

APPENDIX NO. 9

REPORT ON THE MEDICAL STUDIES
OF THE EFFECTS OF THE ATOMIC BOMB

by

DR. MASAO TSUZUKI

Professor of the Tokyo Imperial University

From the Medical Section (Chairman: Dr. Masao Tsuzuki), the Special Committee for the Investigation of the Effects of the Atomic Bomb, the National Research Council in Japan.

N.B. - This report is a summarized one of the Medical Section, based on the various reports which have been presented by the medical investigators in Japan by February 28, 1946. Scientific reports of each survey team and investigator, dealing with special features, will be presented separately.

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CHAPTER I

Injurious Effects of the Explosion of the Atomic Bomb upon the Human Body.

An explosion of an atomic bomb produces various kinds of destructive forces simultaneously and abundantly. These powers injure the human body directly and indirectly. A damaged condition of the human body caused by the explosion of the atomic bomb will be called summarily an "Atomic Bomb Injury".

From the medical point of view, observing the mechanism of the etiology of the atomic bomb injuries, we would like to classify the injurious powers into the following kinds, but we must not forget that these powers will not act separately; they will act always in a combined form.

- (1) thermal energy
- (2) mechanical energy
- (3) radioactive energy

In this chapter, there will be discussed violent energies of these forces and their injurious actions separately; then we will describe in the next chapter the whole course of the atomic bomb injuries which occur by combined effects of the various forces.

1) Thermal Energy and its Injurious Effects.

Enormous amounts of violent light and heat waves (containing a great amount of ultra violet rays), which were produced at the instant of the explosion, caused burn wounds on very many persons within a radius of 4 km from the ground center. The burns were seen mainly on exposed parts of the body. These burn injuries were caused by instantaneous action of thermal (light and heat) energy. The burns outside a 2 km radius were comparatively superficial and slight.

In the circle within a radius of 2 km, there were many burn casualties of a severe type; especially in the central area, within a radius of 1 km, the burn action was so violent and severe that the entire thickness of the skin was burned and moreover the internal tissues and organs were also damaged by heat energy. Consequently many patients suffered from severe burns and lost their lives immediately or within a few days.

These burn injuries we shall call in short, "Atomic Bomb Burn". The burns which are caused by the primary heat waves shall be called "Primary Burn" or "Flash Burn". Many persons within a radius of 3 km from the ground center had their skin secondarily burned from the burning or superheating of their clothing. These burns we shall call "Secondary Burn" --- by burning cloth, "Scorch Burn"; by superheated cloth "Contact Burn". The burns which were caused by burning of the houses shall be called "Flame Burn". We can assume that many patients with flame burns were burned to death by the secondary fires.

Many of the atomic bomb burn patients outside the 3 km radius were comparatively mild cases. They showed simple erythemas or formation of small vesicles, like a case of severe sunburn. They were cured in 1-2 weeks. In the circle within a radius of 3 km the burn injuries were pathologically all of the 3rd degree, i.e., there occurred escharotic changes of the tissues, the depth of injury was different in each case. These flash burns appear quite specific, since they were caused by heat of tremendous intensity and of very short duration (shorter than 1/10 sec). Accordingly such flash burns look just like a specific burn caused by superthermal energy.

The pathology of burn injuries caused by superthermal energy was studied during the war, thereby giving medical profession real experience. Burning by an incendiary bomb was one such a specific example for it was caused by a superthermal flame (over 3,000 C). If such superthermal energy acts upon the human body for an instant, i.e. shorter than few tenths of a second, there will occur a superficial lesion of the skin, where a thin layer of burning crust will be observed. The crust will scale off spontaneously after a few days or a week and there will remain a shiny area of skin with a red-brown colour. The burning crust consists of burned debris of the outer layer of the epithelium and congregation of miliary vesicles in the epithelium. The whole appearance of this burned crust is just like that of herpes. A covered part of the body, even if covered by thin material such as a cap or shirt, is not affected. Therefore, the line between burned and unburned parts is clearly visible. If the superthermal energy would act a little strongly, in other words, for a little longer time or with a little greater intensity, the severity of the injury should become astonishingly greater. In the severest cases, the total thickness of the skin is burned and moreover the internal tissues are also damaged, as if they were roasted and death occurs immediately. Also in such a case, the superthermal energy will blow down with a blast, so it will act as a "blast heat". It will blow off the scorched clothes and the burned skin, too. Between these two extreme conditions, there are, of course, many intermediate cases. Proportional to the intensity of the heat and its duration, the depth of the internal damages increases and the general disturbance due to the internal damage becomes more marked.

If a burn of the skin extends over a certain area, there will be observed a degeneration of the internal organs, especially the liver and kidney. In the severest cases of burn, even if the burned area is limited, such general disturbances have been observed distinctly. It has become clear now that the general disturbances in severe burn cases will not occur only as a complication of damage to the skin, but also direct damage to the internal organs.

In cases of atomic bomb burn, it was recognized that similar circumstances, just as in the severe burns by the superthermal energy, also occurred in the central district. That is a primary direct damage by superthermal energy. In atomic bomb burns, the internal organs would be, moreover, affected simultaneously by radioactive energy, so the degree of the primary direct damage would become rather more marked. Atomic bomb burns however occurring at a distance over 3 km from the ground center, can be treated primarily as a simple superficial burn of the skin, because at this distance, the heat intensity was less and the radioactive

energy was also diminished.

2) Mechanical Energy and its Injurious Effects.

At Hiroshima, all wooden houses were totally destroyed and totally burned in the area within a radius of 2 km from the ground center. Strong concrete buildings were not completely destroyed, but their windows were blown out and the inside of the buildings were totally burned. It was thought by many authorities right after the disaster that the houses were destroyed by secondary fires. It is therefore possible that a primary fire could occur in the circle within a radius of 1,800 m from the ground center. At Hiroshima, the wooden houses between a radius 2 - 4 km from the ground center, were destroyed totally or partly, according to their distance, but fires did not break out. The breaking of window glass was noted even as far as over 16 km, effects on trees over 20 km. The feeling of a blast was recorded over a distance of 60 km.

The mechanical characters of the blast pressure, brought forth by the explosion of the atomic bomb, were surveyed from various points of view by the Scientific as well as Engineering Sections of the Special Committee. Many special conditions of blast pressures and their effects have already been discovered, but the direct effects of blast upon the human body have not yet been so clear. It was alleged some persons were blown for several meters by the blast action. Some were suffering from damage to their internal organs. The blast injuries which we observe usually at the explosion of ordinary bombs or shells - i.e., no visible wounds on the surface of the body and some injuries or hemorrhages of the internal organs (brain, lung, liver etc.) - were not found on the records of the patients of the rescue organizations or in the personal experience of the physicians. On the other hand, in the central district, there were many patients severely burned, with the burned, torn skin flaps hanging loose. On account of these facts, we would like to suppose that the blast effects of the atomic bomb would be a little different than those of the ordinary one. But we have not been able to grasp the real aspects of the effects of the blast action of the atomic bomb, in the data, which we have studied.

There occurred many cases of various kinds of mechanical injuries, e.g. crush deaths, severe injuries of internal organs or bones by falling houses. Many mechanical wounds were caused by destruction and scattering of houses and furniture. Wounds by broken glass were too many to be counted even at places far distant from the ground center.

It was suspected that the majority of the severely wounded persons under the falling devastated houses would be burned to death by the subsequent fires. It could be presumed by the following facts: among the wounded persons who were admitted into the rescue organizations directly after the accident, the great majority of cases (over 90%) were burn patients, cases of mechanical wounds, such as fractures of bone, were very few. Those mechanically wounded had escaped mostly by their own efforts from the ruined houses. In the clinical course of these mechanical wounds, no differentiation has been proved, compared with an ordinary bomb wound. Few fracture cases were examined, but no abnormality in their healing process was noted. These cases showed no peculiarity by x-ray examination. Some slight wounds or lacerations become often worse sometimes had a tendency toward gangrenous changes, when these patients showed manifest

symptoms of radiation sickness. It may be based upon the alternation of tissue reaction against injury or infection, due to the damage of functions of internal organs, caused by radioactive energies. These relations will be discussed again later in the following paragraphs.

3) Radioactive Energy and its Injurious Effects

Various radioactive energies are emitted by an explosion of an atomic bomb. Roentgen rays, gamma-rays and neutrons are 3 important energies which can cause significant effects upon the human body.

Within a radius of 1 km, there reached tremendous amounts of radioactive forces. Persons who were outdoors at that occasion were affected by all kinds of these forces. Persons in well-covered places in concrete buildings or in a strong underground trench, were less affected. The active injurious range of radioactive energies seemed to reach about 4 km. Outdoors the effect was much more severe than that indoors.

What happened to a human body by such a strong radioactive energy? First of all, damage to blood, then to hematopoetic organs - bone marrow, spleen and lymph nodes. All are destroyed or damaged severely. Lymphocytes are most sensitive and are destroyed first. Then other internal organs, such as the lungs, intestines, liver, kidney etc. are affected and their functions are disturbed subsequently. If these damages happen to be severe, then organisms die mostly within a few days, some of them die in 2 weeks. When a moderate degree of damage is caused, the majority of cases complain of severe symptoms in 2 - 6 weeks and many of the sufferers die. Slight damage would cause no death, but some disturbances might occur during several months.

Our survey has revealed that severe damage was seen within a radius of 1 km, moderate damage in the area 1 - 2 km, slight damage in the area 2 - 4 km.

The patients who were affected severely, died mostly in a few days. Affected outdoors, they suffered also from severe burns simultaneously, some of them had moreover a blast effect in addition. Typical symptoms of these severe effects were high fever, extreme general malaise and exhaustion, vomiting, hematemesis, hemoptysis, hematorrhoea, hematuria, etc. These symptoms arise from severe damage to blood and internal organs of the whole body. The bleeding symptoms in an early stage are said to be based on the damage of the alveoli of the lungs, mucous membranes of the stomach and intestines, and tubules of the kidney. Few patients complained of unconsciousness or excitation, but most of them were lucid until their death, which occurred accompanied by general weakness. Some persons escaped from crush death or severe injury, even though they were in a building at a distance within 500 m from the ground center. These persons were damaged relatively severely by the radioactive energies. They complained in several days of severe bleeding symptoms - hematemesis or hematorrhea and often gingival bleeding, mucous and bloody diarrhoea. Many of those patients died of these bleeding symptoms in the course of several days. Those patients showed a continuous fever - 38°C - 40°C. It was said therefore at that time that an epidemic disease like a dysentery might have broken out. Some official procedures for prevention of infectious diseases were suggested. It was also a fact that at that time

some real cases of dysentery and typhoid fever did occur. These circumstances produced consequently much confusion, when we were working afterwards to make clearer the real aspect of the atomic bomb injuries.

Among the persons who were in wooden houses (mostly upstairs) or in shadow outdoors in the area 500 - 1,000 m from the ground center and had no severe mechanical wounds or severe burns, there were many, after about 2 weeks, who complained of epilation, fever, and then hemorrhagic and necrotic gingivitis or tonsillitis. They had successively reddish-violet hemorrhagic spots on the skin of their faces, trunks and extremities. Some of them had mucous or hemorrhagic diarrhoea. The diarrhoeal feces were characteristic in containing no pus. Some complained of epistaxis.

The patients, having these hemorrhagic symptoms afterwards, used to vomit mostly on the day of the explosion or after a few days. 1 - 2 weeks before the outbreak of the symptoms they usually lost their appetite. At the onset of the symptoms they had a high continuous fever of about 39°C and sometimes superthermal fever of 40°C. A few patients complained of chill or rigor, but many of them did not.

The clinical courses of these patients were similar. The majority of the patients died with a continuous high fever in about one week. If the fever curve shows a tendency toward descending by crisis or lysis after about one week, the prognosis becomes favorable and all clinical symptoms change for the better.

The persons who were within a radius of 1 - 2 km from the ground center suffered from moderate effects of radioactive energy. Especially the persons outdoors had comparatively severe damage with burns, but the persons who were in houses or in shadows and suffered from no severe mechanical nor burn wounds, had of course comparatively less damage by radioactive energy. About half of those patients complained of symptoms of epilation, fever and hemorrhage after 3 - 6 weeks. Some showed severe symptoms and died. Almost all of those patients who vomited directly after the bombing had a loss or diminution of appetite. Such digestive symptoms usually passed in a few days and the patients were feeling better for varying intervals and then the symptoms of epilation, hemorrhage etc. broke out. The inciting factors, by which these patients developed such severe symptoms, were overwork, cold and digestive disturbance etc.

As soon as the symptoms of epilation and bleeding had broken out, the slight, almost cured, lacerated or burned wounds changed their appearances suddenly, becoming worse and showed a necrotic tendency. The condition of those wounds could not be easily cured by ordinary methods of wound treatment. The patients whose wounds became worse proved mostly to have a poor prognosis. The majority of these cases died.

The patients who had a severe or moderate damage by radioactive energy showed remarkable changes of their blood pictures. Hemoglobin content diminished to 50%, the number of erythrocytes decreased to 2 - 3 millions in one cubic millimeter. Sedimentation of the red blood corpuscles was counted over 50 mm in one hour, sometimes over 100 mm in one hour. The most remarkable change of the blood picture was a decrease of the number of the white blood corpuscles: In the severe cases, the number was usually under 1,000 in one cubic mm, often under 500. In the moderate cases, it was usually

under 2,000.

The mechanism of the decreasing of the number of the white blood corpuscles seems to proceed in the following bi-phasic way. At first the lymphocytes decreased remarkably, directly after the bombing. In some severe cases it was found that almost all lymphocytes disappeared within several days! Then, in 1 - 2 weeks, it was noticed that the granulocytes were decreasing markedly. It seemed to coincide with the period in which the fever or the bleeding symptoms appeared. When the decrease of the number of the granulocytes became manifest, that was in 2 - 4 weeks, the number of lymphocytes had already increased a little. Consequently a decrease of granulocytes and a relative increase of lymphocytes was observed at this period. So we have therefore "Agranulocytosis".

The number of platelets did not decrease so much in the early stage. After 2 weeks it decreased markedly, in some severe cases under 10,000.

The picture of the bone marrow of the severe cases was one of extreme devastation, the number of nucleocytes was 1,000 - 4,000. The number of myelogenous and erythroblast types were decreased greatly. On the contrary, reticulocytes and plasmacytes were increased. Lymphocytes were relatively in a high percentage.

When the clinical symptoms became better with a lessening of fever, the blood picture improved also. A real recovery of the blood picture to a normal condition will occur after a certain time (about one month). In the recovery of the blood picture, there is a difference between the relationships of various elements. Comparing the recovery of leucocytes with that of erythrocytes, the former recovered more quickly than the latter. Therefore, there remains for some while an anemic condition to a certain degree.

The persons who were in the area within a radius of 2 - 4 km from the ground center suffered from mechanical or burned wounds of moderate or slight grade respectively. They had moreover some damage by the radioactive energy too. Most of these persons did not show any symptoms of radioactive damage, but in many of them it was proved that the number of their leucocytes decreased somewhat, to about 3,000 - 4,000. Few of them complained of epilation or bleeding symptoms (gingival bleeding, skin spots etc); they recovered rapidly of course, because they were affected only slightly.

The following observations were reported: the persons who had slight flash burns on the small area of their face, neck, shoulder, hand or foot etc., complained rarely of above mentioned disturbances by radioactive damage. Occasionally, even though they did show such symptoms, these were always mild. It is conceivable that the degree of the damage would be less, because almost all of these persons were affected at a distance over 2 km from the ground center. On the other hand, there are the following, rather hypothetical opinions. Those patients were obliged to keep themselves quiet on their beds, due to their mechanical or burned wounds. Superficial burn wounds would stimulate the affected hematopoietic organs and promote the regeneration of blood elements. Consequently outbreaks of the symptoms of the radioactive damage might be slighter.

The above mentioned damaged condition by the radioactive energy may be called as a whole an "Atomic Bomb Radiation Injury" or an "Atomic Bomb Radiation Sickness". We would not like to agree here that only a pure (rather theoretical) damaged condition by radioactive energy is picked out and called "Atomic Bomb Injury". It can also not be agreed that the burns, caused by the atomic bomb be placed outside of the category of the so-called atomic bomb injury, because they are produced by the action of heat energy. On account of the blood pictures 4 - 6 weeks after bombing, i.e. a decrease of the granular cells, some investigators suggest classifying the change of blood caused by the atomic bomb damage as an "Agranulocytosis". Some of them, moreover, would like to designate only such "Agranulocytosis" cases as a "pure atomic bomb injury". These opinions are not rational because they are not based on observation and consideration of the whole picture.

The above mentioned "Atomic Bomb Radiation Injury" is the primary damage; there is another type of radioactive effect, called the secondary damage. The secondary damage is caused on the one hand by the radioactive energies (mainly beta-rays) from all elements which are induced by neutrons at the time of explosion and on the other hand by the radioactive energies produced by fission fragments fallen on the ground. The degree of the secondary damage is of course very small compared with the primary one, but it shall be touched upon. We will describe it afterwards in the chapter on problems of contamination.

4) The Atomic Bomb Injury

The injurious forces, produced by the explosion of the atomic bomb, are classified as mentioned above, into the following 3 kinds: 1, thermal energy, 2, mechanical energy, 3, radioactive energy.

These 3 powers are able to cause respectively their own characteristic damage, but these powers will act actually in combination as a whole at the time of the explosion, and will produce a very complicated damaged condition.

For these reasons, we would like to call such a pathologic condition as a whole an "Atomic Bomb Disease". These two terms are used in the same meaning. Every one can use either term, according to his taste. I, myself, use the term "Atomic Bomb Injury," because I think the atomic bomb is to be a new type of powerful weapon.

To observe separately the various kinds of damage produced by the various forces of the atomic bomb, it may be convenient that each damaged condition be designated as follows: Atomic bomb burn, Atomic bomb wound, Atomic bomb radiation injury (or Atomic bomb radiation sickness) etc. These pathologic conditions, even though they may be concerned with burns, mechanical wounds or radiation injuries respectively, are all quite characteristic. They have their own specific features, caused by the effects of the atomic bomb.

For convenience in understanding the pathologic conditions of human bodies caused by the effects of the atomic bomb, we would like to summarize them in the following table:

Atomic Bomb Injury (Atomic Bomb Disease):

I. Atomic Bomb Burn.

- 1) Primary Burn : Flesh Burn.
- 2) Secondary Burn : Scorch Burn, Contact Burn, Flame Burn.

II. Atomic Bomb Wound.

- 1) Primary Injury : Blast Injury
- 2) Secondary Injury: Burial Injury, Crush Injury, Fragment Injury

III. Atomic Bomb Radiation Injury (Atomic Bomb Radiation Sickness).

- 1) Primary Radiation Injury
- 2) Secondary Radiation Injury