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# Original Signs and Symptoms in Patients Surviving Five Years after Atomic Bomb Exposure under 1,000 Meters

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## HISTORY

The Hiroshima bomb was detonated at an altitude of approximately 580 meters at 8:15 A.M. on August 6, 1945. Immediately many Japanese scientists began making mental notes of what happened to them and to the hordes of patients arriving at the temporary clinics and first-aid stations [9]. About forty-eight hours later the first Japanese investigating teams arrived in the chaotic city. These teams were from the huge scientific centers, such as Tokyo, Kyoto, Osaka, Okayama and Kyushu. Their brilliant work [2] was handed to the American team which entered Hiroshima about a month later. The American group, which was commonly known as the Joint Commission, was composed of Navy, Army and Japanese personnel, and those from the Manhattan project. The Joint Commission completed their task by the beginning of 1946. Using the Japanese findings as a foundation, they expanded, confirmed and carried out further studies [1]. During the month of November, 1945, the Joint Commission was joined by a British Survey Team which evaluated the damage in the light of their experiences during the London "blitz" [5,10]. From January to November, 1946, there were no American investigating groups in Hiroshima as far as could be ascertained. In November, 1946, a small group known as the Brues-Henshaw Commission entered Hiroshima. This group had military as well as civilian personnel and took the name Atomic Bomb Casualty Commission (ABCC) [11]. In April, 1947, by act of Congress, the

NUMEROUS reports have been published reviewing the signs and symptoms of atomic bomb victims [1-5]. These reports, although dealing many times with the same patients, approached the medical aspects from different viewpoints. Subsequently, other investigators re-evaluated again the dreadful events and consequences of that clear August morning in 1945 [6-8]. The reasons for the intense interest in the early complaints of the victims are obvious: a new disease syndrome; the specter of malignancies, blood dyscrasias and genetic mutations; flash burns due to unrivaled intensities of radiant heat; and the evaluation of a new weapon of warfare and a new source of energy for peaceful purposes.

This report deals only with survivors who were exposed 1,000 meters or less from the hypocenter in Hiroshima and were living at least five years after the dropping of the atomic bomb. Although a thermonuclear weapon was detonated in March, 1954, at Bikini Isle, it does not render obsolete the findings in the population of Hiroshima following the atomic bomb explosion. With a thermonuclear weapon the scale of injuries will be many times greater, but the types of injuries will be similar. If in the future another wide conflict occurs, atomic weapons as well as thermonuclear weapons will be used. The information in this paper, therefore, may be of some aid to civilian defense groups as well as physicians.

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Committee on Atomic Casualties was formed. This group took over the name Atomic Bomb Casualty Commission and it is this commission which is still carrying on investigations in Hiroshima.

### MATERIALS AND METHODS

In 1949, ABCC conducted a census of all survivors of the atomic bomb in Hiroshima. This took six months to complete. One thousand fifty persons were found who had been exposed within 1,000 meters from the hypocenter. This group served as the basis for the adult Medical Program (ME-55) which was started in 1951. This program was composed of (1) all survivors exposed under the 1,000 meters and 10 per cent of the survivors exposed within 1,500 meters, totaling approximately 2,500 people, and (2) a control group consisting mainly of (a) people matched by sex and age with the exposed group, residing in the city of Kure (about 20 miles from Hiroshima) and (b) persons who moved into Hiroshima after January 1, 1946.

The Adult Medical Program started in 1951. All survivors on that program (and the few children on the pediatric program) exposed within 1,000 meters from the hypocenter were included in this study if they were still alive. There were 619 patients; 431 persons of the total 1,050 were lost due to death, refusal or inability to locate. Each case making up this paper was reviewed independently by each of us, and if there was any disagreement in a finding, we both reviewed the case.

Each patient was evaluated in two ways: (1) from the radiation symptoms and signs and (2) from the traumatic history. The radiation symptoms and signs were assigned numerical values as follows: vomiting, 1; fever, 2; oropharyngeal lesions, 4; purpura or petechia, 8; epilation of any degree, 16. Patients with any number or combination of numbers totaling between 8 through 31 were labeled severely radiated; from 4 to 7, moderately radiated; and from 1 through 3 lightly radiated. The basis for choosing the radiation symptoms enumerated were the chi square contingency tables between radiation symptoms worked out by Dr. L. Woodbury [12].

The evaluation of trauma was much more difficult. The effects of blast, burn and mechanical injuries were weighed by a doctor and patients were placed in one of the following three

TABLE 1\*  
SEX AND AGE OF PATIENTS IN SAMPLE

Age at Time of Bombing (yr.)	Males	Females	Total
10-19	49 (17)	92 (27)	141 (23)
20-29	46 (16)	111 (33)	157 (25)
30-39	60 (21)	60 (18)	120 (19)
40-49	70 (25)	50 (15)	120 (19)
50-59	44 (16)	16 (5)	60 (10)
60 and over	12 (4)	9 (3)	21 (3)
Totals....	281 (45)	338 (55)	619 (100)

\* All tables herein list both the absolute numbers of persons in various categories and the percentages in parentheses.

categories: (1) lightly injured, (2) moderately injured and (3) severely injured. These groupings were on a subjective basis. However, a patient so crippled by injury that he would have to depend on others for survival was classified in group 3. This group did not include persons temporarily unconscious who were able to care for themselves on recovery. Patients severely injured but capable of locomotion without aid were placed in group 2, e.g., punctured eyeball or fractured fibula. All patients with lesser type injuries were classed in group 1.

### RESULTS

*Trauma.* There were 619 patients in the sample studied; 55 per cent were females and 45 per cent were males. (Table 1.) Most of the females were in their twenties, while the males were mainly in their forties. One might surmise that the numerous work parties in the city of Hiroshima would be composed of these age groups, as the females in their twenties are the most resilient and the strongest; the males in the third and fourth decades were in the Imperial Armed Forces. There were no children in the first decade in this sample. This has been explained by any one or a combination of the following factors [13]: "(1) A large mortality rate among children as a result of the bombing. (2) The evacuation of children from the cities prior to the bombing. (3) The inability to get exact information from young children."

The sample by exposure distance confirms the fact that there were more survivors the

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TABLE II  
SAMPLE BY EXPOSURE DISTANCE

Distance (meters from hypocenter)	Males	Females	Total
001-250	2 (0.7)	.....	2 (0.3)
251-500	14 (5.0)	17 (5.0)	31 (5.0)
501-750	47 (16.7)	57 (16.9)	104 (16.8)
751-1,000	218 (77.6)	264 (78.1)	482 (77.9)
Totals.....	281 (45)	338 (55)	619 (100)

further the distance from the hypocenter. There were no differences due to sex. (Table II.)

In the number of injuries per person, excluding radiation injury, there was one person without any injury and ninety-seven people with abrasions. People with only one injury represented 60 per cent of the sample, 20 per cent had two injuries and 2 per cent had three injuries. Lacerations accounted for 80 per cent of all injuries, burns for 25 per cent and contusions for 15 per cent. It might be supposed that contusions should be the most common injury as undoubtedly most of the lacerations had a contused area.

In the group with two injuries, there were fifty-seven people with the combination of burns and lacerations, forty-five with contusions and lacerations, and twelve with burns and contusions. Of the twelve persons with the combination of three injuries, five had the combination of burns, contusions and lacerations.

The body was divided into five areas in locating injuries: (1) head, face, neck; (2) upper extremity; (3) thorax, back; (4) abdomen, pelvic girdle, genitalia; and (5) lower extremity.

Of the number of body areas injured, 221 persons had two areas injured and 226 persons had only one body area injured. Twenty-five people had injuries to all the body areas, ten to three body areas and thirty-four to four of the body areas.

During World War II, in the inter-war period, and during the Korean conflict, pleas were voiced [14-16] for the accurate location of wounds. Unfortunately the same chaotic conditions existing during combat were present following the bombing.

The head, face, neck area and the upper extremity area were the locations of the majority of the injuries. There appears to be a

TABLE III  
DURATION OF HEALING

Type of Injury	Total Accumulative Per cent				
	25	50	75	90	95
Mechanical.....	2 wk.	4 wk.	11 wk.	20 wk.	24 wk.
Laceration.....	1 wk., 2 days	3 wk., 6 days	10 wk.	20 wk.	23 wk.
Flash burn.....	3 wk.	3 wk., 5 days	9 wk.	18 wk.	23 wk.

difference between the sexes as to number of injuries to the lower extremity ( $P = 0.001$ ). The females with the higher percentage may have, in the privacy of their dwellings, shed their "mompei"\* since it was early in the morning and during the heat of the summer. This would have removed a protective covering from flying glass and tile, and the flash.

The maximum duration of healing in mechanical injury ranged from less than one week to almost two years. (Table III.) In evaluating this type of injury for triage, the stockpiling of the equipment and the availability of beds, as to occurrence and duration the 25, 50, 75, 90, and 95 per cent levels were selected. Fifty per cent of the patients were completely healed by the fourth week following injury. By the twentieth week 90 per cent were healed, and four weeks later 95 per cent were healed.

*Burns:* There were twelve fire burns and 128 flash burns. The fire burns were contact burns; the flash burns were due to radiant heat transmitted in the visible and infrared regions of the spectrum [17]. The ultraviolet rays caused erythema but no burn. When an atomic bomb explodes, the flash is divided into two periods [4]. At first there is a short blue-white flash lasting about 0.01 second; this radiation does not persist long enough to ignite the surfaces on which it falls. This flash is followed by a longer flash which dies away relatively slowly [2]. Starting at about 20 to 25 milliseconds, skin burns are produced, with the most severe occurring between 0.1 and 0.2 second. By increasing increments of exposure, the major severity of thermal burns was attained within the first 0.3 second after the bomb exploded and the maximum severity within the first 0.5 second. No burns were produced after the first 0.6 second [17]. Therefore, protection from the

\* Female work trousers demanded of all Japanese women during World War II.

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TABLE IV  
TYPE OF HEALING

Type of Healing	Flash Burns	Fire Burns	Lacerations
Primary intention.....	59 (46.8)	7	261 (53.7)
Keloid, with primary healing.....	1 (0.8)	0	0
Keloid, suppuration with delayed healing.....	5 (4.0)	0	0
Keloid, suppuration without delayed healing....	7 (5.6)	0	0
No keloid, suppuration with delayed healing...	17 (13.5)	2	152 (31.3)
No keloid, suppuration without delayed healing.	35 (27.8)	3	73 (15.0)
No keloid, suppuration, non-healing.....	2 (1.6)	0	0
Totals.....	126	12	486

flash between 0.1 and 0.6 second after occurrence would result in no burn. Species differences and skin pigmentation also play a role in the severity of burns. Dark pigmentation at the same distance caused a more severe and more penetrating burn than light pigmentation; healing also took longer [17]. It is plausible to assume that the injuries due to flash burns may have been more severe because of skin pigmentation in our sample of Japanese people.

In 126 cases of flash burns (Table III), 50 per cent were healed by the fourth week, 90 per cent by the eighteenth week and 95 per cent by the twenty-third week.

The majority of the cases of flash burns healed by primary intention. About 10 per cent (thirteen cases) had keloids; in only one of the thirteen cases suppuration did not occur. Suppuration was present in sixty-six of the cases (52 per cent). (Table IV.)

Only twelve persons gave a history of fire burns. (Table IV). No keloids developed but there were several instances of suppuration.

Lacerations were the most common mechanical injury; 222 persons of 495 so injured gave a history of known duration of healing. (Table III.) Glass cuts represented 72 per cent of all lacerations. The 50 per cent level of healing was at four weeks, the 90 per cent level at twenty weeks, and the 95 per cent level at twenty-four weeks. The type of healing was recalled by 486 patients with lacerations. (Table IV.) Almost 50 per cent had suppuration of their wounds,

TABLE V  
COMPLICATIONS OF HEALING

Complications	Males	Females	Total
Psychobiological.....	0	1	1
Cosmetic disfigurement.....	5	8	13
Physical incapacitation.....	10	9	19
Cosmetic disfigurement plus physical incapacitation.....	7	8	15
Totals.....	22 (45.8)	26 (54.2)	48

although the majority healed by primary intention.

There were few skeletal injuries (total twenty-seven), and it is surmised that most patients with multiple fractures or a single incapacitating fracture perished in the "fire storms." Other fractures were undoubtedly missed because the patient never even suspected a fracture and it was only by x-ray examination that the diagnosis was made. Most of the fractures healed well with good alignment (fifteen of twenty-three). Only two patients had delayed healing. Six patients had poor alignment although the fracture healed well. The type of healing was unknown in four.

Forty-eight patients were found to have a complication resulting from healing. (Table V.) It is well known that many victims of any type of trauma always place the blame for any illness real or imaginary, on that event. Certainly the victims of the atomic bomb were not exceptions. However, the psychoneuroses and neuroses that may have resulted from that explosion were ignored in this study. The one patient listed as having a psychobiological complication was a schizophrenic. Whether she gave evidence of this condition prior to the bomb cannot be resolved. Twenty-eight patients suffered cosmetic disfigurement and it certainly can be assumed that there was some psychological overlay. The thirty-four cases of physical incapacitation were mainly due to contractures following burns.

Summarizing the severity of the trauma (Table VI), less than 1 per cent were very severely injured and about 93 per cent had mild traumatic injuries. Certainly this was to be expected, as the severely injured did not survive.

TABLE VI  
DEGREE OF TRAUMA

Severity of Trauma	Males	Females	Total
None to mild.....	260 (92.6)	314 (93.0)	574 (92.7)
Moderately severe....	20 (7.1)	23 (6.8)	43 (6.9)
Very severe.....	1 (0.4)	1 (0.3)	2 (0.3)
Totals.....	281	338	619

TABLE VIII  
ONSET OF RADIATION SIGNS AND SYMPTOMS

Symptom	Total Accumulative Per cent				
	25	50	75	90	95
Fever and/or vomiting.....	? hr.	? hr.	1 wk.	4 wk.	4 wk.
Oropharyngeal lesions.....	1½ wk.	3 wk.	3½ wk.	5 wk.	5 wk.
Purpura.....	1½ wk.	3 wk.	3½ wk.	5 wk.	6 wk.
Epilation.....	>1 wk.	2 wk.	4 wk.	6 wk.	8 wk.

*Blast:* Blast injuries as such have not been mentioned. There were very few reports of such in Hiroshima and this quotation from the British Mission's Report [5] is a very appropriate one:

"In Nagasaki but not in Hiroshima, a rumor was current which age has made almost respectable, for it appeared in the London Blitz and before that in Barcelona during the Spanish Civil War. This was that large numbers of people had been ripped open by the blast, and their entrails exposed; their eyes and tongues were said to have hung out. Experience in this country (England) has shown that blast pressure alone does not in fact cause these sensational effects on the human body. It was, therefore, not unexpected that two Nagasaki survivors who had spoken of seeing hundreds or thousands of such bodies on examination reduced their claim to one or two. Flying debris would be expected to produce a few such injuries. Cases of genuine injury from high blast pressures, such as ruptured ear-drums, were rare among survivors."

*Radiation Signs and Symptoms.* As mentioned earlier, radiation injury was based on vomiting, fever, oropharyngeal lesions, purpura and epilation. There were 490 patients with symptoms, representing almost 80 per cent. (Table VII). The vast majority had

TABLE VII  
SEVERITY OF RADIATION SYMPTOMS

Severity	Males	Females	Total
No symptoms.....	69 (24.6)	60 (17.8)	129 (20.8)
Mild symptoms.....	30 (10.7)	33 (9.8)	63 (10.2)
Moderate symptoms....	0	0	0
Severe symptoms.....	182 (64.8)	245 (72.5)	427 (69.0)
Totals.....	281 (45.4)	338 (54.6)	619 (100)
Total number with symptoms and per cent of 619 patients.....	212 (75.4)	278 (82.2)	490 (79.2)
Per cent of 490 patients.....	212 (43.3)	278 (56.7)	490 (100)

TABLE IX  
DURATION OF RADIATION SYMPTOMS

Symptom	Total Accumulative Per cent				
	25	50	75	90	95
Fever and/or vomiting.....	6 days	2 wk.	2 wk.	2 wk.	2 wk.
Oropharyngeal lesions.....	1 wk.	2 wk.	3½ wk.	6 wk.	8 wk.
Purpura.....	<1 wk.	2 wk.	3½ wk.	7 wk.	8 wk.

severe radiation injuries with purpura and/or epilation, and perhaps other symptoms.

Fever and/or vomiting were the least significant symptoms of radiation injury, both biologically and statistically [12], and were evidenced by 74 per cent of the sample. (Table VIII.) The 50 per cent level of these symptoms occurred within hours of the detonation; these patients almost without exception had the symptom of vomiting. At the end of one week almost 75 per cent of this group had symptoms. The 90 and 95 per cent levels were reached in the fourth week. The duration at the 50 per cent level was two weeks and the main symptom was fever. (Table IX.)

Oropharyngeal lesions (Table VIII) were most difficult to evaluate from the history. The final criterion was ulceration of the oropharyngeal mucosa. Undoubtedly many cases did not meet this standard. When this type of lesion was present, the 50 per cent level was reached in the third week with the 90 and 95 per cent levels attained in the fifth week. The duration of this injury (Table IX) was comparatively short,

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50 per cent being healed in two weeks and 95 per cent within eight weeks.

Purpura, which included petechiae and spontaneous bleeding from the gums, signified severe radiation injury. It was a manifestation startlingly noticed by the layman, easily remembered and not influenced by the age of the patient. Over 50 per cent of the sample (Table VIII) had this symptom, with the 50 per cent level occurring in the third week, the 90 per cent level in the fifth week and the 95 per cent level in the sixth week. This sign lasted for two weeks (Table IX) for the 50 per cent level, and by nine weeks had disappeared for the 95 per cent level.

Epilation (Table VIII) was also a sign of severe radiation injury. It was startling and well remembered, but suffers as an indication of radiation because there appears to be a relationship with age [12], and also many men are bald-headed. The disappearance of epilation or reappearance of hair is not a good end point. The 50 per cent level occurred in the second week and the 95 per cent level in the eighth week. Although duration could not be evaluated, the degree of epilation was noted. (Table IX.) Over 60 per cent of the epilated patients lost almost their complete head of hair. Many patients remarked that their new growth of hair was at first finer and of a red tinge.

In trying to relate the traumatic injury to the radiation injury, it was believed that an inverse relationship might appear; the more severely traumatized the less severely radiated and, conversely, the less severely traumatized the more severely radiated. This was not borne out by analysis.

From these results one can hypothesize the modal patient in this sample study who survived at least five years after an atomic explosion and who was exposed within 1,000 meters. This patient was a twenty to twenty-nine year old female exposed between 750 and 1,000 meters from the atomic bomb. There was a 60 per cent chance of being lacerated and a 20 per cent chance of being burned. If an injury occurred it was most likely to the head-face-neck area or to an upper extremity. For any type of trauma the likelihood was that the injury healed by primary intention within four weeks. There was very little chance of any permanent complication of healing.

There was an 80 per cent chance of some radiation sign or symptom appearing. If there

was fever and/or vomiting it probably started the first day (vomiting) and lasted two weeks (fever). If there were oropharyngeal lesions they appeared within three weeks and had a two-week duration. Purpura would be apparent within three weeks and would last three weeks. Epilation would begin within two weeks and would involve 76 to 100 per cent of the scalp.

This modal patient would experience severe radiation and mild trauma.

Several other studies similar to the present one have been made. It is of interest to compare the results. Table X lists the percentages of radiation, mechanical and thermal injuries found at different times by various investigators. These results were compared in the groups exposed through 1,000 meters. An excellent survey by Snell [7] could not be used, as his closest surviving group was exposed up to 1.0 mile. The Hatano survey [6] had a sample of 100 people, ninety-one of whom were exposed within 1,000 meters. Figuring that 10 per cent were exposed beyond 1,000 meters, this percentage was used to exclude the injuries that survey listed for the entire sample. As can be seen in Table X, the figures of the Joint Commission and this report are very similar. However, over-all there appears to be an increase in mechanical injuries and a decrease in thermal and radiation injuries. The increase in mechanical injuries could conceivably be due to the patients remembering injuries either occurred or imagined and not remembered five years previously, although this is very doubtful. The decrease in complaints due to thermal and radiation injury could be due to lapse of memory. There is another possibility which must be investigated: have the groups which were exposed within 1,000 meters with radiation and/or thermal injuries been dying at a faster rate than the groups with mechanical injuries or no injuries? In an effort to see if such a hypothesis could be advanced, all deaths of the exposed population within 1,000 meters on the MIE-55 program were collected. Of the original 1,050 contacts, fifty-four were dead. The various groups are listed in Table XI. The groups are so small that little can be said. There is an assumption that must be made: all patients flash-burned below 1,000 meters undoubtedly had some gamma radiation. At the present time the ABCC is making a detailed analysis of all deaths occurring in Hiroshima since the atomic explosion. It is from this

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TABLE X  
COMPARISON OF PERCENTAGES OF INJURIES FOUND AT DIFFERENT TIMES BY VARIOUS INVESTIGATORS

Type of Injury	J. I.* [2] Aug. 6, 1945	J. I. [2] and J. C.† [1] Aug. 8, 1945	J. C. [1] Sept. 1945	Hatano [6] Nov. 1945	ABCC‡ Jan. 1955
	Time Elapsed				
		% Dead before 20 days	% Alive after 20 days	% Alive after 104 days	% Alive after 5 yr.
Radiation.....	100	95.1	81.2	24.7	79.2
Severe radiation symptoms.	...	58.5	75.2	...	69.0
Burns.....	90	57.2	25.1	16.0	24.4
Mechanical.....	...	57.2	61.8	71.8	88.7

\* Japanese Investigation Group.  
† Joint Commission.  
‡ Present report.

TABLE XI  
NUMBER OF DEATHS BY TYPE OF INJURY AND EXPOSURE DISTANCE

Injury	Distance (in meters) from Hypocenter				Total
	0-250	250-500	500-750	750-1000	
Burns.....	0	0	1 (33.3)	2 (66.7)	3
Radiation injury.....	1 (3.2)	2 (6.4)	2 (6.4)	26 (74)	31
Radiation injury and burns.....	0	0	1 (14.3)	6 (75.7)	7
Neither.....	0	1 (7.7)	3 (23.1)	9 (69.2)	13
Totals.....	1	3	7	43	54

analysis that the answer to the question posed previously will be found. One other attempt was made for a partial answer. The Metropolitan Life Insurance Company was asked about the death rates of survivors from the Texas City disaster, the Coconut Grove fire and severe automobile accidents. Their reply was that they had no information available and did not know of any group that might have such information. It would be of interest to know the effect of flash alone or with radiation injury on survival rates.

SUMMARY

Atomic bomb victims who were exposed under 1,000 meters and survived over five years were reinvestigated. There were 619 patients who comprised a total sample.

Mechanical, blast, burn and radiation in-

juries were evaluated as to onset, duration, severity, body area affected and type of healing. The modal patient experienced severe radiation and mild trauma.

Results were compared with similar earlier studies. The question emerges as to the possibility that patients exposed within 1,000 meters with radiation and/or thermal injuries have been dying at a faster rate than those with mechanical or no injuries.

A short history of the development of the Atomic Bomb Casualty Commission is included.

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