological changes seen in radiation sickness.

This was my first experience with these complications but I would diagnose hepatic degeneration followed by cholemia. As we all know very well, the liver is the largest organ which eliminates toxic substances and in the case of Mr. I presume that the radioactive elements, which destroy nuclei, entered his body through the mouth or skin and thus caused these changes in the liver. Other causes then produced serious degeneration in the liver which was already damaged. As Dr. Kumatori has explained in the case of Mr. there was hematopoietic dysfunction corresponding to aregenerative anemia caused by the Bikini ash, and naturally blood or plasma transfusion was required. For this reason the disease was often called serous hepatitis, which is distinctly a possibility. However since this matter will concern the course of future therapy in Japan we will conduct careful studies and furnish you with our findings for further synthesis. Our findings in the liver were very similar to the findings in serous hepatitis or infectious hepatitis; but we cannot

determine whether such changes are caused by virus alone. As I mentioned, it is possible that such changes result from internal radiation via fission products produced in the liver and it is also possible that the marrow or the mesodermal or mesenchyme organs, which are susceptible to radiation, were indirectly attacked and that those changes followed. This point must be carefully studied from various angles. Let me add that if any virus is found in Mr. liver, part of which I sent to Dr. Jo for detection of virus, I will have to reconsider the case. However we cannot deny that in the case of Mr. there was some liver dysfunction caused by radioactive elements of which we have known nothing until now. Mr. succumbed to hepatic dysfunction but it remains an important task to discover the true character of radioactive changes in the liver. For this purpose, I sincerely hope that you will encourage and guide us.

As I mentioned at the beginning, Mr. condition had been serious for quite a long time. Ordinarily he would have died earlier. Therefore I feel that there were certain serious morphological changes which had not been recognized until now. For instance the mycotic involvement could be raised for discussion and we must consider very carefully the chance that it might have disguised important findings on radiation sickness. Anything remaining after these considerations would be radioactive morphological changes, at the time of Mr. death. There is no doubt that the main causes of death were exposure to the radioactive Bikini ash and morphological changes following the exposure.

Furukawa: Dr. Okamoto, can we not expect to see the results of the radioautograph of the organs?

Okamoto: I have been examining the radioautograph in cooperation with Professor Ken of Chiba University, and I expect to discuss the data in a couple of days with the Kimura Laboratory and Dr. Eto of the premedical laboratory. The Kimura Laboratory will probably make an announcement about it. The newspapers reported that the Kimura group observed reaction in the kidney and the liver. Dr. Ohashi, what are the findings on our animal experiment?

Ohashi: The animal experiment performed by Dr. Okamoto involved the use of radioactive strontium on rabbits. In the liver certain degeneration with necrosis was observed around the lobules and I recall some morphological changes at the same time along with cell infiltration near the Glisson's sheath. I thought if such conditions were prolonged they would develop into rather serious hepatic dysfunction. For this reason I find the experiment very valuable. Of course, considerable degeneration was observed in the lymphatic system of the spleen, the kidney, and the intestines, together with hematopoietic dysfunction in the marrow, etc.

I should like to add that eumycetes were found in sputum taken while Mr. was alive. In urine samples we found aspergillus. Microscopic examination of the lungs showed suppurative pneumonia mixed with mycelia of aspergillus mostly in the center of the alveoli. It is safe to say that some mycelia broke down the walls of the blood-vessels and some penetrated the walls. But this occurred toward the end, and it has been noted in the literature that aspergillosis is

often seen in anemic patients and in those whose illness is accompanied by disturbances in consciousness, Mr. case included both of these conditions and it was considered probable that such fungi were present toward the end. The question is whether these fungi did any harm. Antibiotics must be used in general systemic conditions of this type where there is danger of infectious diseases complicating the existing hematopoietic dysfunction; mycotic involvement is an inevitable result of the use of these antibiotics. The doctors in the case also took great pains to prevent this. When we appeal to antibiotics or transfusions in the future treatment of radiation sickness we will have to consider the problem of fungi and viruses. Through the case of Mr. we have learned a great deal.

Fujimori: What caused the enlargement of the right atrium?

Ohashi: I think it arose from the resistance to pneumonia. The partial condition of the right atrium may have occurred from such cause, although I am not certain of it.

Fujimori: Dr. Ohashi and Dr. Kumatori explained in detail the problem of the liver. But the matter of transfusion turns out to be quite subtle and I believe that the treatment will become more and more complicated. Transfusion is absolutely necessary for proper treatment; but I would like to see whether any data are available about the relationship between the quantity of transfusion and the dysfunction of the liver.

Kumatori: We cannot abandon transfusion cases of panmyelophthisis. I examined those who gave blood for the Bikini patients and found that other patients who received blood from the same persons did not develop jaundice. A different person supplied blood to the Bikini patients each time. I am now examining the dry blood-plasma.

Koyama: Transfusion of blood-plasma is also a problem. Some of the 16 patients, who were not given transfusions, had low-grade jaundice after receiving blood-plasma.

From the very beginning we considered serous hepatitis so we kept the sera of all the patients separately from the time of initial hospitalization until now. These can be examined as the occasion demands. It has been my experience that no patient has died of jaundice or hepatitis which occurred after blood transfusion. All of them, recovered smoothly, without suffering recurrences. Dr. Kumatori is now examining the dry blood-plasma.

Goto: Dr. Ohashi has described the autopsy in detail. He told us that he could not rule out serous hepatitis in the case of Mr. hepatic dysfunction. Does this mean that although serous hepatitis might be considered, the dysfunction resulting from the presence of radioactive substances was the primary thing?

Ohashi: Yes. I think the main object of our study should be to clarify these doubtful points. Of course, I am not eliminating serous hepatitis. It is also an important problem; and as the study of radiation sickness is really difficult, I hope we can all cooperate in further research on this subject.

Goto: Since this is a very important problem, I hope you will give us a complete picture.

Fujimori: Dr. Ohashi described the serious pathological findings in the testicles and I think this will affect the survivors psychologically.

Kumatori: I examined the reproductive function of certain patients and found that the number of spermatozoa had decreased, the shape had become abnormal (although the number of spermatozoa was normal), or the motility had been reduced.

Fujimori: Let me mention something which I felt at the time of Mr. death. Mr. death was of course a shock to the whole nation. We were deeply moved when we were asked to perform the autopsy, and I was very grateful that his surviving family granted permission. (As I recall, His Imperial Highness Prince Chichibu left a will concerning his own autopsy.) As an old friend of Dr. Ohashi, I vividly remember him performing this autopsy with sincerity and humility. When I heard him speak with such gravity I was deeply touched.

Ohashi: I thank Dr. Fujimori for his tribute. We were asked to perform the autopsy by those who were with Mr. when he died. I think it was mainly the great sacrifices by the doctors in charge that impressed the immediate members of the family who were with the patient. Without waiting for the arrival of other relatives who were in Shizuoka, they asked for an autopsy within 5 hours of death, which moved us deeply. The wishes of Mr. and of his relatives and the efforts of the physicians in charge were important factors surrounding the autopsy. Ordinarily an autopsy is performed when all the family members are assembled. Had this been the case, his autopsy might have been performed the next morning. The fact that we could perform the autopsy so early was very helpful as there are post-mortem changes; we are very grateful for this.

Treatment of the Patients, and Other Matters

Furukawa: I should like to mention the attitude toward receiving such special patients on the part of the Toichi Hospital. The organization of persons to care for the patients, the liaison within the hospital, and the liaison with the University were all very well handled. Other hospitals which might have such cases in the future might be interested to hear about this. Would you please discuss it for us?

Koyama: I think it was on 16 March that I received a telephone call from the Ministry of Welfare. As soon as the conversation was over I made a report to the hospital director, who said that he would do his best to take care of the patients. I then replied to the Ministry that we could comply with their request. We did not know when the patients were coming or how many to expect, but we made preparations anyway. We were told that most of the cases would pose hematological problems. I proposed forming a group of doctors to take care of these patients, with Dr. Kumatori as the chief, and did so at the instruction of the director. We then learned that the patients would be coming in on the 25th. As we thought of isolating the patients for the time being, we asked the nurses to make suitable preparations. We were told to keep

the patient's things separate so we immediately prepared for that. At that time most of the wards were full, and there was none with 21 empty beds. We thought of evacuating the urology ward at the corner above the auditorium, since it would be very easy to supervise. But in that ward we had a patient whom we could not move; besides, the beds were high and the ward was located three flights up, so it would have been troublesome for the nurses. Therefore we vacated two adjoining wards for internal medicine, removing the patients in the ward, with their beds, to other wards. We put 16 beds in the ward and got two nurses from another ward. We prepared urinals, urine storage vessels, bedpans, sputum cups, etc, two each, with proper bed numbers.

We decided to discuss examinations with Dr. Okamoto of the Radiation Department and also with the Testing and Surgical departments.

In addition to Dr. Kumatori, we also assigned two interns (Niitani and Fukuda). Now, with Dr. Shibuya, who returned from the institute, the number of doctors on the project rose to three. Since these cases also involved the Otorhinology, Ophthalmology, and Dermatology departments, we decided to discuss the situation with the chief of each department. After Dr. Shibuya returned, the therapy proceeded quite smoothly. Dr. Kumatori was responsible for cell counts and marrow studies. Under the splendid guidance of Dr. Kumatori, the young people did so well that everything went along very nicely.

Dr. Ashi of the Testing Department examined the urine. We asked Mr. Hino to examine liver functions and Dr. Ishi of the Testing Department to perform the chemical analyses of blood and urine. As our hospital was not equipped with a flame spectrophotometer we asked Professor Matsumura of the Biochemistry Department of Tokyo Women's Medical University, a part-time member of our hospital, to do the quantitative analysis of salts, and excellent results were achieved. We all thank him for his efforts.

Dr. Kumatori maintained constant contact with Dr. Miyoshi of Tokyo University.

In treating burns and changing bandages we relied on EDTA baths and put the patients in the care of the Surgical and Dermatological departments when they came out of their baths. A time schedule was arranged and the process moved along very smoothly.

Furukawa: Public and journalistic opinion ran very high. You must have suffered somewhat from these opinions.

Koyama: At the beginning Dr. Kumatori primarily was taking care of Mr. [redacted]. But as the patient grew worse, he became very busy so Dr. Kuriyama and I were often called in to help.

Kumatori: The reporters who were concerned with this case were very understanding, and although there were some misunderstandings and complications at the beginning, they are very understanding even now. But we were often troubled by press photographers.

Ohashi: We performed the autopsy in a room with all the windows tightly closed, as in a steam bath, but we forgot to close the overhead

window through which we were photographed. We understand their eagerness to take pictures, but I think their behavior was a bit excessive.

Kunatori: The picture appeared in Yomiuri, the Tokyo, and the Sun. But we protested by telephone and all the papers except the Sun dropped the picture from their third edition.

Okamoto: I would like to add one thing. Thus far the doctors in charge have described to us the treatment and symptoms of the disease. Dr. Ohashi has discussed his pathological findings in detail. I think it will be very important for us, who are in charge of the examination of radioactivity, to investigate thoroughly the symptoms, the findings, and their relationship with the complicated radiation exposure factors.

Furukawa: I have still many things to ask you; but as our time is running out, let us close the discussion here.

Mr. death was a great shock to the people of Japan. A signature campaign against atomic and hydrogen explosions is now being conducted on a nation-wide scale. We hope that Mr. death will not have been in vain and that such atomic and hydrogen explosions which bring misfortune upon mankind will be stopped. Today's evening papers carried an article about the patients leaving the hospital one after another, and I am very pleased about it. I sincerely hope that all the patients will recover speedily and soon be discharged from the hospital. Now, in conclusion, I pray for the repose of Mr. soul. Thank you again for taking time from your busy schedule to come and join this discussion.

(The diagrams used in this discussion are from the monograph by Koyama et al. See FDD Translation Number 187.)

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