19 April 46

Subject: Transmittal of Report.

To: Colonel Stafford L. Warren, M.C.
Chief of Medical Section
Manhattan Engineer District
P.O. Box E
Oak Ridge, Tenn.

1. Enclosed herewith is the FINAL REPORT OF FINDINGS OF THE MANHATTAN DISTRICT ATOMIC BOMB INVESTIGATING GROUPS AT HIROSHIMA AND NAGASAKI.

2. A preliminary report of the findings was submitted in December 45.

3. This final report, prepared under the general direction of the undersigned, consists essentially of three sections. They were prepared under the immediate direction of the following personnel:

A. General introduction and medical study:

Part I. Prepared and written by Capt. H. L. Barnett, M.C. and reviewed by Lt. Col. H. L. Friedell, M.C. and G. V. LeRoy, M.D. The statistical analysis and interpretation was done by M. J. Wantman and D. Tiedeman. M. J. Wantman also assisted materially in the writing of Part I.

Part II. Prepared and written by Capt. J. Howland, M.C.

B. Radiation: Prepared and written by Capt. R. Tybout, C.E.

C. Physical Damage study:

Part I. (Hiroshima) Prepared and written by Major N. Varley, C.E.

Part II. (Nagasaki) Prepared and written by Major W. C. Youngs, C.E.

4. Translations of Japanese documents was done under the direction of Lt. I. V. Munch, M.I.

(Signed) Henry L. Barnett
Capt., M.C.

HLB:sb

FINAL REPORT OF FINDINGS OF THE

MANHATTAN DISTRICT ATOMIC BOMB INVESTIGATING GROUPS

AT

HIROSHIMA AND NAGASAKI

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INTRODUCTION

Following the atomic bombings of Hiroshima on 6 August 1945, and Nagasaki on 9 August 1945, a group of 21 Manhattan District officers and enlisted personnel were sent from the various continental installations to Tinian, Marianas. The group was to proceed to Japan for the general purpose of investigating the two Japanese cities as early as possible, if and when Japan surrendered.

The general purpose of the mission was twofold. The more comprehensive aspect was to observe the total effects of the atomic bombs on the cities and the people exposed. The specific objective was to investigate any unique effects due to radiation. An investigation of the latter was, at the time of the surrender, particularly important for two reasons: The Japanese were reporting the appearance of "uncanny delayed effects" in persons exposed to the bombs, which seemed unquestionably to be due to radiation; in addition, they were stating that people going into the cities after the bombings were developing similar symptoms. From the standpoint of protecting the health and morale of occupation troops, as well as from other considerations, it became imperative to determine the validity of these reports as early as possible. This was the primary purpose of the entire mission.

The group doing the investigation consisted essentially of medical personnel and civil and electronic engineers. One-half of the group was in Nagasaki from 20 September to 6 October, and the remaining half in Hiroshima from 3 to 7 October.

The medical study is presented herewith. The study concerning radioactivity (Tybout) is presented in Section B of this report. The investigations of physical damage to Hiroshima (Varley) and to Nagasaki (Youngs) constitute Section C.

SUMMARY

The best estimates available at the present time of the number of casualties due to the atomic bombings of Hiroshima and Nagasaki are:

	Hiroshima	Nagasaki
Population	320,000	260,000
Dead	78,000	35,000
Injured	37,000	30,000
Total Casualties	115,000	65,000

These casualties were primarily due to burns and mechanical injuries. In addition, there were patients who showed a group of unusual symptoms and findings which were concluded to be due to radiation. Some of these patients, otherwise uninjured, died. The mortality among 249 patients showing these effects was found to be about 16%. Most of these deaths occurred during the fourth week after the bombings.

Estimates based on the study of a selected group of 900 patients indicated that total casualties occurred as far out as 4250 meters at Nagasaki and 3750 meters at Hiroshima. Burns extended considerably farther than the other two and physical injuries somewhat farther than the radiation effects. The average radius of partial physical damage at Hiroshima was 3900 meters.

From medical findings, the evidence is that persons not exposed to the bombs were not injured by radioactivity persisting in the areas.

Integrated radiation dosages were calculated from gamma ray intensities measured about six weeks after the bombings. These indicate

that the highest total dosage that would have been received at Hiroshima was between 6 and 25 roentgens of gamma ray radiation, and the highest in the Nagasaki area between 30 and 110. It was also determined that this persistent radioactivity originated almost entirely from deposited fission products rather than from elements made radioactive by the neutrons.

The gamma ray intensities at the time of the explosion were calculated from measurements using X-ray films found in Hiroshima. These indicate intensities of 12 roentgens at 2300 meters, as compared with a theoretically predicted maximum of 3 roentgens. Both of these figures are considerably below what would have been expected from the medical findings.

The bombings affected over-all areas of 18.7 square miles (including 3.0 square miles of river) at Hiroshima, and 42.9 square miles (including 8.5 square miles of water) at Nagasaki. Only about 9.8 square miles of the latter was built up, however, the remainder being sparsely settled. The areas most severely damaged in both cities had an average radius of about one mile. Within this area all buildings not of substantial construction, particularly wooden frame and masonry buildings, were completely destroyed by the blast. In other more substantial buildings, such as those with heavy reinforced concrete frames, the buildings did not collapse, but damage to building interiors and casualties were nevertheless severe from both blast and fires. Approximately 39 per cent of 50,000 buildings in Nagasaki were destroyed or seriously damaged.

SECTION A

Medical Study

Part I. Clinical and Laboratory

Part II. Pathology

Appendix

Section A. Medical Study

Part I. Clinical and Laboratory

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FORWARD

It was not intended that the medical section make any detailed study beyond (1) establishing the presence or absence of effects due to radiation; and, (2) if such effects were observed, determining whether they were due entirely to radiation released at the time of the explosions, or in part to persistent radioactivity. In the course of the investigation, however, certain impressions were gained of the more comprehensive effects of the bombs in producing casualties.

It was obvious that any detailed investigation of the casualty-producing effects of atomic bombs as used against Japan would require at least several months study. The investigation initiated by the Manhattan District group was therefore continued by a joint medical atomic bomb investigating group, composed of medical personnel derived from three additional, independent units. The chief of these was an Army group organized under Colonel Ashley Oughterson, M.C., AUS, for The Surgeon General. A second was a Navy group under Commander Shields Warren (now Captain), (MC)(S), USNR, for the U. S. Naval Technical Mission to Japan. The last was a group of Japanese investigators under Dr. Masao Tsuzuki, for the Japanese government.

Organization of the Joint Commission was completed and the detailed work begun by the time the Manhattan District group left Japan in October, 1945. The material collected by the Joint Commission was brought to Washington, D. C., during early January, 1946, and analysis of it was begun. The Manhattan District group is actively engaged in this study at the present time. However, for the most part only data brought back

in October was used in the report submitted here. A preliminary report of the initial investigation (Appendix I - Report I) was submitted in December, 1945; this is the final report. Although the study of the Joint Commission will be far more complete from the medical standpoint, nevertheless, this report answers the specific questions concerning radiation and persistent radioactivity for which the mission was sent.

CHAPTER I

Personnel and Procedure

1. Investigating group
2. General sample of patients studied
3. Method of collection of data
4. Reliability
5. Data studied

Chapter I. Personnel and Procedure

1. Investigating Group

In Nagasaki the material studied was collected by four AUS Medical Corps officers working with four young, recently graduated Japanese doctors and one Japanese school teacher who acted only as an interpreter. In Hiroshima, the collection of data was done similarly by four AUS Medical Corps officers with the help of Japanese physicians.

2. General Sample of Patients Studied

The patients studied in this group were mainly hospital patients. This group is therefore a selected one, in that the more seriously injured would be more likely to be admitted to hospitals. In Nagasaki an attempt was made to include all of the hospital patients who had been injured by the bomb, whereas in Hiroshima an attempt was made to restrict the selection to patients who were thought to show effects of radiation injury. The few non-hospital patients seen in Nagasaki were usually ambulatory and were interviewed and examined, if possible, whenever they were encountered and the circumstances permitted.

3. Method of Collection of Data

Information about specific patients was obtained by one or a combination of methods. The records of patients who had been in the hospitals, but who were not there at the time of the investigation, either because they had died or had been discharged, were translated and copied. Histories were taken and physical examinations done on

patients in the hospitals at the time of the investigation. Earlier laboratory work was copied from the patients' records and laboratory files in both types of patients; laboratory studies were done on the latter group. Usually the AUS Medical Corps officer and the Japanese physician worked together in obtaining the histories and doing the examinations. Data on a few of the patients, particularly the earlier cases, were obtained by interview with the Japanese physicians who had taken care of the patients.

4. Reliability

In judging the reliability of the data obtained in this study, several factors must be kept prominently in mind. In the first place, it is apparent that all of the information on the effects of the bombs on people of the two cities during the first 50 to 60 days is based entirely on the observations of the Japanese. Although conclusions from these observations can be drawn from retabulating and reanalyzing the cases, the observations during this important period are not first hand. Some general opinions of the reliability of the Japanese observations were formed during the period of the investigation. This judgment can be applied to evaluating the reliability of the earlier observations. There was wide variation in the accuracy of the observations of the various groups of Japanese physicians. By general comparison with American medical methods, it was felt that more attention is given by Japanese physicians to the history than to the physical examination. Fortunately, however, the important findings from physical examinations, e.g., epilation, purpura, ulcerative stomatitis, etc., are obvious manifestations and undoubtedly were recorded correctly by the Japanese.

The comment above on the Japanese methods refers more to the physical diagnosis of such internal diseases as heart disease, evaluation of systemic diseases, etc., which are of little consequence in this study. Furthermore, it was felt that there was a tendency even among the best groups of Japanese investigators to draw definite conclusions from meager data.

Other specific factors influence the reliability of the data. Prominent among these was the overwhelming load on the hospitals which followed the bombings, due to the tremendous number of casualties and damage to hospital buildings and personnel. This was sufficiently great during the first few days almost to preclude anything but emergency treatment of patients. (See Appendix II - Report I for first-hand description of arrival of Nagasaki patients at Omura Naval Hospital.) Although this overloading undoubtedly contributed to the difficulty in making and recording complete examinations, it should be emphasized that records were kept remarkably well under the circumstances.

The completeness of this investigation was limited by the short period of time allowed (16 days in Nagasaki and 6 days in Hiroshima). It is felt that more reliance can be placed on the material collected by the joint efforts of American and Japanese physicians after our arrival, than on the material based entirely on earlier Japanese observations. The distribution of the Nagasaki cases in this respect is shown in Table I. Distinction between sources was not recorded for the Hiroshima cases at the time the data were collected.

TABLE I(1)

Source of Information by Hospital for Patients Studied
(Nagasaki)

Hospital	Japanese Source Only	Japanese & American Source
Shinkozen	15	54
Ishahya	13	39
Omura	204	134
Hospital Unrecorded	1	8
TOTAL	233	235

A final word on the reliability of the data should be said with respect to the attitude of the Japanese physicians. It was felt that at no time during the period of the study did any intentional dishonesty or attempts to impede the investigation in any way occur. On the contrary, the study received the greatest cooperation from the Japanese physicians, without which it would have been very much more difficult, if not impossible.

The groups studied in this report represent a highly selected group of patients, and the findings represent those reported during the first 50 days and observations made during the following two weeks. Therefore, they are not representative of effects on the total population, nor do they describe the effects over the entire period from the time the bombs were dropped.

(1): Tables not marked by asterisks show data on group studied. All other tables are marked by asterisks and the source of information is given.

5. Data Studied

In addition to the usual medical observations, special emphasis was placed on factors pertinent to the purposes of the investigation. This is related primarily to the distance of the subject from the explosion(1); the shielding of the subject by intervening objects, including clothing; and the occurrence and the time of onset of symptoms due to radiation. (See Chapter IV-4.)

The distance from GZ in Nagasaki was determined by use of a rectangular coordinate map on which patients interviewed pointed out their approximate location at the time of the explosion. From this the distance and direction of the subject from GZ was determined. For patients in Hiroshima, only the distance as stated by the patient was recorded.

Whether the patients were indoors, outdoors, or near intervening objects, and how they were clothed was asked of patients seen. This information was not available for a large enough proportion of the patients studied to permit analysis.

Effects which could be due to ionizing radiation were particularly investigated. As soon as the nature of the bombs became known to the Japanese, and cases with epilation were observed, special attention was given to the presence or absence of this finding. The same is true for

---

(1): The points on the ground which were determined to be directly under the points of detonation in each city (See Section C) will be referred to in the Joint Report, as they are in the British Report, as GZ, meaning "Ground Zero". This is distinguished from AZ, meaning "Air Zero". For the sake of brevity and consistency, these designations will be used henceforth in this report.

petechiae and for oropharyngeal lesions. The latter were described by a large variety of terms, which, in the analysis could not be differentiated. Laboratory examinations of particular interest were the white and red blood cell counts, differentials, and platelet counts.

CHAPTER II

Description of Group Studied

1. Total group
2. Distribution by city and sex
3. Distribution by hospital
4. Distribution by age

Chapter II. Description of Group Studied

1. Total Group

Data were obtained and recorded by the methods described on approximately 1600 cases at Nagasaki and 500 cases at Hiroshima. When these records were reviewed prior to analysis, it became evident that certain of them had to be immediately rejected solely on the basis of insufficient information. This applied for the most part to Nagasaki cases. As has been described, the procedure at Nagasaki was to collect data on all of the patients who were, or had been, in the hospitals, irrespective of how little information was available on the discharged patients. At Hiroshima, on the other hand, patients for whom more complete data were available and who were thought to show some evidence of radiation injury were selected. This initial rejection of patients was done on the following basis: Cases in which neither the distance from GZ nor the outcome beyond two weeks after the bomb were known, were discarded. The remaining patients were included in the study.

The group studied comprised a total of 900 patients. Of these, 432 were from Hiroshima and 468 from Nagasaki. The known differences in the types and efficiencies of the two bombs, as well as differences in the construction and the land contours in the two cities, suggested that the two groups should not be considered homogeneous. The patients from the two cities were therefore considered separately.

2. Distribution by City and Sex

Of the 432 patients at Hiroshima, 149 were females and 274 males. No sex was recorded for the remaining 9 patients. Of the 468 patients studied at Nagasaki, 319 were females and 298 were males. The city and sex distribution is shown in Table II.

TABLE II

Patients Studied as Grouped by City and Sex

Sex	Hiroshima	Nagasaki	Total
Female	149	170	319
Male	274	298	572
Unrecorded	9	-	9
TOTAL	432	468	900

3. Distribution by Hospital

The hospitals in the two cities in which the greatest number of patients were studied were the Ujina, Red Cross and Teshin hospitals in Hiroshima, and the Omura, Shinkozen, and Ishahya hospitals in Nagasaki. The distribution and survival figures for patients studied in these hospitals is shown in Table III. At first a study of cases by hospital groups was considered. However, from Table III it may be observed that the groups become relatively small in number when broken down by hospital. Because of these small numbers, and because of the relatively small differences in survival results, the patients from the three hospitals in each city were treated as a single group.

TABLE III

Distribution of Outcome by Hospital
for Patients Studied

	Total No.	Deceased %	Survived %
Hiroshima Hospitals			
Ujina	205	9.8%	90.2%
Teshin	89	14.6	85.4
Red Cross	135	12.6	87.4
TOTAL	429	11.7	88.3
Nagasaki Hospitals			
Shinkozen	69	21.7%	78.3%
Ishahya	52	25.0	75.0
Omura	289	48.4	51.6
Hospital Unrecorded	9	11.1	88.9
TOTAL	419	40.3	59.7

(Outcome is unknown for 3 Hiroshima and 49 Nagasaki patients.)

4. Distribution by Age

Table IV gives the distribution of age by sex for both Hiroshima and Nagasaki patients. The Hiroshima females ranged in age from 10 to 69 years; the males from 1 to 89 years. Both male and female Nagasaki patients ranged in age from 1 to 69 years.

TABLE IV

Distribution of Age by City and Sex
for Patients Studied

Age in Years	Females	Males	Total
Hiroshima Hospitals			
80-89	0	1	1
70-79	0	1	1
60-69	7	7	14
50-59	19	18	37
40-49	29	36	65
30-39	28	56	84
20-29	34	115	149
10-19	30	31	61
0-9	0	4	4
Age Unrecorded	2	5	7
TOTAL	149	273	422
Nagasaki Hospitals			
80-89	0	0	0
70-79	0	0	0
60-69	4	10	14
50-59	11	13	24
40-49	14	26	40
30-39	14	62	76
20-29	42	67	109
10-19	78	110	188
0-9	6	7	13
Age Unrecorded	1	3	4
TOTAL	170	298	468

(Both age and sex were unrecorded for 9 persons in Hiroshima.)

In the study of the medical findings, one of the factors which was controlled was age. At no point, however, did age seem to be pertinent.

In addition to these, it was planned when the analysis was begun to analyze the findings by military or civilian status and by direction

from GZ. Division of the groups by the former was not done because of insufficient information. Direction from GZ was known only for Nagasaki patients. In this group even though there were some suggestive trends, very little consideration could be given to them because of the many unknown factors involved.

CHAPTER III

Description of Findings

1. Casualty estimates

   A. Total casualties
      (1) Relation to distance
      (2) Cause
   B. Casualties among patients surviving immediately after the explosion
      (1) Relation to distance
      (2) Relation to time
      (3) Cause

2. Burns

   A. Description
   B. Incidence and relation to mortality
   C. Relation to distance
   D. Summary

3. Mechanical Injuries

   A. Description
   B. Incidence
   C. Relation to mortality
   D. Relation to distance
   E. Summary

4. Radiation Injury

   A. Description of symptoms
   B. Incidence of symptoms and inter-relationship
   C. Relation to time of onset
   D. Relation to distance
   E. Relation to outcome
   F. Laboratory findings
   G. Miscellaneous effects
   H. Description of types
   I. Summary

1. Casualty Estimates

Many eye-witness accounts of the bombings of Hiroshima and Nagasaki have been written. (See Appendix II, Reports I and III.) The extensive destruction of civic installations (hospitals, fire and police departments, government agencies) and the state of utter confusion immediately following the explosions, as described in these reports, attest to the inherent difficulties in making estimates of casualties. In addition, the Japanese do not have registration laws and the peripdic censuses are not complete. Finally, the great fires that raged in each city totally consumed many bodies.

A. Total Casualties

The number of total casualties have been estimated at various times since the bombings with wide discrepancies. At the time of the departure of the Manhattan District group, the first week in October, the most generally accepted figures were those given in Table V below.

TABLE V*

Estimates of Casualties(1)

	Hiroshima	Nagasaki
Pre-raid population	320,000	260,000
Dead	66,000	23,359
Missing	10,000	1,927
TOTAL DEAD OR MISSING	76,000	25,286
Injured	58,000	40,993
TOTAL CASUALTIES	134,000	66,279

*Hiroshima Source: Official Japanese News Report.
Nagasaki Source: Nagasaki Prefecture.

(1): An extensive study of casualties conducted by the Joint Commission is being completed and will be presented in the Joint Report. In general it will indicate that the dead in Hiroshima were greater by perhaps 20% than the 66,000 reported. Additional incompletely analyzed data indicates that in Nagasaki the number dead should be as much as 50% greater than the 23,359 reported on 1 September.

(1). Relation to distance

The relation of total casualties to distance from GZ is of primary importance in evaluating the casualty-producing effects of the bombs. Estimates of this relationship for the total population of Nagasaki are shown in Table VI.

TABLE VI*

Relation of Total Casualties to Distance from GZ(1)

Distance from GZ (Meters)	Number Killed	Number Injured	Number Missing	Total Casualties	Calculated No. Killed per Unit (0-500 M.) Area
0 - 500	7,505	960	1,127	9,592	7,505
500 - 1000	3,688	1,478	1,799	6,965	1,229
1000 - 1500	8,678	17,137	3,597	29,412	1,736
1500 - 2000	221	11,958	28	12,207	32
2000 - 3000	112	9,460	17	9,589	6
TOTAL	20,204	40,993	6,568	67,765	

* Source: Nagasaki Municipality (20 August 1945).

(1): No figures for total pre-raid population at these different distances were available. These would be necessary to compute percent mortality. A calculation given in the British Report(2) and based on a preliminary analysis of the forementioned study of the Joint Commission (p. 17), gives the following calculated values for percent mortality at increasing distances from GZ:

Distance from GZ (Feet)	Percent Mortality
0 - 1000	93.0%
1000 - 2000	92.0
2000 - 3000	86.0
3000 - 4000	69.0
4000 - 5000	49.0
5000 - 6000	31.5
6000 - 7000	12.5
7000 - 8000	1.3
8000 - 9000	0.5
9000 -10000	0.

(2): Report of the British Mission to Japan on an investigation of the effects of the atomic bombs dropped at Hiroshima and Nagasaki.

 ~~SECRET~~ UNCLASSIFIED

(2) Cause

It seems highly probable from the various reports that the greatest total number of deaths were those occurring immediately after the bombings. The cause of these can only be surmised, and, as so aptly stated in the British Report, those near the center were probably "killed as it were several times over, by each casualty-producing agent separately". It is the general impression that the proper order of importance for possible causes of death in this group is: Burns, mechanical injury, and blast. Early estimates by the Japanese are shown in Table VII.

TABLE VII*

Cause of Immediate Deaths

City	Cause of Injury	Number of Cases	Percent
Hiroshima	Burns	-	60.%
	Falling Debris	-	30.
	Other	-	10.
Nagasaki	Burns	101	95.%
	Falling Debris	10	9.
	Flying glass (cuts)	8	7.
	Other	8	7.

* Source: Report of Japanese Army Medical Committee

B. Casualties among Patients Surviving Immediately after the Explosions

More information is available concerning the number and distribution of casualties surviving immediately after the explosions. Table VIII shows total figures from various hospitals.

TABLE VIII*

Number and Distribution of Casualties

Place Treated	No. of Patients Treated	Known Dead		Known Alive		Outcome Unknown (discharged)	
		N.	%	N.	%	N.	%
Nagasaki							
Omura Naval Hosp.	758	155	20.4%	158	20.8%	445	58.7%
Ishahya Navt.l Hosp.	689	239	34.7	74	10.7	376	54.6
Hiroshima							
Ono Hospital	1,231	484	39.3%	151	12.3%	596	48.4%

* Source: Interviews with hospital officials.

The percent dead in Table VIII are minimum figures for patients surviving immediately after the explosions, who sought medical care. They refer to total casualties without regard to distance from GZ.

(1). Relation to Distance

Table IX presents mortality results in relation to distance from GZ for the small select sample studied by us.

TABLE IX

Relation of Distance from GZ to Percent Mortality in Patients Studied

Distance from GZ (KM.)	Hiroshima			Nagasaki		
	Total N.	Deceased N.	%	Total N.	Deceased N.	%
0.25 - 0.74	18	2	11.%	12	3	25.%
0.75 - 1.24	148	26	18.	98	19	19.
1.25 - 1.74	102	10	10.	90	14	16.
1.75 - 2.24	82	1	1.	30	13	43.
2.25 - 2.74	14	-	-	14	-	-
2.75 - 3.24	4	-	-	12	1	1.
3.25 - 3.74	-	-	-	7	-	-
3.75 - 4.24	3	-	-	5	-	-
TOTAL	371	39	10.5%	268	50	18.7%

(2). Relation to Time

The time of occurrence of deaths of patients who survived immediately after the explosions is shown in Figure 1. It can be seen that there is a marked preponderance of deaths during the fourth week at Hiroshima. At Nagasaki, on the other hand, by far the greatest number of deaths in any single week occurred during the first week. This figure shows the difference in the method of sampling in the two cities probably better than any other analysis presented. The most plausible explanation for the difference is that, as previously described, an attempt was made at Hiroshima to select patients showing signs of radiation injury, whereas all hospitalized Nagasaki patients were included(1). From this, it can be inferred that the greatest number of deaths in patients showing recognizable effects of radiation occurred during the fourth week. For the total hospital population, on the other hand, the greatest number of deaths occurred during the first week.

(3). Cause

The main causes of death among patients surviving immediately after the explosions are burns, mechanical injuries, and radiation. The greatest percentage of deaths among hospital patients was during the first week, as shown in Figure 1. Many of these were known to be due to burns, and fewer to mechanical injuries. The recognizable

(1): This explanation for the difference in time of death among patients who survived immediately after the explosion, is far more likely than any based upon actual differences between the two cities.

RELATION OF DEATHS AMONG PATIENTS SURVIVING
THE IMMEDIATE EXPLOSION TO TIME OF DEATH.

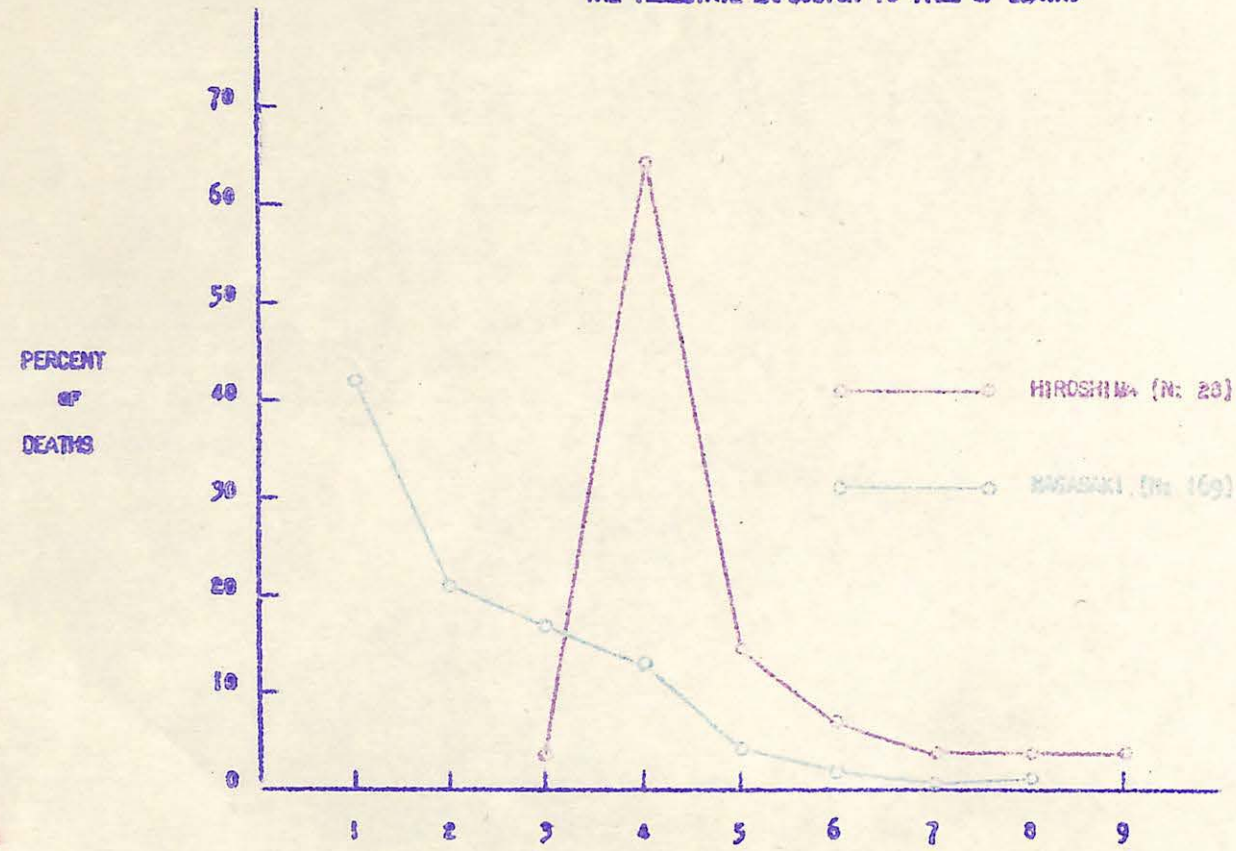

FIGURE 1

effects due to radiation rarely occurred during the first week (see Chapter III-4), so that the proper order of importance would appear to be that given(1).

The proportion of total deaths (both immediate and later) due to the various causes cannot be determined from this study of selected patients.

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(1): Any estimate of what part radiation may have contributed to the immediate deaths or to deaths occurring before the recognizable effects appeared, are on the basis of speculation, and should be interpreted as such.

2. Burns

A. Description

Two types of burns were observed. These are generally differentiated as flame or fire burns and so-called flash burns. The early appearance of the former type as reported by the Japanese, and the later appearance as observed, was not unusual. The flash burns, on the other hand, presented several interesting features. Marked redness of the affected skin areas appeared almost immediately, according to the Japanese, with progressive changes in the skin taking place over a period of a few hours. When seen after 50 days, the most distinctive feature of these burns was their sharp limitation to exposed skin areas facing the center of the explosion. For instance, a patient who had been walking in a direction at right angles to a line drawn between him and the center of the explosion, and whose arms were swinging, might have burns only on the outside of the arm nearest the center, and the inside of the other arm. Plates I and II show examples of this type of burn.

For the most part, any type of shielding protected the skin against such burns, although burns through one, and very occasionally more layers of clothing did occur in patients near the center. In such cases, it was not unusual to find burns through black, but not through white clothing, in the same patient. Flash burns also tended to involve areas where the clothes were tightly drawn over the skin, such as the elbows and shoulders.

PLATES I-II.

FLASH BURNS

Japanese pictures of patients showing characteristic distribution of so-called flash burns during the early healing stage. Note the sharp borders of the burns and their limitation to exposed skin surfaces facing the center. This is particularly striking in Plate I.

(See Text: Chap.III-2)

PLATE I. FLASH BURNS
(SEE TEXT III-2)

PLATE II. FLASH BURNS
(SEE TEXT III-2)

The degree and extent of burns in the 900 cases studied were not revealing because of insufficient data. The incidence of the various degrees of flash burns in hospital patients, however, is of interest and some estimates are available from Japanese reports. Of 208 burned patients admitted to Omura Naval Hospital, Nagasaki, for instance, 29 were classified as 1st degree, 148 as 2nd degree and 31 as 3rd degree. (See Appendix II, Report II.) The appearance of the burns as observed during healing would tend to confirm the fact that the majority of the flash burns were 2nd degree, although it is felt that 3rd degree pure flash burns were unlikely or very infrequent.

The appearance of both types of burns when seen during the healing stage was characterized by several other features. Although undoubtedly almost all of the incompletely healed burns showed some signs of infection, their general appearance was unusually good, when considered in the light of the unbelievably poor circumstances under which they had to be treated. There were frequently, however, large amounts of keloid formation which would suggest general secondary infection. A further rather striking feature of the healing flash burns was the almost constant presence of some degree of skin pigmentation, occasionally with an adjacent area of depigmentation.

B. Incidence and Relation to Mortality

The comparative incidence of the two types of burns in the 900 cases studied could not be determined. The decision usually could not be made in patients whose findings were known only from records and

this constituted a large enough number that the differentiation was not significant. Estimates of this by the Japanese in patients reaching the hospitals vary considerably, but it was the general opinion that most of the burns were flash burns. (See Appendix II, Report I, which states that 197 of 208 burned patients admitted to Omura Naval Hospital, Nagasaki, had flash burns.)

Table X shows the incidence of burns in the group studied.

TABLE X(1)

Incidence of Burns in Patients Studied

City	Sex	Total Patients N.	Patients with Burns N.	%
H	F	140	27	19.%
H	M	269	110	41.
N	F	99	34	34.
N	M	136	84	62.

It can be seen from Table X that 19% of 140 females and 41% of 269 males at Hiroshima had burns. Corresponding figures for Nagasaki reveal 34% of 99 females and 62% of 136 males having burns. Since no selection of the type of hospital patients was made in the Nagasaki group, the latter figures are probably better estimates of the incidence of burns in all hospital patients.

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(1): In this and in several of the following Tables it will be noted that the number of patients considered varies and is less than the total number included in the study. The reason for this is that in the study of inter-correlations, only patients for whom there was definite information as to whether each of the symptoms studied was present or absent were included.

The Japanese report the incidence of burns in patients surviving more than a few hours after the explosions, and seeking medical attention, as high as 95%. (See Appendix II, Report I.) As mentioned, the Japanese also report that the majority of the burns were 2nd degree. It seems apparent, therefore, that a large proportion of the medical and hospital care required during the early period after the bombing was related to the care and treatment of burns.

The total mortality due to burns alone cannot be estimated with any degree of accuracy. As discussed above, it is believed that the majority of all of the deaths occurred immediately, and how many of these were due to burns is unknown. Estimates as high as 75% have been made by the Japanese, and most of the reports attribute over 50% of the deaths to burns.

The relationship between burns and death in the groups studied is shown in Table XI.

TABLE XI

Relation Between Burns and Death in Patients Studied

City	Sex	Survivors N.	Deceased N.	Survivors Showing Symptom %	Deceased Showing Symptom %	X^2	P
H	F	128	16	19.%	25.%	.07	.79
H	M	249	20	42.	30.	.68	.41
N	F	97	43	37.	79.	19.33	<.01
N	M	147	99	65.	92.	21.55	<.01

This shows that for Hiroshima females, 19% of 128 survivors and 25% of 16 deceased had burns. For Hiroshima males, 42% of 249 survivors and 30% of 20 deceased had burns. This does not indicate a significant(1) relation between burns and death in the Hiroshima patients, but it must be kept in mind that a selection of patients showing symptoms of radiation disease was attempted there, which excluded many patients with burns. At Nagasaki, on the other hand, 37% of 97 female survivors and 79% of 43 female deceased had burns and 65% of 147 male survivors as compared with 92% of 99 male deceased had burns. This indicates a highly significant relation between burns and death.

C. Relation to Distance

That a relation exists between the occurrence of burns and the distance from the center of the explosion is mentioned in most Japanese reports. They state that the closer to GZ, the greater the proportion of people burned. Although this would certainly appear at first glance to be reasonable, there are several factors which would tend to attenuate the relationship as observed in this study. It required much less shielding to protect against flash burns than against any other casualty-producing agent. Although unprotected persons very close to

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(1): The differences between the percents showing the symptoms for survivors and deceased were tested statistically. This was usually done by the chi square technique. The conventional levels for significance have been adopted:

$P > .05$	Not significant
$.01 < P < .05$	Significant
$P < .01$	Highly significant

GZ undoubtedly all received flash burns, a large number of such persons were in the groups killed outright, and would therefore not be included in studies of persons surviving immediately after the explosions. Finally, at greater distances, where the burns would be expected to be less severe, many people receiving such burns probably did not get to the hospitals. For the groups studied, the relationship between the presence of burns and the distance from GZ is shown in Table XII.

TABLE XII

Relation between Occufrence of Burns and Distance from GZ in Patients Studied

City	Sex	Total N.	Symptom Absent N.	Symptom Present N.	Symptom Absent M Distance (Km.)	Symptom Present M Distance (Km.)	Standard Deviation	Point Biserial Correlation
H	F	130	108	22	1.48	1.38	5.69	-.07
H	M	237	147	90	1.35	1.48	5.31	.12
N	F	111	66	45	1.32	1.49	6.61	.12
N	M	157	58	99	1.31	1.67	7.72	.22

This relationship has been expressed in the column headed Point Biserial Correlation(1). These correlation results are not in the expected direction. Thus, it is evident that the selection factor is operating.

(1): The point biserial correlations were computed by means of the Pearson product-moment correlation formula with one of the two variables dichotomized, viz, presence or absence of symptom. A negative result would indicate that the farther away from GZ the individual was located, the less likely he was to have the symptom. In order to be considered significant, correlations would have to be greater than -.20, when based on samples of less than 200 cases.

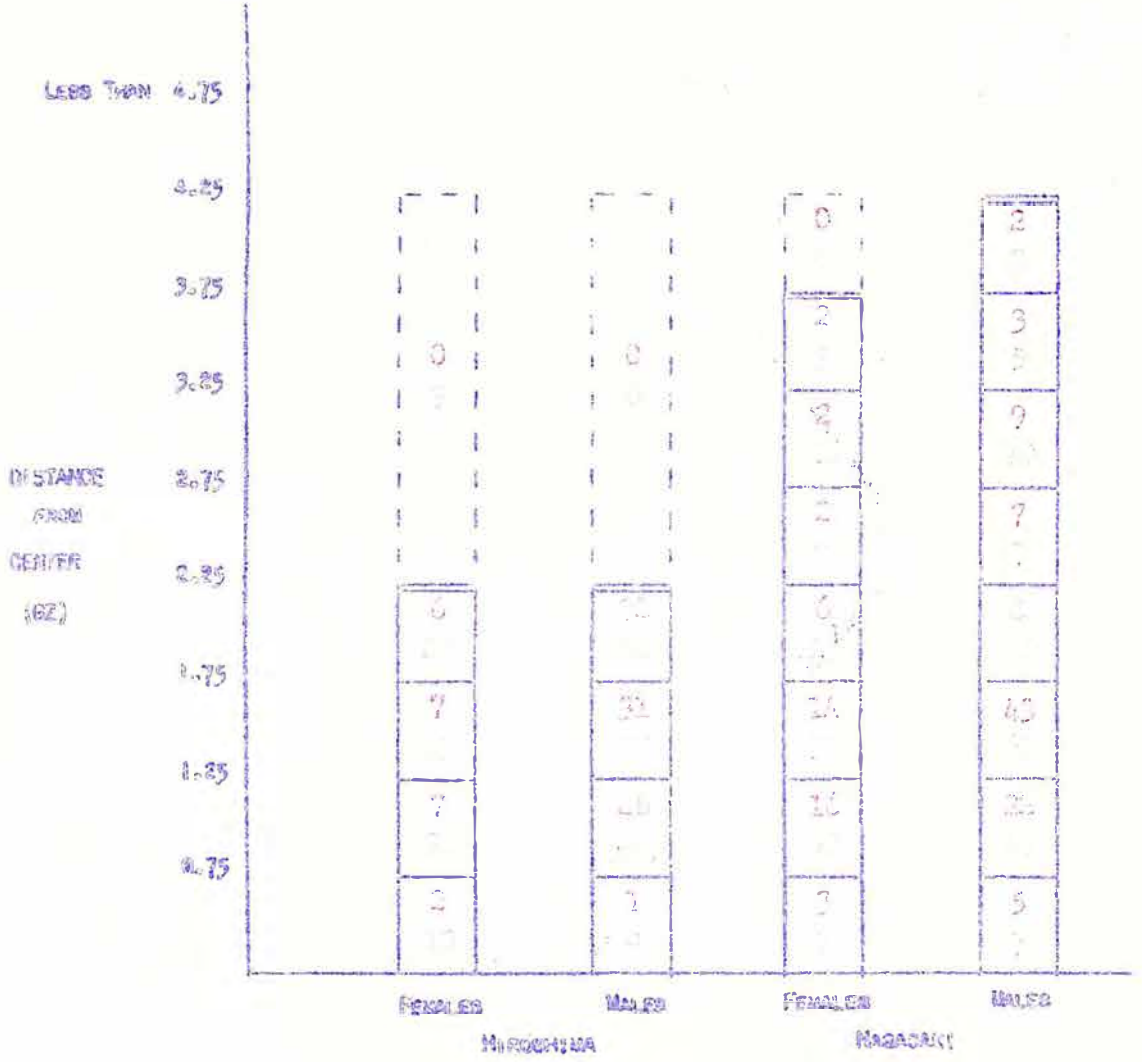
It is of paramount interest, however, to know the maximum distance from GZ at which burns were observed(1). The number of patients with burns and their distance from GZ is shown in Figure 2. This figure indicates that there is a marked difference between the two cities although this might be due in part to the difference in methods of selection of patients. It can be estimated that patients with burns at Hiroshima were all less than 2250 meters from the center at the time of the bombing. At Nagasaki, patients with burns were observed out to the remarkable distance of 4250 meters. Burning of physical objects was observed out to 2700 meters at Hiroshima, as described in Section C.

The types of physical agents causing the burns will be discussed in Chapter IV-1.

D. Summary

Two types of burns, fire or flame and so-called flash, were observed in patients injured by the atomic bombs. They were of all degrees of severity and probably accounted for the majority of the injuries and deaths. It is estimated from this study that they ex-

(1): The reliability of these observations is limited by the method of obtaining the information, as previously discussed. The findings reported here will be checked by those in the Joint Report in which the verbal accounts of the distances of patients from GZ was in many cases checked by going with the subject to the location specified.



NUMBER OF PATIENTS WITH BURNS AND TOTAL NUMBER OBSERVED AT VARIOUS DISTANCES FROM THE CENTER.

FIGURE 2

tended out to 2250 meters at Hiroshima and 4250 meters at Nagasaki. Protection appeared to be given from flash burns by almost any intervening object. A large proportion of the medical and hospital care required during the early periods after the bombings was related to the care and treatment of burns.

3. Mechanical Injuries

A. Description

The mechanical injuries included fractures, lacerations, contusions, abrasions, and other effects to be expected from crumbling walls, flying debris and glass, and other indirect blast effects. The appearance of these various types of mechanical injuries was not remarkable.

The direct blast effects deserve some mention. Many of the Japanese reports describe immediate effects such as ruptured abdomens with protruding intestines and protruding eyes. No estimate of the number of immediate deaths or early symptoms due to direct blast can be made. It is quite certain, however, that very few ruptured ear drums occurred, and it is the general feeling that the direct blast effects were not great.

B. Incidence

The incidence of mechanical injuries recorded in the group studied is shown in Table XIII.

TABLE XIII

Incidence of Mechanical Injuries in Groups Studied

	Females (Total N. - 140)		Males (Total N. - 269)	
	Patients with Injuries			
Hiroshima	N.	%	N.	%
Mechanical Injury(1)	42	30%	100	37%
Nagasaki	(Total N. - 99)		(Total N. - 136)	
Lacerations	58	58%	64	47%
Contusions	38	38.	44	32.
Fractures	6	6.	5	4.

(1): The different types of mechanical injuries could not be determined for the Hiroshima patients.

No estimates are available for the total incidence or proportions of different types of mechanical injuries for the total populations, or surviving groups.

C. Relation to Mortality

The relationship between mechanical injuries as represented by lacerations, and death in the groups studied is shown in Table XIV.

TABLE XIV

Relationship between Mechanical Injuries (Lacerations) and Death in Patients Studied

City	Sex	Survivors N.	Deceased N.	Survivors Showing Symptoms %	Deceased Showing Symptoms %	X^2	P
H	F	128	16	30.%	38.%	.12	.73
H	M	249	20	37.	35.	.00	.99
N	F	97	24	61.	62.	.01	.94
N	M	145	29	51.	83.	8.64	.01

It can be seen from Table XIV that no significant association between the presence of lacerations and death existed except in the case of the Nagasaki males. Even though this P value is at the highly significant level, the P values for the other groups are so high that one is forced to minimize the importance of this result. The rejection of patients having lacerations but not showing radiation symptoms in the Hiroshima group would influence this finding, as would the overall selection of all the groups. There are no Japanese estimates available on the relation of mechanical injuries to deaths of the total exposed populations or of the survivors.

D. Relation to Distance

The association between the occurrence of mechanical injuries as manifested by lacerations, and the distance from GZ is shown in Table XV.

TABLE XV

Association Between Occurrence of Mechanical Injuries and Distance from GZ in Patients Studied

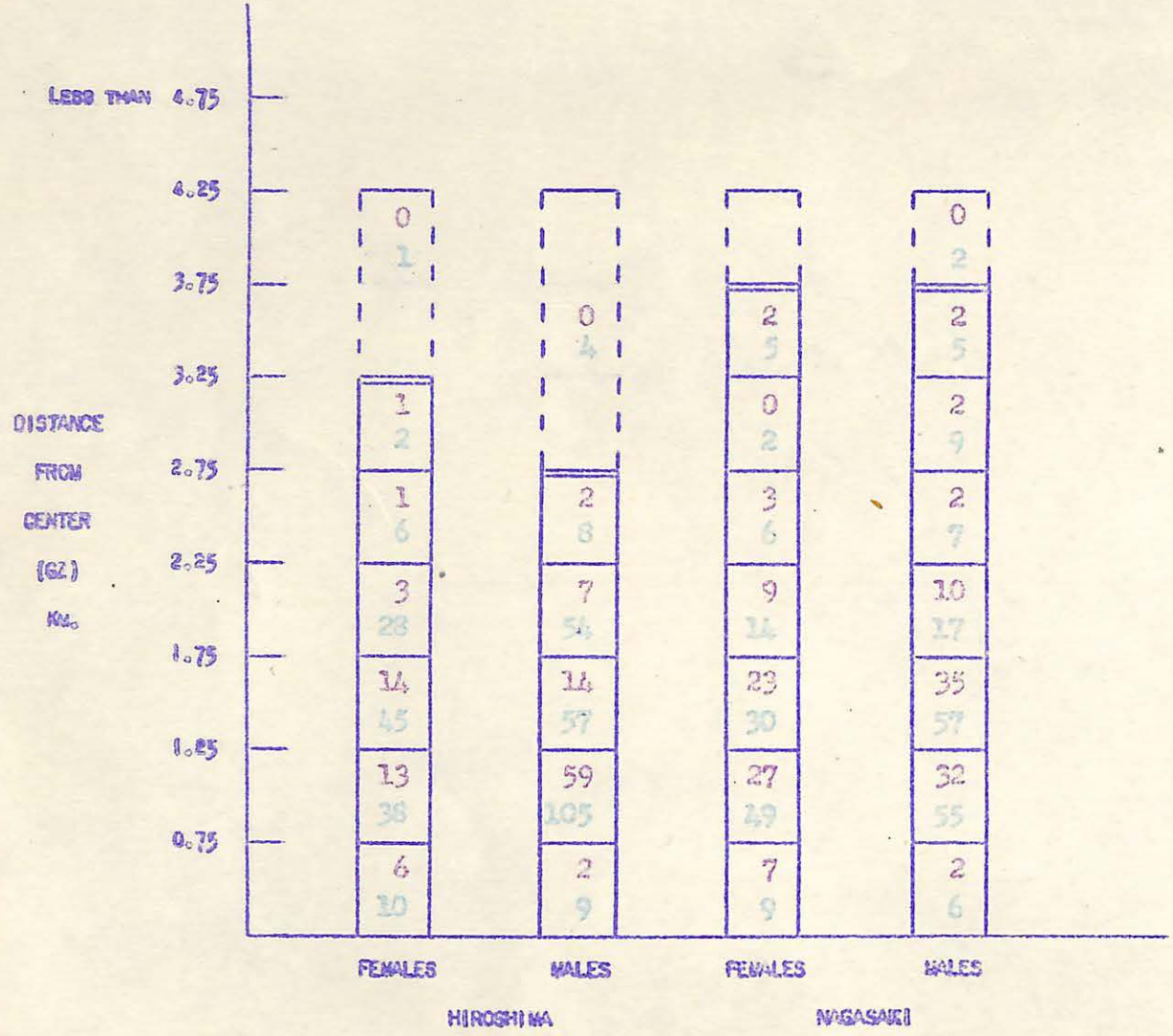
City	Sex	Total No.	Symptoms Absent No.	Symptoms Present No.	Symptoms Absent M Distance (Km.)	Symptoms Present M Distance (Km.)	Standard Deviation	Point Biserial Correlation
H	F	130	92	38	1.54	1.26	5.69	-.23
H	M	237	153	84	1.52	1.19	5.31	-.29
N	F	115	44	71	1.49	1.34	7.04	-.11
N	M	158	73	85	1.66	1.41	7.61	-.17

The fact that all four correlations are negative and that two of them can be considered significant indicates that even in this selected sample, the incidence of mechanical injuries varies inversely with distance.

Figure 3 shows the number of people with lacerations and their distance from GZ. Although not as marked as with burns, it can be seen that there is a difference between the two cities. It can be estimated that patients with lacerations at Hiroshima were less than 3250 meters from GZ, whereas at Nagasaki they were out to 3750 meters.

E. Summary

Without doubt, mechanical injuries accounted for a large number of immediate deaths, as well as deaths among the people surviving immediately



NUMBER OF PATIENTS WITH LACERATIONS AND TOTAL NUMBER OBSERVED AT VARIOUS DISTANCES FROM CENTER.

NUMBER WITH LACERATIONS
TOTAL NUMBER AT DISTANCE

FIGURE 3

after the explosions. No estimates of the number of these are available. The incidence varied inversely with distance. Lacerations extended out further at Nagasaki than at Hiroshima, although the difference between the two cities and the total distances were less than for burns.

4. Radiation Injuries

A. Description of Symptoms

Although fewer in number than the casualties due to burns and mechanical injuries, the symptoms of greatest general medical interest, and of particular interest to the members of this investigating group, were those due to ionizing radiation(1).

According to the Japanese observations, the early symptoms in this group of patients closely resembled the symptoms observed in patients receiving intensive roentgen therapy, as well as those observed in experimental animals receiving large doses of X-rays. The important symptoms and findings reported by the Japanese and observed by us were epilation, purpura and other hemorrhagic manifestations, oropharyngeal lesions, vomiting, diarrhea and fever. Associated with these symptoms, certain important laboratory examinations were reported by the Japanese and examples of these were also observed.

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(1): The proper designation of this type of injury is somewhat difficult. Probably the two most direct designations are radiation injury and gamma ray injury. The former is not entirely suitable in that it does not define the type of radiation as ionizing and allows possible confusion with other types of radiation (e.g., infra-red). The objection to the latter is that it limits the ionizing radiation to gamma rays, which were undoubtedly the most important; but the possible contribution of neutrons and even beta rays to the biological effects cannot be entirely ignored. Radiation injury has the advantage of custom, since it is generally understood in medicine to refer to X-ray effects as distinguished from the effects of actinic radiation. Accordingly, radiation injury will be used in this report to mean injury due only to ionizing radiation. This designation will also be used in the Joint Report, although gamma ray injury is used in the British Report.

As might be expected, every gradation of severity was observed, depending primarily on shielding from the ionizing radiation either by air (distance from bomb) or by intervening objects. The description of these symptoms and findings and a study of the factors responsible for variations in severity is the main subject of this section of the study.

Epilation was one of the most spectacular and obvious findings. The appearance of the epilating patient was typical. (Plates III - VIII) The crown was involved more than the sides, and in many instances the resemblance to a monk's tonsure was striking. In extreme cases the hair was totally lost. In some cases regrowth of hair had begun by the time we saw the patients 50 days after the bombings. Curiously, epilation of hair other than that of the scalp, was extremely unusual.

Petechiae and other hemorrhagic manifestations were also striking findings. Bleeding began usually from the gums and in the more seriously affected was soon evident from every possible source. Petechiae and purpura appeared on the limbs and on pressure points. (Plates IX - XI.) Large ecchymoses developed about needle punctures and wounds partially healed broke down and bled freely. Retinal hemorrhages occurred in many of the patients. (See Appendix I, Report II.) The bleeding time and the coagulation time was prolonged. The platelets were characteristically reduced in numbers.

PLATES III-VIII

EPILATION

Patients at Hiroshima and Nagasaki showing varying degrees of epilation. Note that epilation is almost exclusively limited to the hair of the scalp.

(See Text: Chap.III-4A)

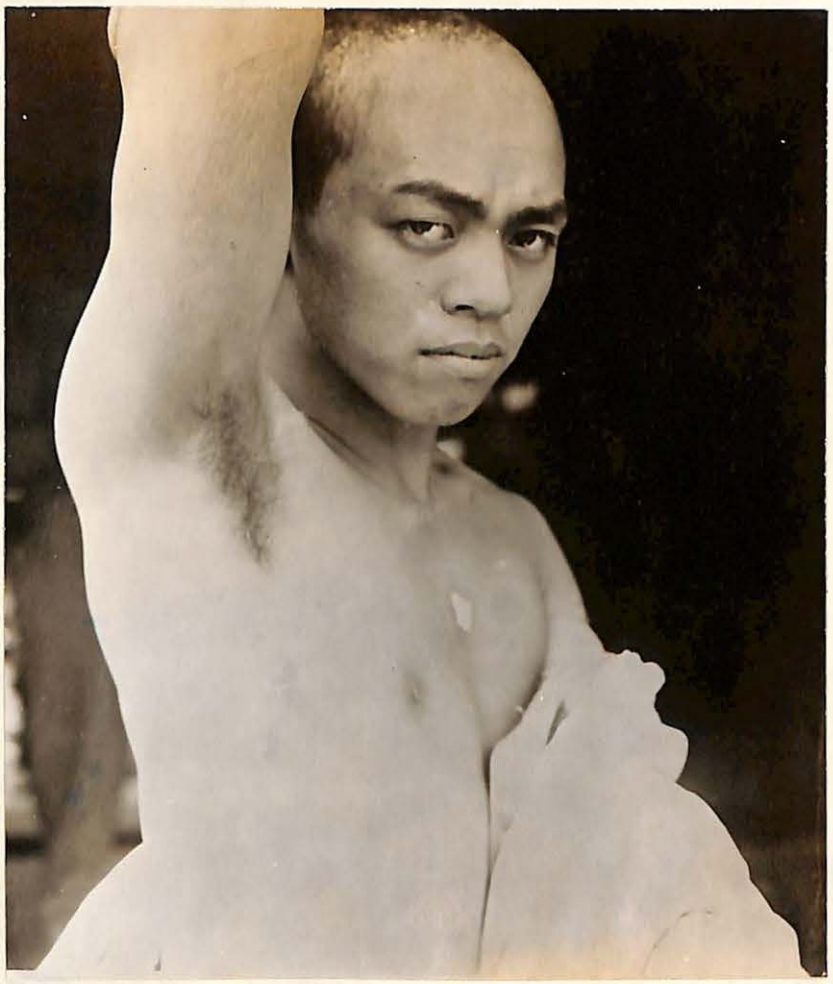


PLATE III. EPILATION
(SEE TEXT III-4A)

PLATE IV. EPILATION
(SEE TEXT III-4A)

PLATE V. EPILATION
(SEE TEXT III-4A)

PLATE VI. EPILATION
(SEE TEXT III-4A)

PLATE VII. EPILATION
(SEE TEXT III-4A)

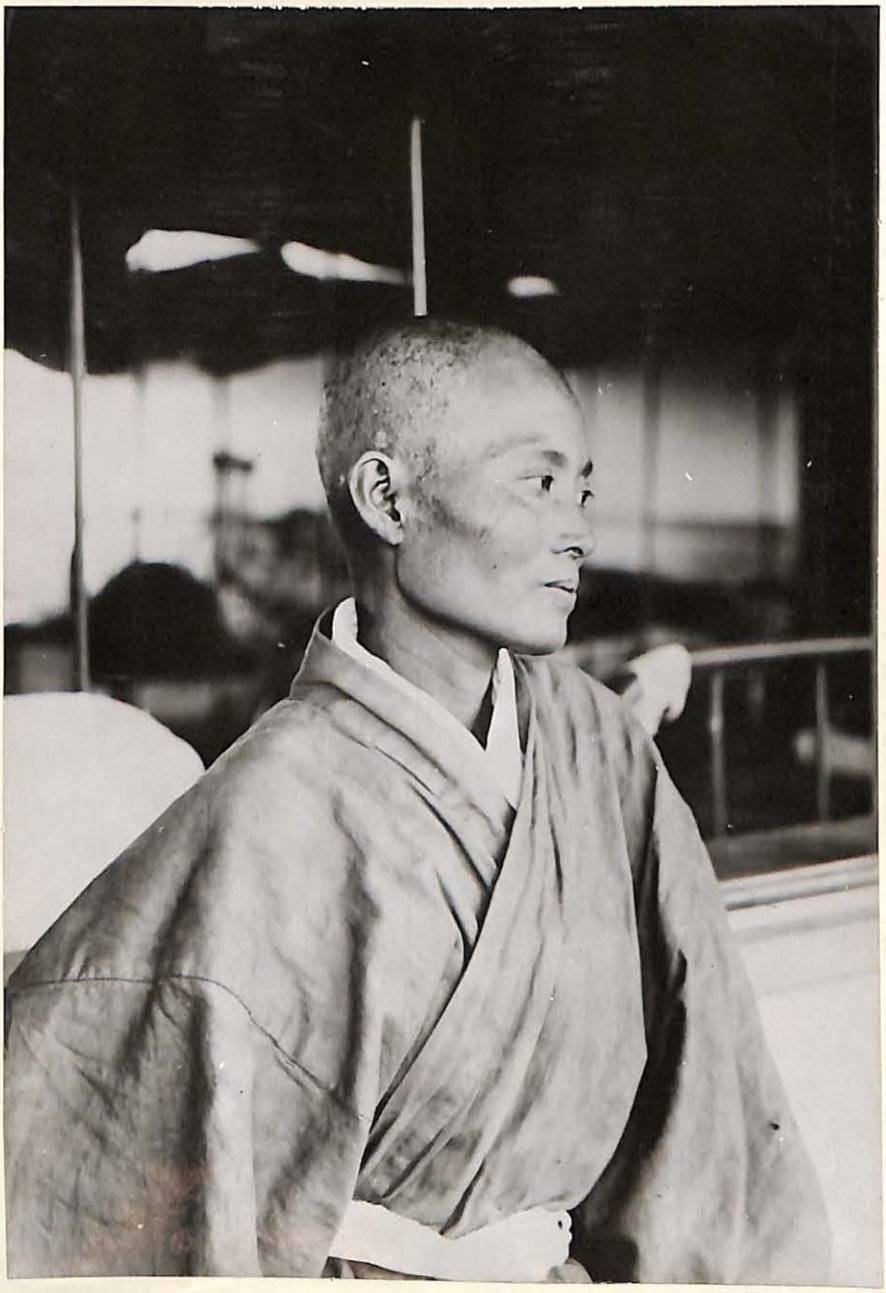


PLATE VIII. EPILATION
(SEE TEXT III-4A)

PLATES IX-XI

PETECHIAE

Three patients (one at autopsy) showing generalized petechiae.

(See Text: Chap.III-4A)

PLATE IX. PETECHIAE
(SEE TEXT III-4A)

PLATE X. PETECHIAE
(SEE TEXT III-4A)

PLATE XI. PETECHIAE
(SEE TEXT III-4A)

Nausea and vomiting appearing within a few hours after the explosions was reported rather frequently by the Japanese. This usually had subsided by the following morning, although occasionally it continued for two to three days. Vomiting was not infrequently reported and observed during the course of the later symptoms, although at these times it generally appeared to be related to other manifestations of systemic reaction associated with infection.

Diarrhea of varying degrees of severity was reported and observed. In the more severe cases, it was frequently bloody. For reasons which are not at all clear, the diarrhea in some instances was very persistent.

Lesions of the gums, the oral mucous membranes, and the throat were observed. The affected areas became deep red, then violacious in color; and in many instances ulceration and necrosis followed. These lesions differed in no way from the familiar lesions of agranulocytic angina. Blood counts done and recorded by the Japanese, as well as counts done by the Manhattan District group on such patients regularly showed a leucopenia. In extreme cases the white blood cell count was below 1,000. In association with the leucopenia and the oropharyngeal lesions, a variety of other infective processes were seen. Wounds and burns which were healing adequately suppurated and serious necrosis occurred. Decubitus ulcers became more severe and more extensive. At the same time, similar ulcerations were observed in the larynx, the bowel and in females, the genitalia. Fever usually accompanied these lesions.

Effects on the reproductive system were reported. These were manifested for the most part by amenorrhea and interruption of pregnancies. (See Chapter III-4G).

B. Incidence of Symptoms and Inter-relationship

The above were the prominent symptoms, findings and laboratory data reported to us by the Japanese, and, except for the initial nausea and vomiting, observed by the Manhattan District group. An attempt was made to determine the relation of these to one another, to the time of onset; to the distance from the center, and to outcome of patients, in order to describe the chronology of this type of injury and to evaluate the protective effect of shielding.

The percentage incidence of the symptoms observed and recorded in the groups of patients studied are listed in Table XVI.

TABLE XVI

Percentage Incidence of Selected Signs and Symptoms in 644 Patients Studied

	Hiroshima		Nagasaki	
	Percent Having Symptom		Percent Having Symptom	
	Females	Males	Females	Males
Nausea	51.%	34.%	17.%	4.%
Vomiting	-	-	8.	3.
Diarrhea	39.	39.	42.	49.
Bloody stools	-	-	10.	12.
Epilation	26.	36.	35.	18.
Petechiae	56.	55.	18.	13.
Fever	-	-	55.	56.
Oropharyngeal lesions	35.	25.	35.	27.
TOTAL N.	140	269	99	136

Inter-relationships between these symptoms were not significant in the selected group studied. It was not possible, therefore, to define symptom categories on the basis of this study.

C. Relation to Time of Onset

The week of onset, without regard to distance from GZ(1), of epilation in 57 patients, petechiae in 35, and pharyngitis in 57 is shown in Figure 4. These data refer to Nagasaki patients only. This information was not available for patients at Hiroshima. The onset of pharyngitis is assumed to follow in a general way the onset of leucopenia, although the relationship between the two cannot be considered to be as close as that between thrombocytopenia and petechiae. Figure 4 shows a definite peak for the time of onset of epilation during the second week, with a number of cases beginning, however, as early as the first and as late as the fifth week. The week of onset of petechiae and pharyngitis ranged from the first to the sixth week. With both of these symptoms a definite peak occurred during the fourth week.

---

(1): It would be of great value to be able to relate such factors as this to equivalent radiation dosage by considering the amount of shielding by air (distance) and other intervening materials. The small number of patients and lack of information does not allow this in this study. In this particular analysis of the time of onset of radiation symptoms, it is true also that any variation in time of onset of any one symptom dependent entirely on dosage would be negligibly small, compared with variation in time of onset of different symptoms. The latter is what these figures are intended to describe.

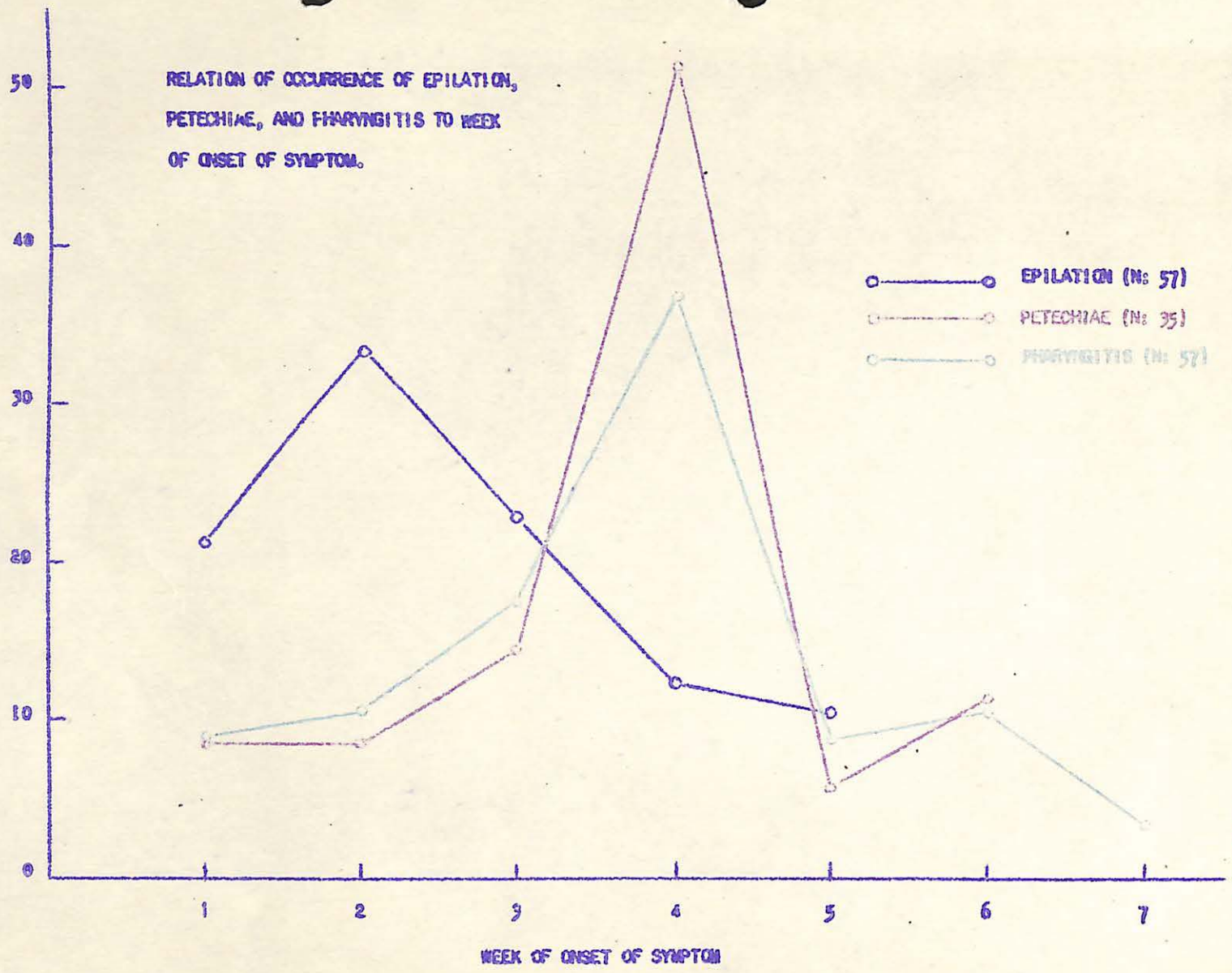


FIGURE 4

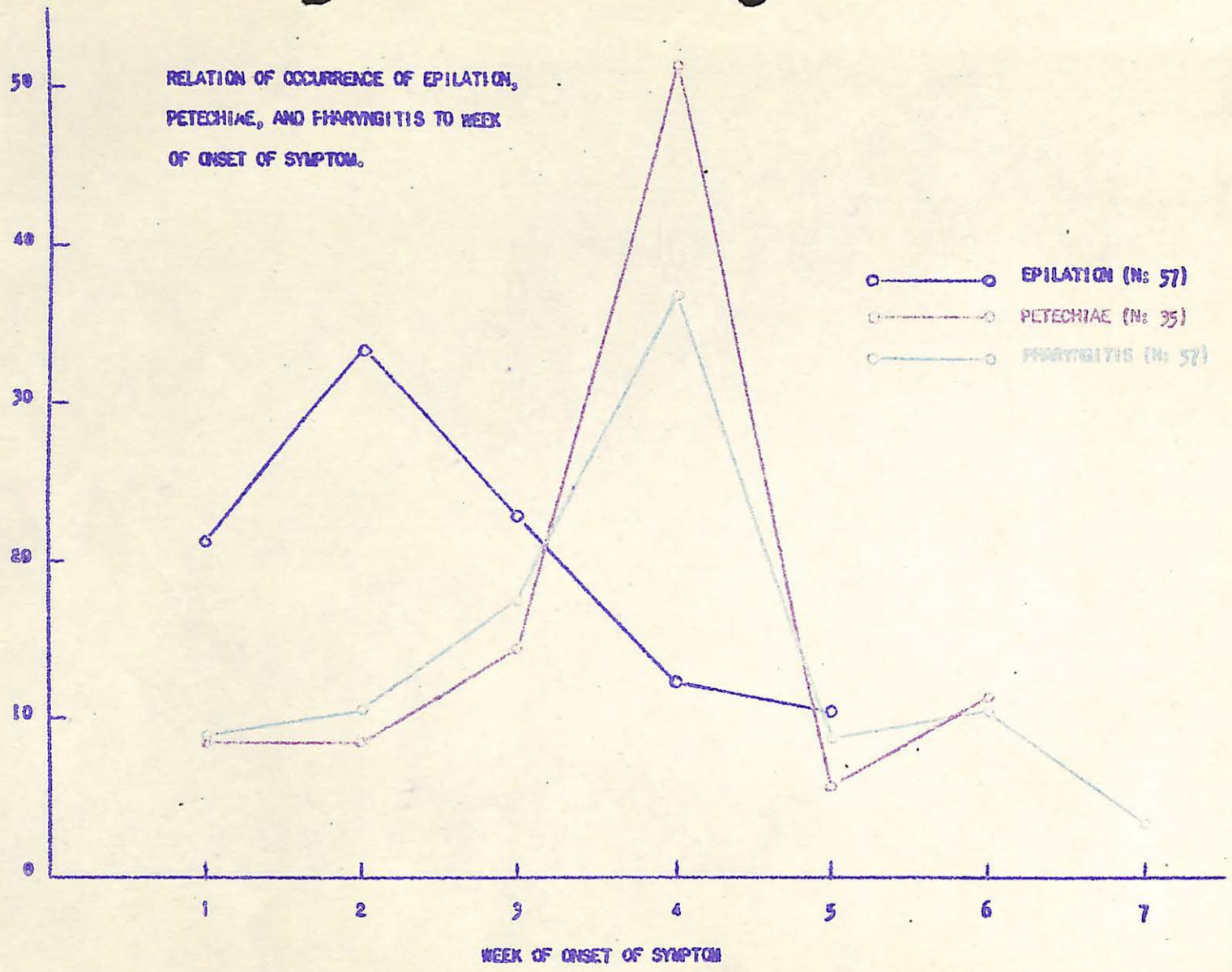


FIGURE 4

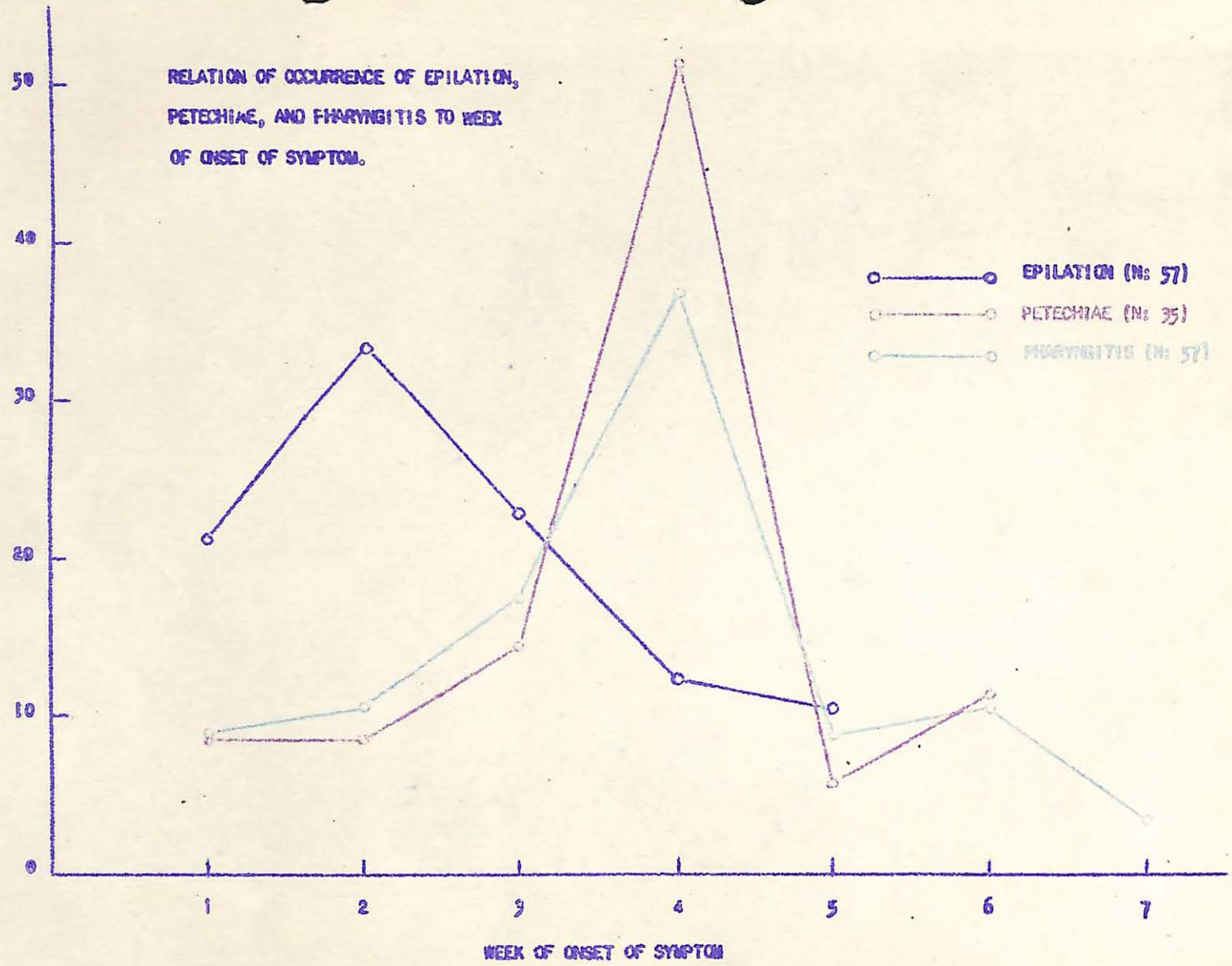


FIGURE 4

The time of onset of other symptoms which need to be considered with these selected symptoms for a chronological description of the disease state observed, is shown in Figure 5. From this it can be seen that a peak for the time of onset of diarrhea occurred in the first week. After an initial drop, there is a fairly well sustained curve with no definite trend throughout the six weeks. The curve for bloody diarrhea shows no particular trend. The time of onset of fever shows a definite peak during the first week, with a second peak in the fourth week. It should be noted that the latter coincides with the peak observed in Figure 4 for pharyngitis.

D. Relation to Distance

The relation of these symptoms and findings to distance from GZ is shown in Table XVII. It can be seen that epilation, petechiae, hemorrhage other than petechiae, bloody stools, vomiting, diarrhea and amenorrhea are negatively related to distance in all four groups of patients. The results are significant for the Hiroshima cases for the first four of the six findings, i.e., for epilation, petechiae, other hemorrhage, and vomiting.

Although significant inter-relationships between these symptoms were not found, the significant relationships between them and distance is suggestive evidence, at least, that this group of symptoms were directly related to the bomb.

The maximum distances from GZ of patients having epilation and petechiae are shown in Figures 6 and 7. From these, it can be seen

RELATION OF OCCURRENCE OF DIARRHEA, BLOODY DIARRHEA, AND FEVER TO WEEK OF ONSET OF SYMPTOMS.

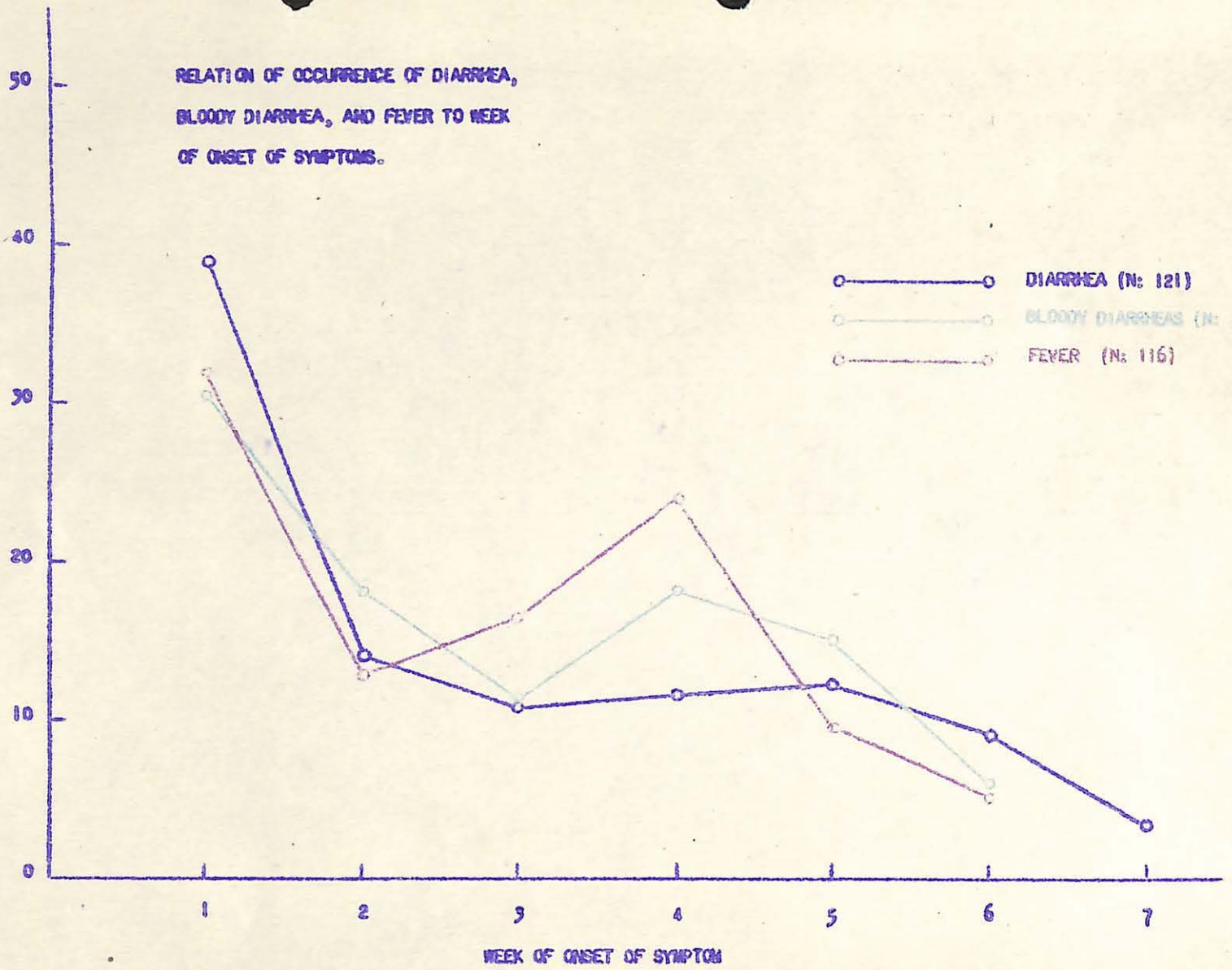


FIGURE 5

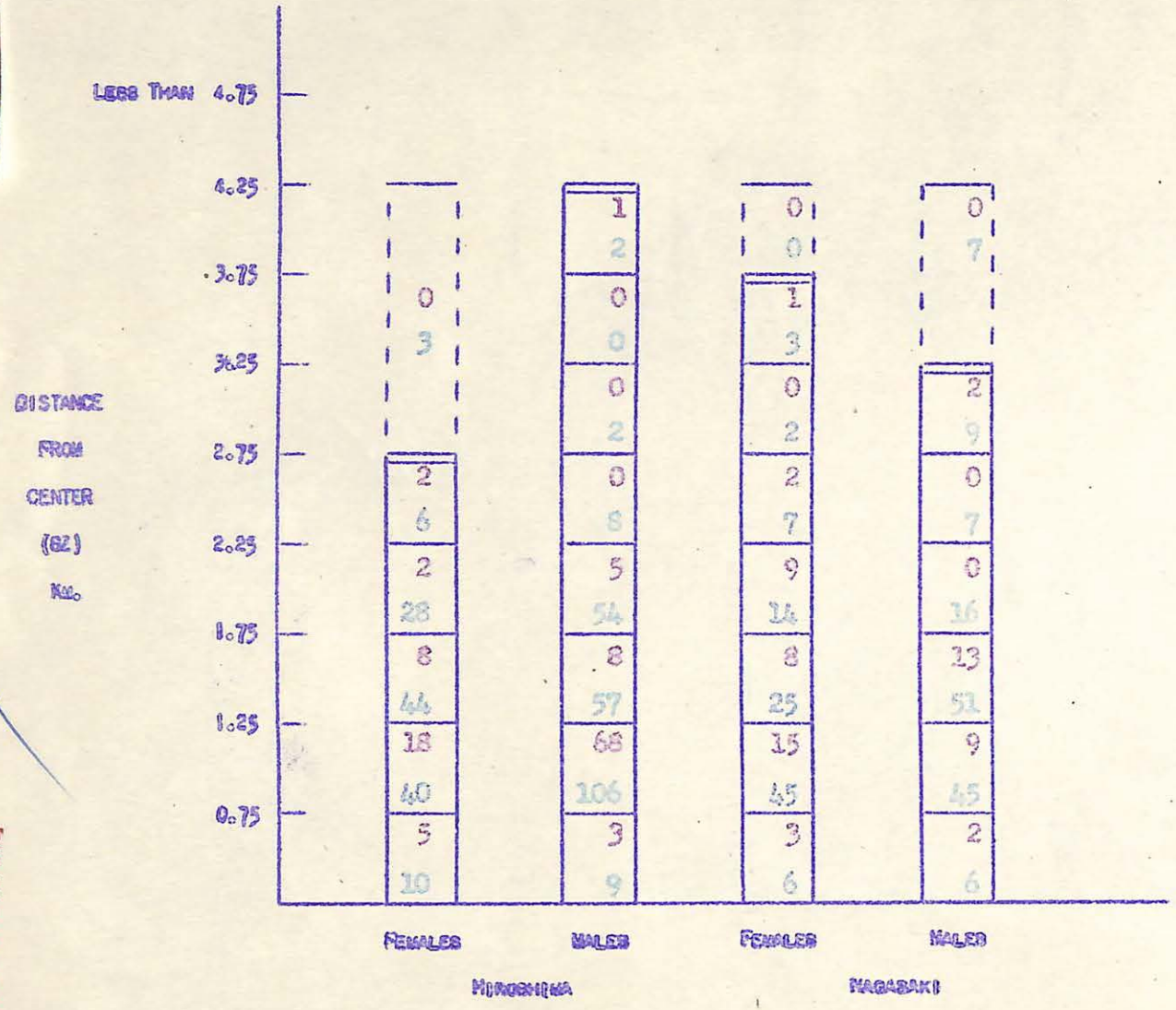
TABLE XVII

Relation of Symptoms to Distance in Patients Studied

Symptom	City	Sex	Total N.	Symptom Absent N.	Symptom Present N.	Symptom Absent M Distance (Km.)	Symptom Present M Distance (Km.)	Standard Deviation	Point Biserial Correlation
Epilation	H	F	131	96	35	1.57	1.15	5.69	-.33
	H	M	238	153	85	1.56	1.11	5.32	-.41
	N	F	102	64	38	1.41	1.40	6.81	-.01
	N	M	141	115	26	1.61	1.32	7.93	-.14
Petechiae	H	F	133	55	78	1.59	1.35	5.66	-.21
	H	M	240	146	94	1.52	1.20	5.31	-.29
	N	F	100	81	19	1.44	1.24	6.84	-.12
	N	M	141	119	22	1.59	1.42	7.90	-.08
Hemorrhage other than petechiae or bloody stools.	H	F	53	44	9	1.19	.86	3.66	-.34
	H	M	43	36	7	1.24	.87	4.68	-.29
	N	F	87	69	18	1.47	1.16	6.43	-.20
	N	M	134	107	27	1.63	1.33	7.70	-.16
Vomiting	H	F	82	24	28	1.51	.98	3.73	-.44
	H	M	40	30	10	1.31	.86	4.79	-.41
	N	F	21	6	15	1.58	1.29	4.61	-.29
	N	M	15	2	13	1.40	1.22	5.46	-.11
Diarrhea	H	F	133	84	49	1.58	1.23	5.66	-.30
	H	M	239	143	96	1.41	1.37	5.31	-.04
	N	F	100	56	44	1.49	1.31	6.86	-.13
	N	M	142	71	71	1.66	1.47	8.00	-.12

TABLE XVII (cont'd)

Symptom	City	Sex	Total N.	Symptom Absent N.	Symptom Present N.	Symptom Absent M Distance (Km.)	Symptom Present M Distance (Km.)	Standard Deviation	Point Biserial Correlation
Amenorrhea	H	F	45	32	13	1.11	1.05	3.80	-.08
	N	F	85	47	38	1.48	1.44	6.90	-.03
Oropharyngeal lesions	H	F	130	81	49	1.43	1.48	5.69	.04
	H	M	238	172	66	1.42	1.32	5.32	-.09
	N	F	101	75	26	1.36	1.55	6.83	.12
	N	M	141	111	30	1.61	1.46	7.98	-.08
Fever	H	F	133	66	67	1.58	1.32	5.66	-.23
	H	M	240	111	129	1.55	1.26	5.31	-.28
	N	F	70	21	49	1.77	1.40	6.91	-.24
	N	M	92	20	72	1.35	1.47	6.65	.07

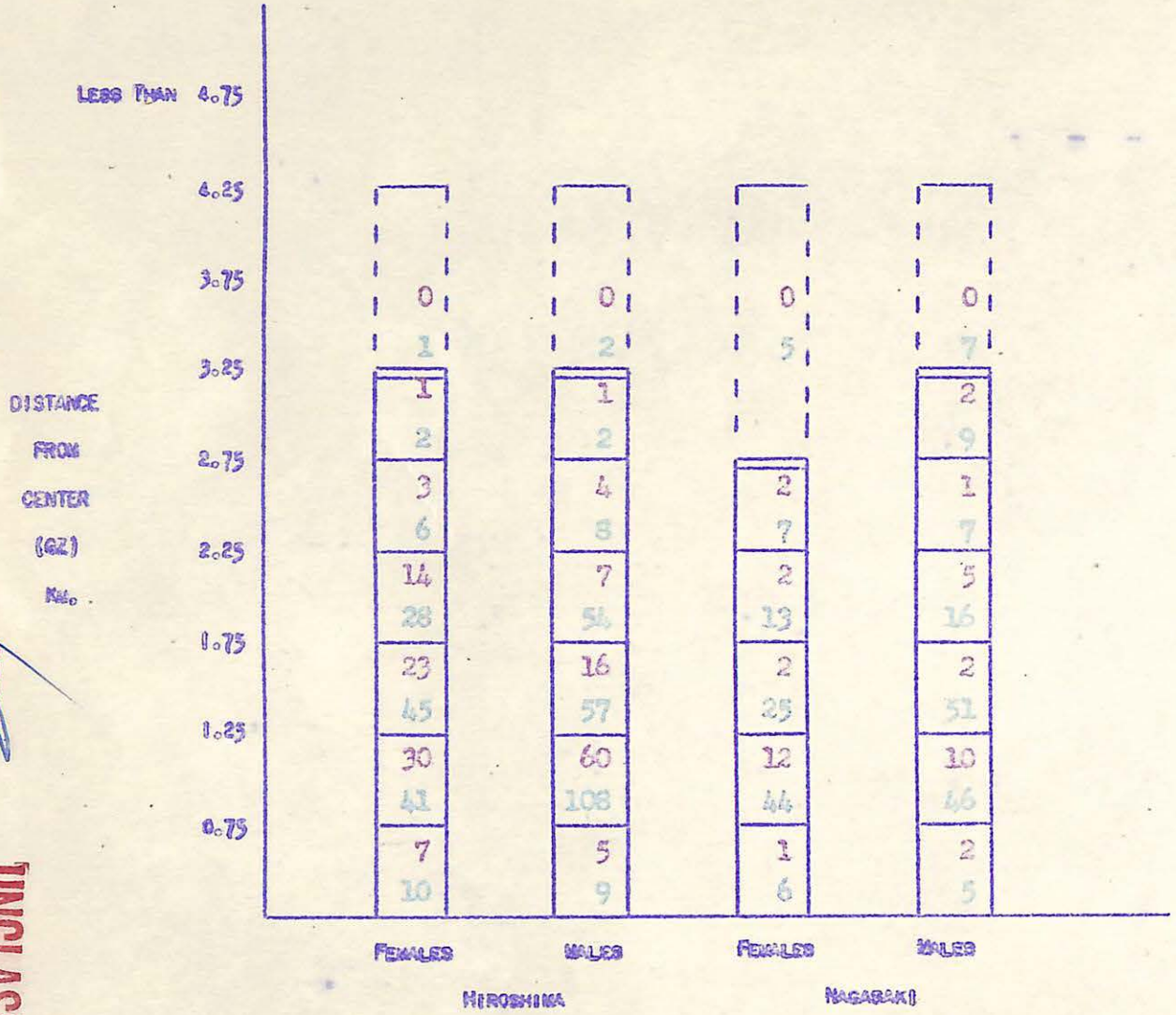


NUMBER OF PATIENTS WITH EPILATION AND TOTAL NUMBER OBSERVED AT VARIOUS DISTANCES FROM THE CENTER.

RED: NUMBER WITH EPILATION

GREEN: TOTAL NUMBER AT DISTANCE

FIGURE 6



NUMBER OF PATIENTS WITH PETECHIAE AND TOTAL NUMBER OBSERVED AT VARIOUS DISTANCES FROM THE CENTER.

RED: NUMBER WITH PETECHIAE

GREEN: TOTAL NUMBER AT DISTANCE

FIGURE 7

that there was no definite difference between the two cities or between the two symptoms. It can be estimated that cases of epilation extended out to 3750 meters at Nagasaki and to 2750 meters at Hiroshima. Cases of petechiae extended out to 3250 meters at both cities.

f. Relation to Outcome

The relationship between the occurrence of these symptoms and death is shown in Table XIX (pp. 65 and 66). It can be seen that petechiae and other hemorrhage are significantly related to death in both cities and in addition that epilation is significantly related to death in Hiroshima females and Nagasaki males. Diarrhea, oropharyngeal lesions, and fever were significantly related to death in irregular groups. These irregularities cannot be explained.

Table XX shows the mortality among hospital patients with radiation injury(1), in relation to distance.

TABLE XX

Relation of Distance to Percent Deaths Among Patients Showing Radiation Effects.

Distance from GZ Km.	Hiroshima Patients with Radiation Injury N.	Deaths %	Nagasaki Patients with Radiation Injury N.	Deaths %
.25 - .74	9	11.0%	5	20.0%
.75 - 1.24	105	21.9	27	33.0
1.25 - 1.74	38	18.4	2	-
1.75 - 2.24	19	-	12	8.3
2.25 - 2.74	6	-	3	-
2.75 - 3.24	-	-	2	-
3.25 - 3.74	-	-	1	-
3.75 - 4.24	1	-	-	-
TOTAL	178	17.4%	71	15.5%

(1): For this analysis, only patients having epilation alone, or both petechiae and leucopenia of less than 4000 were considered.

TABLE XIX

Relation between Occurrence of Symptoms and Death in Patients Studied

Symptom	City	Sex	Number Survivors	Number Deceased	Survivors Showing Symptom %	Deceased Showing Symptom %	X^2	P
Epilation	H	F	127	18	21%	72%	18.03	< .01
	H	M	248	22	36.	41.	.06	.81
	N	F	96	17	35.	53.	1.21	.27
	N	M	139	17	19.	71.	18.51	< .01
Petechiae	H	F	129	18	51.	100.	13.45	< .01
	H	M	249	23	33.	61.	6.02	.01
	N	F	95	13	13.	77.	25.31	< .01
	N	M	139	9	12.	78.	22.12	< .01
Hemorrhage other than petechiae or bloody stools	H	F	42	10	10.	50.	6.63	.01
	H	M	34	8	9.	50.	5.22	.02
	N	F	79	13	16.	69.	14.31	< .01
	N	M	130	15	16.	87.	33.43	< .01
Vomiting	H	F	43	8	51.	62.	.04	.84
	H	M	33	6	18.	50.	1.38	.24
	N	F	20	1	75.	0.	.24	.63
	N	M	14	1	86.	100.	1.25	.26
Diarrhea	H	F	129	18	36.	61.	3.30	.07
	H	M	249	22	39.	45.	.14	.71
	N	F	95	17	43.	65.	1.90	.17
	N	M	138	24	49.	88.	10.98	< .01

TABLE XIX (cont'd)

Symptom	City	Sex	Number Survivors	Number Deceased	Survivors Showing Symptom %	Deceased Showing Symptom %	X^2	P
Amenorrhea	H	F	39	5	28.%	40.%	.00	1.00
	N	F	87	3	41.	67.	.08	.78
Oropharyngeal lesions	H	F	126	18	37.	44.	.15	.70
	H	M	249	21	23.	57.	9.86	<.01
	N	F	96	14	25.	36.	.28	.60
	N	M	139	10	19.	70.	11.42	<.01
Fever	H	F	129	18	50.	83.	5.65	.02
	H	M	249	23	58.	52.	.09	.76
	N	F	60	26	68.	38.	6.38	.01
	N	M	81	40	74.	100.	10.81	<.01

It can be seen that 17.4% of the patients showing radiation injury at Hiroshima and 15.5% at Nagasaki, died. It is interesting to note that although the percentage incidence of radiation injury in the group selected at Hiroshima was 41.2% contrasted with 15.2% in the group selected at Nagasaki, the mortality in those showing radiation injury was approximately the same.

F. Laboratory Findings

The important laboratory findings were related to disturbances in the hematopoietic function and were manifested by leucopenia, anemia, and thrombocytopenia. Particularly severe degrees of leucopenia had been reported during the latter part of August by the Japanese in both cities. In September, by which time most of the patients were showing increasing white blood cell counts, marked thrombocytopenia and progressively severe anemia was reported. On the whole, the most severe anemias, other than those coincident with hemorrhage due to thrombocytopenia, were reported toward the end of September and the beginning of October.

The relation of changes in white and red blood cell counts to time after the bomb and distance of the subject from GZ was investigated in the groups studied. These relations are shown in Tables XXI and XXII. The data refer to single counts on individual patients. An inspection of Table XXI shows that the trends are not clear cut or consistant. They suggest, however, that leucopenia was more severe in patients near GZ than in those farther out. In addition, it can be observed that there is a tendency for the leucocyte counts done during the first four weeks to be lower than those done after that time.

TABLE XXI

W.B.C. in Relation to Week of Examination and Distance from GZ

HIROSHIMA

Week of Examination	0 - 1.0 Km. Examinations No.	0 - 1.0 Km. Cells per mm^3 Mean	1.1 - 1.5 Km. Examinations No.	1.1 - 1.5 Km. Cells per mm^3 Mean	Over 1.6 Km. Examinations No.	Over 1.6 Km. Cells per mm^3 Mean
4 or less	27	1700	15	4200	7	3700
5	23	2700	28	3100	25	3200
6	17	3600	24	3100	26	4000
7 and over	50	4900	22	4500	6	4500

NAGASAKI

4 or less	14	3400	10	2300	3	6600
5	14	3000	14	3400	10	5700
6	24	6600	21	3900	16	5000
7 and over	11	7200	19	5200	13	4700

TABLE XXII

R.B.C. in Relation to Week of Examination and Distance from GZ

HIROSHIMA

Week of Examination	0 - 0.1 Km. Examinations N.	0 - 0.1 Km. Cells per mm^3 Mean	Over 1.1 Km. Examinations N.	Over 1.1 Km. Cells per mm^3 Mean
4 or less	24	3.14×10^6	18	3.33×10^6
5	8	3.44	4	3.58
6	6	3.27	7	2.89
7 and over	41	2.92	17	3.16

NAGASAKI

4 or less	8	3.23	4	3.23
5	8	2.56	9	2.21
6	11	2.75	15	3.05
7 and over	5	3.76	6	3.35

Unfortunately, when one makes similar comparisons between some of the specific groups, the above conclusions do not hold. Nevertheless, the frequency of these discrepancies is not too large to make the above conclusions untenable.

The changes in the red blood cell count in relation to week of examination and distance from GZ show no trends.

G. Miscellaneous Effects

The relation of nausea and vomiting occurring very soon after the explosions to the appearance of later symptoms known to be due to radiation, if of interest. Immediate nausea and vomiting is known to occur in experimental animals receiving large doses of general body radiation, and similarly in patients treated therapeutically. On the other hand, the occurrence of these symptoms as a result of psychic shock is also well known and many of them could have been due to this. Attempts were made to determine to which of these two factors the immediate nausea and vomiting might be due. In the collection of data at Hiroshima, this early nausea and vomiting was asked for specifically and these symptoms were recorded only if they occurred at this time. At Nagasaki, on the other hand, no special inquiry was made concerning these symptoms and they were recorded if they appeared at any time after the explosion.

The point biserial correlations between the occurrence of immediate nausea and distance from GZ was -.41 for Hiroshima females and -.17 for Hiroshima males. Therefore points representing the percent having nausea at a given distance were plotted. The resulting

curve is shown in Figure 8. From this Figure it may be noted that the relationship between the symptom and the distance is rather striking for the females.

Additional data bearing on this question was obtained as shown in Table XXIII, from a Japanese study on soldiers at Hiroshima who were within 1500 meters of GZ. The leucocyte counts were for the period of 15 to 30 August.

TABLE XXIII*

W.B.C. (per mm^3)	Immediate Nausea and Vomiting	
	Present	Absent
2500	7	1
3500	8	1
4500	7	3
5500	7	7
6500	4	7
7500	0	10
8500	2	7
9500	1	1

* Source: Report of Sawada Committee

In this Table the degree of suppression of the leucocyte count can be considered a measure of the severity of radiation. The trend suggests that immediate nausea and vomiting occur in patients who later show leucopenia.

Since immediate nausea was observed to be related negatively to distance, and immediate nausea and vomiting tended to occur in patients who later showed leucopenia, it can be inferred that they may be radiation effects.

RELATION OF PATIENTS HAVING IMMEDIATE NAUSEA
TO DISTANCE FROM THE CENTER.

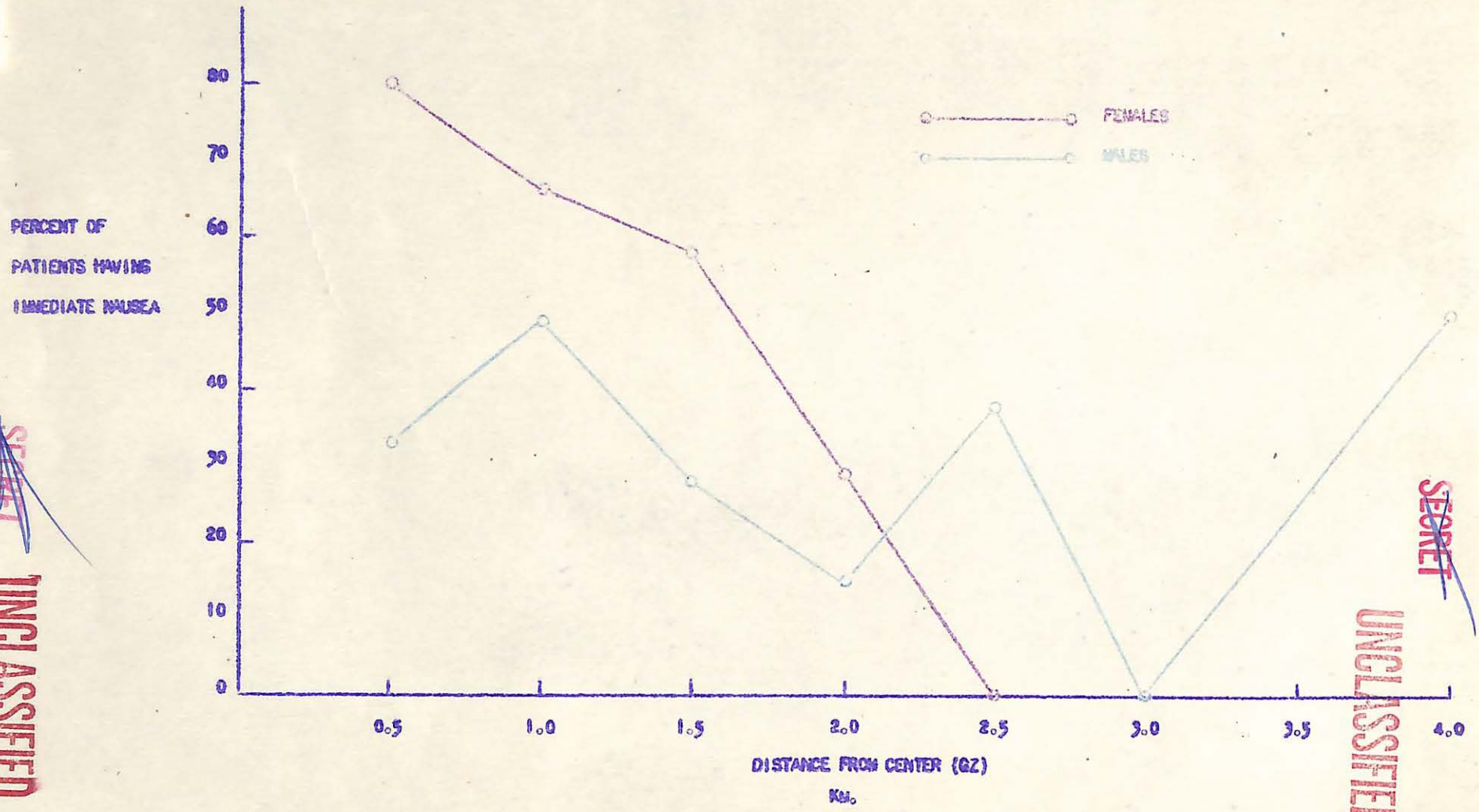


FIGURE 8

The effect of exposure to the bombs on reproduction is of special interest. Amenorrhea was reported frequently and in many instances where the menstrual periods were stated to be regular before the bombings. However, the incidence and the relation of amenorrhea to other factors are grossly influenced by the large amount of "war amenorrhea" which is known to have existed in Japan. The previous menstrual history was not known for most of the patients in this study and consequently it was not felt that reliable relations could be established(1).

No tabulation of abortions or premature deliveries were made in the study of the Manhattan District group, but numerous patients were seen in whom they had occurred.

Ocular injuries produced by the atomic bombings in both cities were the subject of a special investigation made by an AUS Medical Corps officer temporarily attached to the Manhattan District group. (See Appendix I, Report II.) The usual mechanical types of ocular injuries were seen. In addition, lesions consisting of retinal hemorrhage and exudation were observed and 75% of the patients showing them had other signs of radiation injury.

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(1): A detailed study of the effects on the reproductive system is being done in the Joint Report. Although incomplete, this will indicate that almost all pregnancies in women out to 2000 meters were terminated abnormally and that effects on spermatogenesis and menstruation extended out further than my other recognizable radiation effect.

H. Description of Types

On the basis of these findings and impressions together with independent material known from animal experiments and roentgen therapy experience, a total descriptive picture of the symptoms and signs due to radiation can be drawn. Relative radiation dosage in the patients examined could have been estimated only by considering the amount of shielding by air (distance from GZ) or other objects, and, as previously described, this could not be determined. It is known from animal experiments, however, that the greater the dose of general body radiation, the more severe the symptoms and the earlier they appear. On this basis relative dosage in the patients exposed can be judged by the severity and time of appearance of the symptoms and findings. This allows an arbitrary division of the patients into three types on the basis of the severity of their symptoms. These would in general correspond to variations in the dose of radiation received. A general description of these types is shown in Table XXIV. Examples of each type are shown in Figures 9, 10 and 11, which give the hospital course of three Hiroshima patients.

I. Summary

The following symptoms and findings due to radiation were observed: Epilation; leucopenia and its associated infectious processes; thrombocytopenia and its accompanying hemorrhagic manifestations; anemia; and effects on the reproductive system. The time of onset of these various symptoms ranged from the first week after the bombings until at least eight weeks after, at which time the observations were

TABLE XXIV

Summary of Radiation Injury

Clinical Symptoms and Findings

Day after Explosion	Most Severe	Moderately Severe	Mild
1.	1. Nausea and vomiting after 1-2 hours.	1. Nausea and vomiting after 1-2 hours.	
2.			
3.	NO DEFINITE SYMPTOMS		
4.(1)			
5.	2. ~~Bloody~~ diarrhea	NO DEFINITE SYMPTOMS	
6.	3. Vomiting		
7.	4. Oropharyngeal lesions		
8.	5. Fever		
9.	6. Rapid emaciation		
10.	Death		NO DEFINITE SYMPTOMS
11.	(Mortality probably	2. Beginning epilation, ~~progressing until death~~	
12.	100%)		
13.			
14.			
15.			
16.			
17.			
18.		3. Loss of appetite	
19.		and general malaise.	1. Epilation
20.		4. Fever.	2. ~~Anorexia~~ and
21.		5. Herpetiform eruption	malaise.
22.		about mouth and on	3. Sore throat.
23.		buccal mucous membranes	4. Pallor.
24.		progressing to necrotic	5. Petechiae
25.		stomatitis with hemo-	6. Diarrhea
26.		rrhagic gingivitis.	7. Moderate emacia-
27.		6. Pallor	tion.
28.		7. Petechiae, ~~bloody~~	
29.		diarrhea, ~~epistaxis, and~~	(Recovery unless com-
30.		~~hematemesis~~.	plicated by previous
31.		8. Rapid emaciation	poor health or super-
		Death	imposed injuries or
		(Mortality probably 50%)	infections).

(1). There are reports of patients, uninjured by burns or mechanical injuries, who died as early as one week at this stage, and apparently before they had developed leucopenia. The validity of these reports is questionable, but if true, it is not possible to explain the cause of deaths on the basis of known radiation effects.

TABLE XXIV (a)

Summary of Radiation Injury

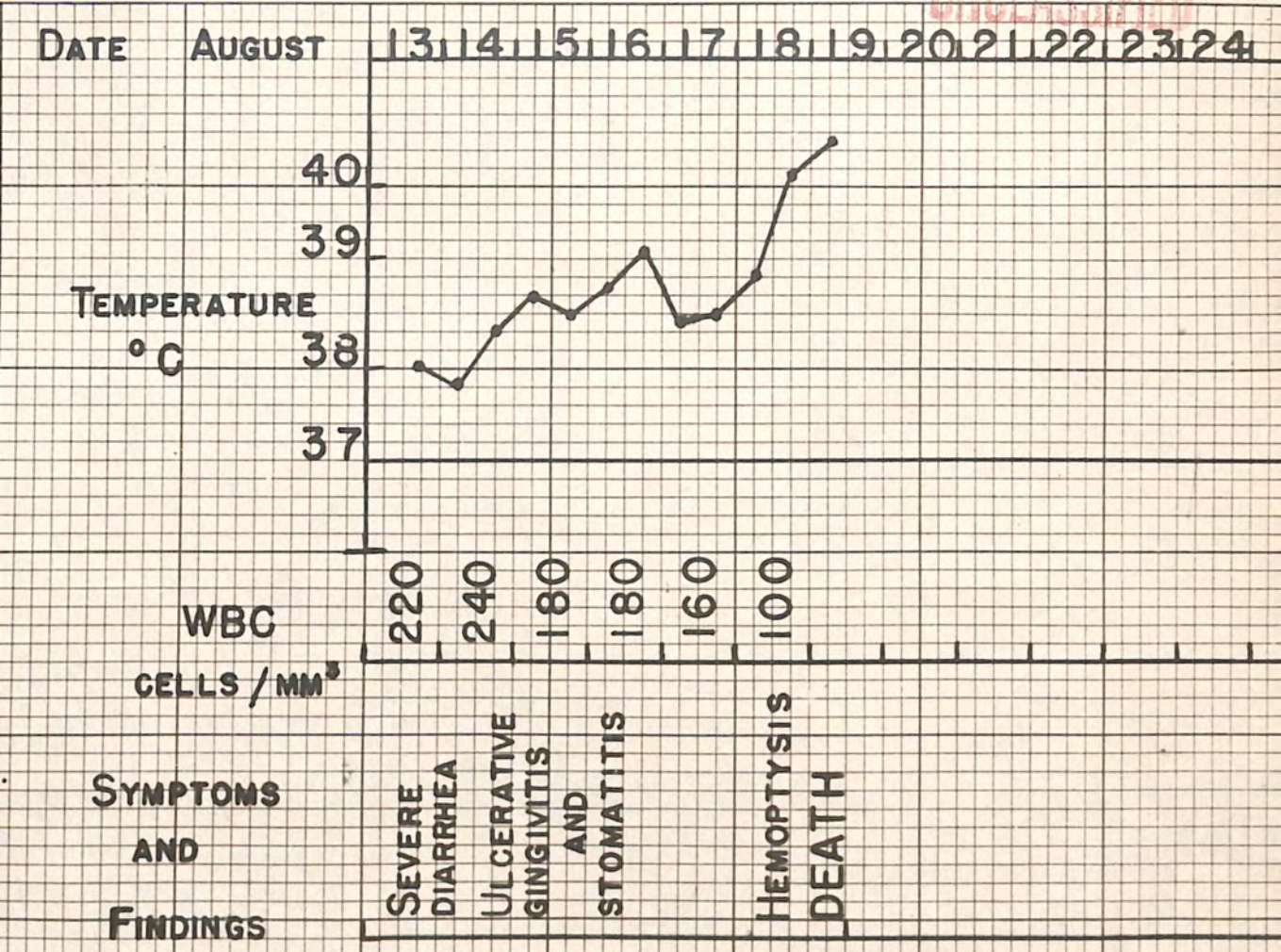
Laboratory Findings

Period of Examination 10-30 Days

	Most Severe	Moderately Severe	Mild
Leucopenia	Extreme	Extreme	Moderate
Anemia	Moderate	Moderate	Moderate
Thrombocytopenia	Extreme	Extreme	Moderate

Period of Examination 45-60 Days

Leucopenia	Moderate	Moderate	None
Anemia	Severe	Severe	Moderate
Thrombocytopenia	Moderate	Moderate	None



AUG 6:

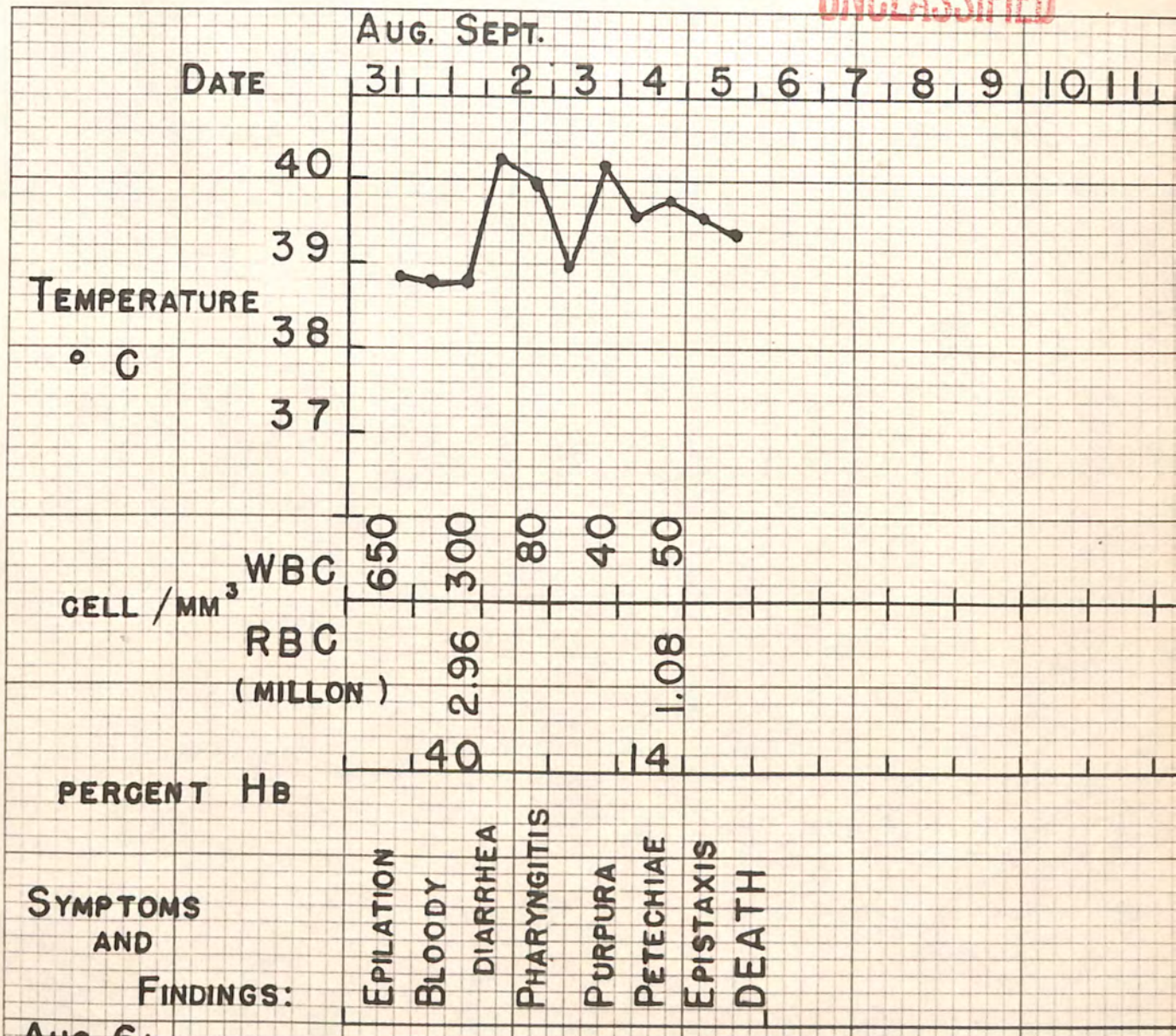
CONTUSIONS OF LIPS AND FOOT

ABDOMINAL PAIN

27 YEAR OLD FEMALE HOUSEWIFE. AT TIME OF BOMBING OF HIROSHIMA WAS 800 METERS SOUTHWEST OF GROUND ZERO INDOORS.

DIAGNOSES: RADIATION INJURY, SEVERE

CONTUSIONS, MILD



AUG. 6:

UNCONSCIOUS 3HRS.

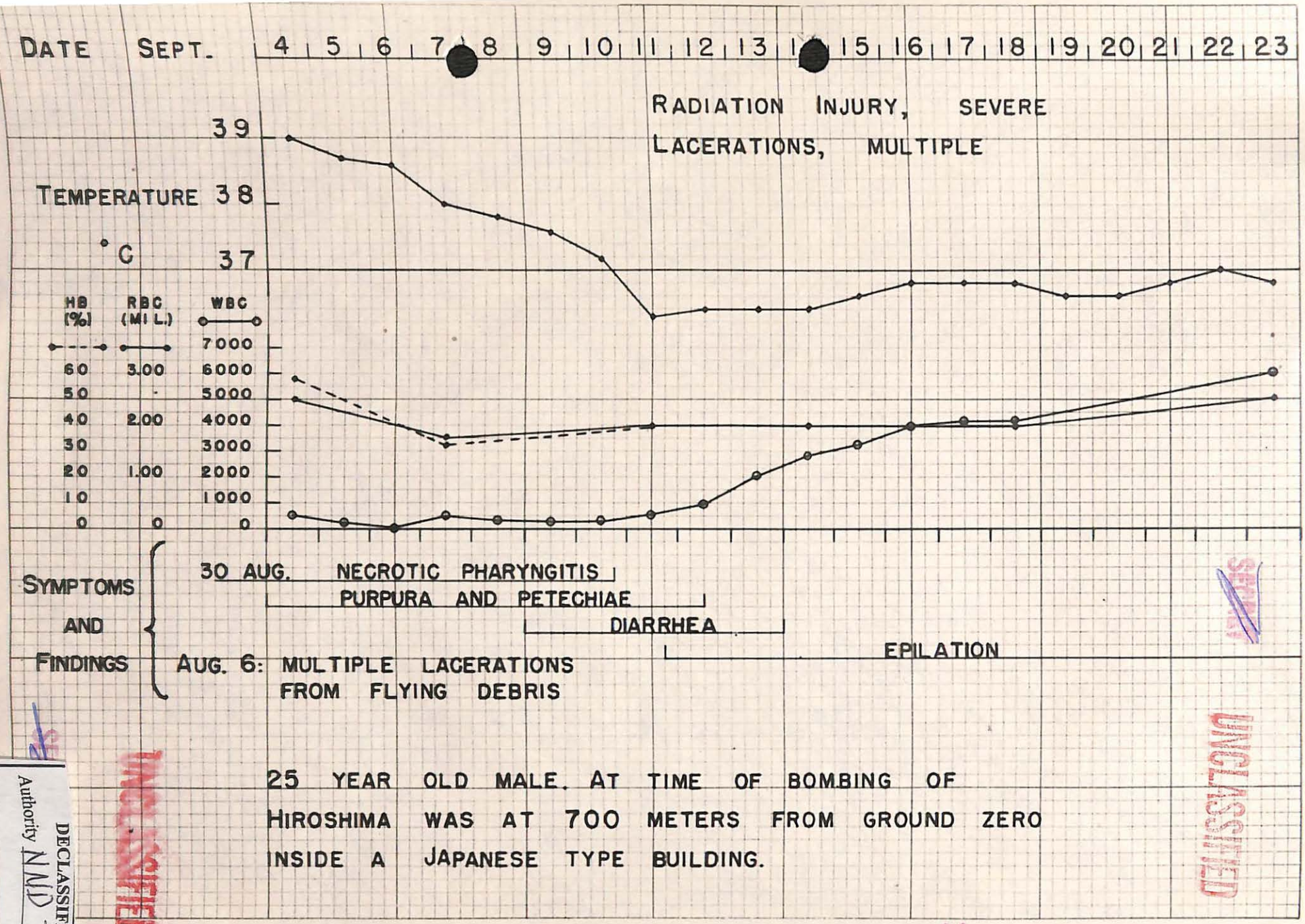
MULTIPLE LACERATIONS

DIAGNOSES: RADIATION INJURY, SEVERE

CEREBRAL CONCUSSION

LACERATIONS, MULTIPLE

16 YEAR OLD FEMALE. AT TIME OF BOMBING OF HIROSHIMA WAS 800 METERS SOUTHWEST OF GROUND ZERO OUTDOORS.



25 YEAR OLD MALE. AT TIME OF BOMBING OF HIROSHIMA WAS AT 700 METERS FROM GROUND ZERO INSIDE A JAPANESE TYPE BUILDING.

SECRET

FIGURE 11

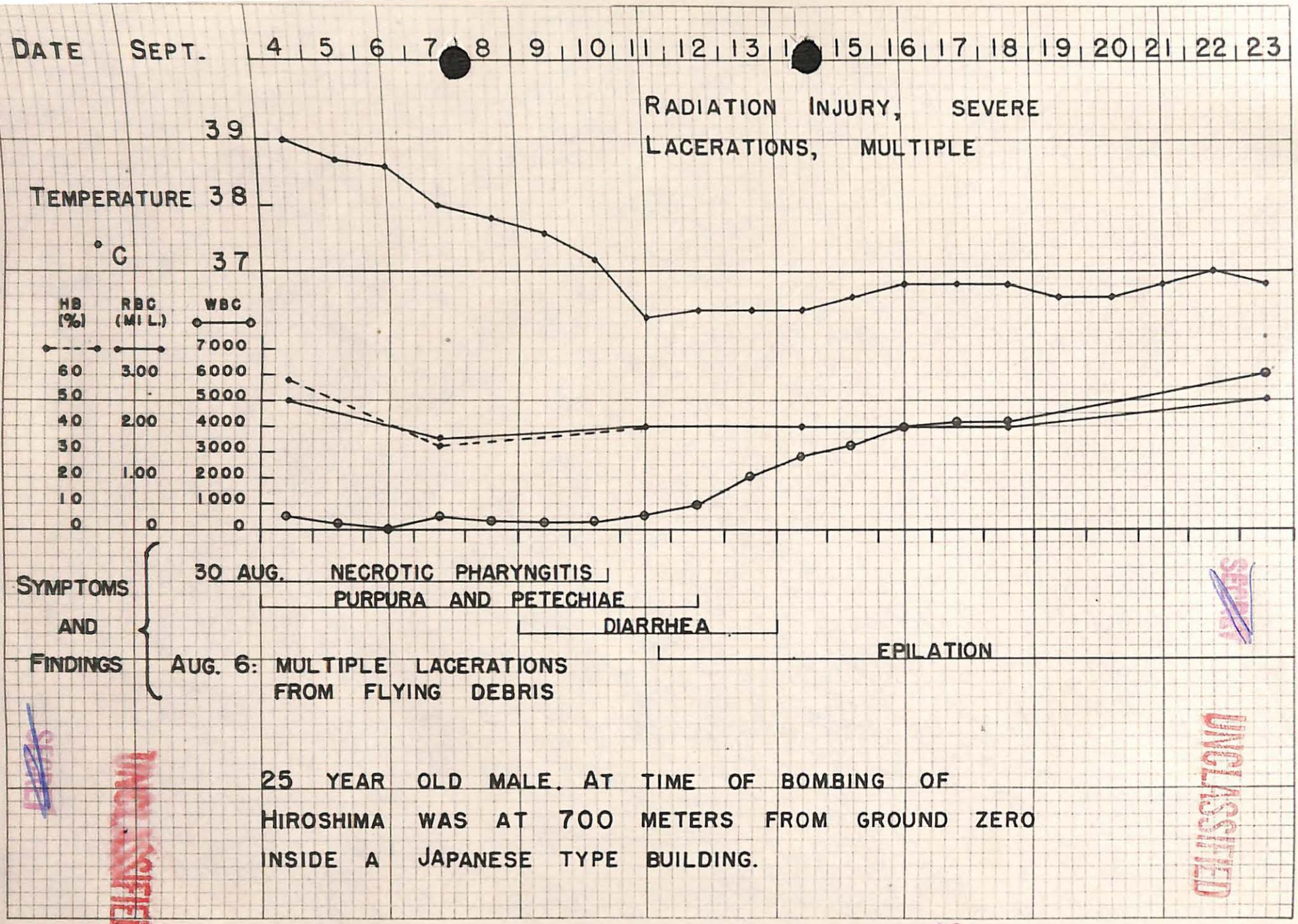


FIGURE 11

concluded. Deaths occurred throughout this period with the greatest number occurring during the fourth week. The occurrence of these symptoms was seen in patients whose location at the time of the bombings was estimated to be out to 3750 meters from GZ at Nagasaki and 3250 meters at Hiroshima.

CHAPTER IV

Cause of Injuries

1. Burns

2. Mechanical injuries

3. Radiation injuries

   A. Evidence that symptoms were due to ionizing radiation.
   B. Evidence concerning injury from persistent radioactivity.
   C. Biological calibration of gamma ray intensity.

1. Burns

There is some disagreement among the various investigating groups in the interpretation of the eye-witness accounts as to how the fires started. Some believe that there was general spontaneous conflagration at least near the center at Nagasaki. It is the opinion of the Manhattan District group, from the accounts, however, that there were no large-scale spontaneous fires as a result of the explosions, although there were many instances of clothes and other very combustible materials so burning. It was thought that the large fires which swept each city soon after the explosion were for the most part due to secondary causes, such as the overturning of cauldrons and electrical short circuits. (See Section C.) Other than this, there is nothing remarkable about the cause of the fire burns.

There are several interesting factors, however, concerning the so-called flash burns. Spectral measurements made at the Alamagordo test showed that the ultra-violet emission was equivalent to that of sunlight. Because of the brief duration (see below) and the good air absorption, this was not of medical consequence. The heating of the air was also not a serious problem at the level of the ground. At the height of these bursts, the superheated air adjacent to the bomb should not have touched the ground.

The effective heat was not all infra-red. It included the entire visible spectrum and may be conceived of as identical with the heating

effect obtained when the sun's rays are concentrated by a reflecting glass.

Assuming that human bodies acted as black bodies (true for infrared, but not for visible light, where perhaps only 50% is absorbed, the rest being reflected), and that the heat capacity and conductivity of the body is equivalent to water, the following data based on the Alamagordo test measurements can be offered. Allowing a duration of heat of one second, the amount delivered at 1000 meters was 25 calories per cm^2. The depth of penetration of the heat, or the noxious heat effect, can be calculated by assuming the amount required to raise the temperature from 30° to 100° C. as shown in Table XXV.

TABLE XXV*

Distance (Meters)	Heat Delivered $cal/cm^2/sec.$	Depth Heated to 100° C. in 1 sec.
500	100	14.0 mm
1000	25	3.0
3000	3	0.4

* Values given by V. F. Weisskopf at conference at U.S. Engineer's Office, Rochester Area, Rochester, N.Y.

This gives reasonable values for the occurrence of burns out to the distances observed. The differences in the calculations as well as in the medical findings between the two cities are not included in this discussion, but from both points of view, the value of 100 $cal/cm^2/sec.$ should probably be reduced by as much as 50% for Hiroshima and increased by 50% for Nagasaki.

2. Mechanical Injuries

The mechanical injuries for the most part resulted from collapse of buildings and from flying glass and other missiles. Two factors chiefly influenced the incidence of such injuries. Proximity to GZ was probably the most important single factor affecting the number of casualties. (See Section C, Part II - Chapter XIII.) The type of building was the second most important factor. The typical Japanese frame building, top heavy with clay tile roofing, and used principally for dwellings, collapsed on the occupants and fire consumed the wreckage. The many masonry (brick or stone) buildings, principally small factories, churches, etc., also collapsed, and people received about the same type of injuries as those in wooden buildings. Injuries to occupants of reinforced concrete buildings were primarily due to flying glass and falling suspended ceilings of wood, or metal-lath and plaster. Injuries to those in structural steel-frame buildings were a combination of the above types.

The injuries due to direct blast, as previously described, were less than expected in proportion to the other injuries. This appears to be due chiefly to the fact that the height above the ground at which the bomb was detonated meant that no person was closer than that distance from the actual point of maximum pressure.

3. Radiation Injuries

A. Evidence that Symptoms were due to Ionizing Radiation

It is stated in the introduction that one of the two specific

purposes of this study was to determine if persons exposed to the atomic bombs at Hiroshima and Nagasaki were affected by radiation. Epilation, leucopenia with its accompanying symptoms, and thrombocytopenia with its manifestations were observed in patients exposed to the bombs, and some of these patients died as a result of these. From roentgen therapy experience and animal experiments, these symptoms are known to result from large doses of ionizing radiation, and it is highly improbable that this particular combination of symptoms could occur on a large scale from any other cause. It was known also, from theoretical predictions, that an instantaneous discharge of high energy gamma rays and of neutrons would occur below the point of detonation of the bombs. That this did occur with neutrons was shown (see Section B) by the detection of induced radioactivity near the centers of the explosions. It was concluded, therefore, that persons did show effects from radiation and that some of these died as a result of it.

B. Evidence Concerning Injury from Persistent Radioactivity

The second specific purpose of this mission was to determine if the effects from radiation were all due to the instantaneous discharges at the time of the explosions, or if people were being harmed in addition from persistent induced radioactivity. This question was investigated from two points of view. Direct measurements of persistent radioactivity were made at the time of the investigation. As discussed in Section B (Tybout), calculations based on these measurements were

made of the integrated radiation dosages. These calculations showed that the highest dosage that would have been received from persistent radioactivity at Hiroshima was between 6 and 25 roentgens of gamma radiation. The highest in Nagasaki was between 30 and 110 roentgens of gamma radiation. The higher figure does not refer to the city of Nagasaki, but to a localized area in the Nishiyama district. In interpreting these findings it must be understood that to get these dosages, one would have had to remain at the points of highest radioactivity from one hour to about six weeks after the bombings. It is apparent that insofar as could be determined at Hiroshima and in the city of Nagasaki, the residual radiation alone could not have been detrimental to the health of persons entering and living in the bombed areas after the explosions. The maximum calculated dosage which could have been received by persons constantly present in the Nishiyama district near Nagasaki is well above the accepted "tolerance dose"(1). From this finding, accordingly, one could not be certain that radiation effects in this district did not occur, although it is highly improbable that any harmful symptoms would have resulted.

The second approach to this question was to determine if any persons not in the cities at the time of the explosions, but coming in immediately after, exhibited any symptoms or findings which might have been due to persistent induced radioactivity. By the time of the arrival of the Manhattan District group, several Japanese studies

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(1) This is defined as the amount of radiation a human being can take day after day indefinitely without influencing the course of his life or producing residual or latent effects.

had been done on such persons. Table I, presented in the report of the Sawada Committee, (Appendix II, Report II), shows the white counts of nine subjects who had come into Nagasaki immediately after the explosion and had been living in self-made huts about 500 meters from GZ from 9 to 31 August 1945. Table III in the same report shows the leucocyte counts of 14 members of the Kyushu University Relief Party who were working in the central area from 14 to 23 August 1945. Table XXVI shows leucocyte counts done by Dr. Sosa's group between 3 and 10 September 1945 on 22 soldiers at Hiroshima who at the time of the explosion were 4.2 Km. away. On 7 August 1945, they went into Hiroshima (500 meters from GZ) to evacuate the injured, and they worked in this central area for one week.

TABLE XXVI*

Leucocyte Counts Done on 22 Soldiers (Hiroshima)

No.	W.B.C.	No.	W.B.C.
1	6,700	12	12,700
2	9,000	13	7,700
3	8,800	14	8,000
4	10,200	15	5,600
5	10,300	16	13,000
6	8,000	17	5,700
7	6,800	18	8,300
8	7,900	19	4,000
9	9,800	20	8,000
10	6,600	21	9,000
11	9,800	22	10,400

* Source: Dr. Sosa's Committee

None of the subjects in any of these studies showed any symptoms which could be attributed to radiation, and, as can be seen from

the Tables, their leucocyte counts were consistently within the normal range.

During the period of our investigation, Japanese doctors and patients were requested to bring to us any patients who they thought might be examples of persons harmed from persistent radioactivity. No such subjects were found.

It was concluded, therefore, as a result of these findings and lack of findings, that although a small quantity of induced radioactivity was found, it had not been sufficient to cause any demonstrable harm to persons living in the two cities after the bombings.

C. Biological Calibration of Gamma Ray Intensity

The type and intensity of radiation causing these symptoms is of special interest. Of the four types of ionizing radiation which could have been responsible, gamma rays and neutrons demand the greatest attention. These are the most penetrating types and applied as general body radiation the only type that could have caused the important symptoms due to bone marrow damage. The less penetrating alpha and beta rays could have contributed to the epilation, but the extent of this, if any, could not be determined. It is extremely difficult to distinguish between the qualitative biological effects of gamma rays and neutrons, except for the induction of radioactivity by the latter. Induced radioactivity in biological tissue was detected only out to a distance of about 1000 meters. It can be considered, therefore, that beyond this distance, at least, the penetrating effects were due to

gamma rays. If an abrupt decrease in the effects on bone marrow should be found at this distance in the studies of the Joint Commission, it could be explained by the observation that neutrons are approximately ten times as hematologically effective as X-rays. There is no indication of this in our studies. In general, however, it seems quite certain that the main biological effects were due to gamma rays.

On the basis of exposure of film found at Hiroshima and theoretical predictions, calculations of gamma ray intensities at increasing distances at Hiroshima and Nagasaki were made. These are discussed in Section C of this report. The values presented there range from 3 to 12 roentgens at 2300 meters at Hiroshima. These do not correspond to what is expected from the biological effects. Any attempt to calibrate radiation intensity on the basis of biological effect, however, is fraught with difficulties, unless done by the most carefully controlled experiments, and is virtually impossible under the circumstances here. Of greatest importance is that data on shielding, both by air and by intervening objects, are insufficient to give reliable estimates of relative exposure (equivalent dosage)(1). Even if this were known, the small number and selection of the patients would not permit evaluation of the factor of variation in individual susceptibility. In addition, the energy spectrum of the gamma rays, on which the number of

(1) This may be roughly determinable in studies done by the Joint Commission.

roentgens to produce epilation, at least(1), depends, is not known; and the influence of the time-intensity factor at these levels is not known.

Despite all of these factors, some estimate of the number of roentgens required to produce radiation effects can be given. Such estimates are shown in Table XXVII.

TABLE XXVII

Roentgens Required to Produce Radiation Effects

Radiation Intensity Kv	Roentgen Dose Required for Epilation
50	200
250	400
1000	500

It was shown in Figures 5 and 6 (pp. 59 and 62) that both epilation and petechiae occurred in patients as far out as 3000 meters, and were very frequent between 1500 and 2000 meters. It seems most unlikely that either the time-intensity factor or variation in individual susceptibility could account for the occurrence of these effects at dosage levels of the order of 5 to 10 roentgens.

(1) As judged from blood changes in the rat, the biological effectiveness per roentgen is practically independent of the wave length of the radiation and in general is a very slow and varying function of the ion distribution. This is not equally true, however, with a surface effect such as epilation.

CHAPTER V

Conclusions

CHAPTER V - Conclusions

The best estimates of the number of casualties at Hiroshima and Nagasaki available at the present time are:

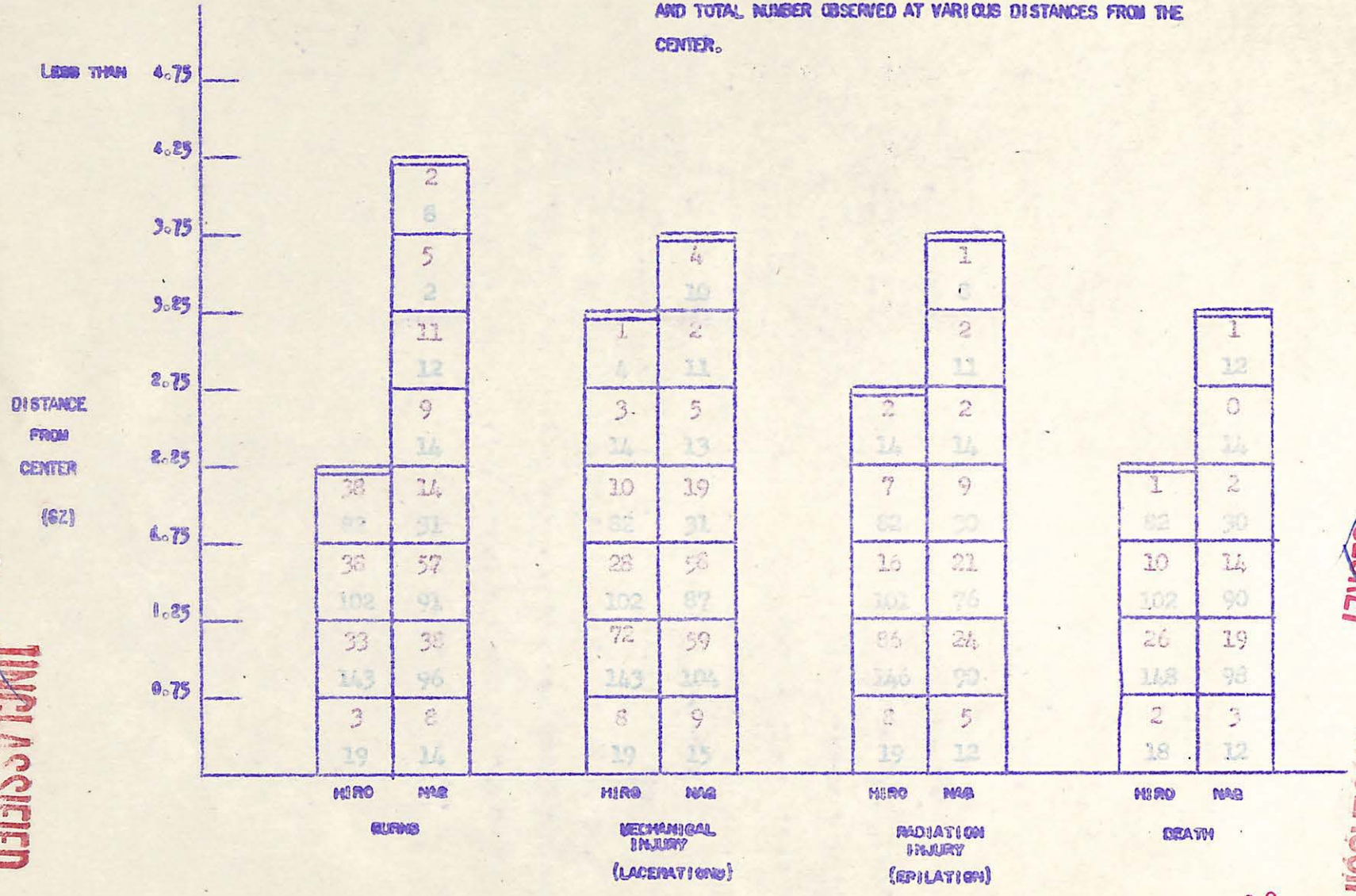
	Hiroshima	Nagasaki
Population	320,000	260,000
Dead	78,000	35,000
Injured	37,000	30,000
Total Casualties	115,000	65,000

These casualties were primarily due to burns, mechanical injuries and radiation. Their importance as casualty-producing agents is in the order listed. The greatest single factor influencing the occurrence of casualties appeared to be the distance from the center of GZ.

Based on the study of 900 selected cases, estimates of the maximum distance at which symptoms due to the various casualty-producing effects and deaths were observed as shown in Figure 12. It can be seen that burns extended considerably farther than the other two effects, and mechanical injuries somewhat farther than radiation injury. In addition, the effects extended further at Nagasaki than at Hiroshima.

The unusual symptoms and findings observed were epilation, petechiae and other hemorrhagic manifestations, and profound leucopenia associated with infectious processes particularly about the oropharynx. There were also indications of disturbances of the reproductive systems. In the patients studied, these symptoms were found in general to be negatively related to distance. It is inferred that

NUMBER OF PATIENTS WITH VARIOUS TYPES OF INJURY AND DEATH AND TOTAL NUMBER OBSERVED AT VARIOUS DISTANCES FROM THE CENTER.



RED: NUMBER SHOWING INJURY
GREEN: TOTAL NUMBER AT DISTANCE

FIGURE 12

nausea and vomiting occurring a few hours after the explosions were also radiation effects. It was further found in the patients studied that certain of these symptoms were significantly related to death.

It is concluded that persons exposed to the bombs at the time of detonation did show effects from ionizing radiation and that some of these patients, otherwise uninjured, died. The precent of deaths due to radiation injury (as well as to other specific causes) cannot be determined from this study. From the general picture, however, it appears that deaths due to recognizable effects of radiation were far less than those due to other causes. The mortality in hospital patients showing definite radiation injury was approximately 16% in both cities. Most of these deaths occurred during the fourth week after the bombings.

The evidence from medical findings points to the conclusion that persons not exposed to the bombs were not injured by radioactivity persisting in the areas.

Section A. Medical Study

Part II. Pathology

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Forward

The analysis of the pathological information obtained from Nagasaki and Hiroshima, presents great difficulty due largely to the incomplete nature of the information on the series of cases from which this study is made. As has been mentioned, the arrival of the American Party did not occur until six weeks after the actual bombings. Hence for the period up to this date, the information was obtained directly from Japanese sources. Due largely to the state of utter confusion and lack of medical resources existing at that time, they are quite incomplete as will be shown.(1)

Because of the nature of the data, the approach of this paper deals with, (1),a brief review of the nature of the physical agents which caused the pathological damage; (2), a general discussion of the pathological material as a whole; and (3), the presentation of the findings observed in the study of the specimens. Stress will be placed on the damaging effects due to gamma (and neutron) irradiation, inasmuch as the nature of these effects on the human subject is comparatively unknown and not well understood.

The previously discussed agents which are important as factors in the pathological damage are, (1), blast and the following succusion wave; (2), the terrific heat radiation which includes the exposures to rays from the infra-red to the ultra-violet ranges of the spectrum,

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(1): The Joint Commission has a considerably larger and more extensive group of cases than those here presented, and it is hoped that many of the gaps existing in this account will be bridged.

and, (3), the ionizing radiation which is similar to X-rays.

The pathological effects of acute neutron radiation are indistinguishable from the gamma radiation damage.

The blast effects, as far as can be determined from eye-witness reports, are very similar to those observed following cyclonic windstorms, and to a lesser extent, other high explosive ordnance. The damage consists for the most part in injuries from missiles coming from falling buildings and the like being thrown against the casualty. Fractures and traumatic wounds of all types were recorded. Cases of evisceration were likewise reported in abundance, but in general the tendency of later clinical observers is to discount the frequency of such events. This is also true of crushing injuries attributed to the force of air pressure from the blast itself.

The flash effects are definitely an entity and will be discussed in some detail later.

Most important as a distinctly new and overwhelming agent is the gamma (and neutron) irradiation. This also includes the effects of any possible radioactivity from fission product deposition. The major portion of the pathological account will be devoted to the specific injuries from gamma radiation.

CHAPTER I

Description of Material Studied

Chapter I - Description of Material Studied

During the limited sojourn in Nagasaki and Hiroshima, it was possible to collect pathological material from 24 autopsies. Ten of these (including most of the early cases) were obtained from Nagasaki, and the remainder from Hiroshima. Parallel clinical records were not obtainable in many of the earlier cases. Autopsies were carried out in many instances by inexperienced observers. Data on the names of the casualties and other specific facts often were inaccurate or not obtained. The fixation of many of the specimens was extremely poor due to lack of chemicals and reagents. This rendered many good specimens unfit for study. Of the 24 collected, fair data are available on approximately 20, as is shown below.

The subdivision of the cases according to date of death is important, since it serves as a method for judging the progression of the pathological changes. The following tabulation shows the grouping of cases into weekly intervals after the explosions:

1st week - none
2nd week - 1
3rd week - 3
4th week - 2
5th week - none
6th week - 1
7th week - 7
8th week - 4
9th week - 2

Of these cases, ten were males, and ten were females.

The distribution of the cases by age is as follows:

0-10	-	4 cases
11-20	-	6 cases
21-30	-	3 cases
31-40	-	5 cases
41-50	-	no cases
51-60	-	3 cases

The distribution of the cases by the nature of the injury was:

Radiation effects only	-	8 cases
Radiation plus burns	-	3 cases
Radiation plus trauma	-	3 cases
Radiation plus burns plus trauma	-	6 cases

In the discussion which follows, an attempt will be made to give a chronological picture of the course in which the pathological picture developed in these fatal cases. The available material is of such a nature that it divides itself sharply into two rather distinct categories: (1), cases observed in the 3rd and 4th weeks; and, (2), cases observed in the 7th to 9th weeks. The pathological descriptions which follow will expand the findings in these two groups at length.

Examination of the nature of the pathology reveals that there is a time classification also. The first gtoup involves those individuals who were injured by the blast, and those burned immediately, either by the heat radiation from the bomb itself, or from the fire of burning buildings and debris. The second and most important group is that which shows radiation injury.

CHAPTER II

Description of Findings

1. Injuries other than radiation
2. Radiation injuries
   - A. Physiological effects on animals
   - B. Pathological effects in animals
   - C. Pathological effects in human beings

Chapter II - Description of Findings

1. Injuries other than Radiation

The type of injury related to blast has been discussed earlier. One additional comment which should be mentioned is the relative rarity of ruptured ear drums (always in high frequency following high explosive detonation), and which would tend to minimize the effect of the blast wave itself.

The burns resemble very closely the flash burn on a very large scale. Individuals who were under the bombs, and even at some distance from them, had the exposed areas of their skin charred to a dark brown color, (third degree burn), and died within a few hours at the most. Those individuals up to approximately 4500 feet showed second and thired degree burns of less intensity, over those areas of skin exposed unprotected to the blast. Even thin clothing gave considerable protection except where tightly stretched across the skin. Dark colored cloth was found very susceptible to ignition and skin areas so covered showed burns.

The pathological picture of the typical skin injury is presented in Plate I. This shows a picture of second degree burn with edema of the epidermis, complete disintegration of the Malpighian layer with much pyknotic debris, edema, and hyalinization of the underlying layers of the skin. Thrombi are visible in the blood vessels and some bacterial clumps are scattered throughout.

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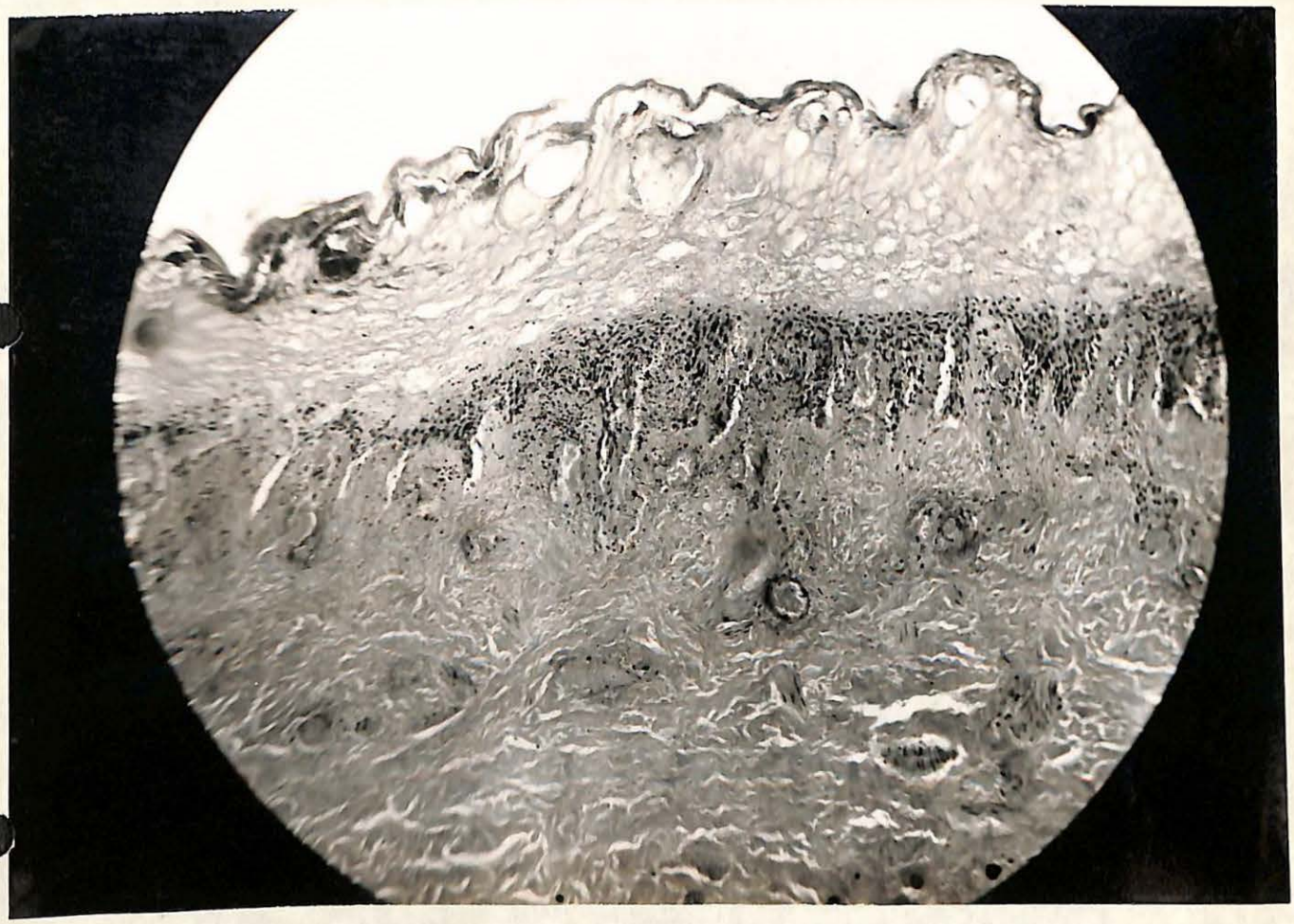

PLATE I. SKIN (HUMAN); 2ND DEGREE BURN

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The picture of burn pathology and its related shocking effects has been discussed at length in the medical journals of the past few years, and requires no further comment. Individuals who survived relatively severe burns and then developed radiation sickness will be discussed later.

2. Radiation Injury

Inasmuch as the pathological material obtained from Nagasaki and Hiroshima was collected from Japanese sources, some six or eight weeks after the bombings, it is expected that gaps would and do occur in the data thus gained. Hence, it is deemed wise to intersperse at this point a brief physiological and pathological summary of the sequence of events occurring after animals (rats, dogs, and monkeys) are exposed to a killing dose of x-radiation. The biological effects of x-rays are indistinguishable from those of the gamma rays liberated by the bombs.

A. Physiological Effects in Animals

After normal animals (dogs) are exposed to a killing dose of x-rays, there is a latent period in the development of symptoms for approximately one to two hours. At this time, a preliminary period of prostration sets in, associated with a primary fall in blood pressure. Some salivation, diarrhea, nausea and vomiting may follow at this time. The diarrhea is seldom of bloody nature. The peripheral blood picture shows an elevation in the circulating polymorphonuclear leucocytes of approximately 20 to 30% over the control values. At the same time,

there is a sharp decline in the circulating lymphocytes to as much as one-tenth of the normal values. The above symptoms progress through the second day and with a continuation of an accelerated heart rate, lowered blood pressure and occasional vomiting. Very little food is taken and some weight is lost.

On the third day, the animal resumes eating and recovers some weight. The polymorphonuclear leucocyte count of the peripheral blood has now fallen to a low level (as much as one-fifth to one-tenth of the normal value), with a parallel depression of the lymphocyte series as well. This state continues up to approximately the ninth or tenth day, or slightly longer, varying with the species, at which time an abrupt rise in temperature of the animal occurs. This is associated with blood concentration caused by a lowering of the fluid elements of the blood. Further concentration is accomplished by the onset of further diarrhea, often of bloody nature. Some copious salivation may occur. Hemorrhages occur into the skin, mucosal areas, as well as other body organs. Signs of sepsis and localized infection then appear. Death occurs with the onset of shock, somewhere between the tenth and twentieth day after the administration of the radiation.

B. Pathological Effects in Animals

Pathological examination of the injured animals (sacrificed at the most opportune periods for accurate study) reveals that the most x-ray sensitive tissues can be grouped in order of their severity of involvement as: (1), the bone marrow, thymus (if persisting) and

testis as a group; (2), next the lymphatic tissues, spleen, gut epithelium and ovary. Little or no damage is observed in the pancreas, kidney, lung, heart, adrenal, nervous tissue, skin or muscle. This latter statement refers to direct x-ray damage and not to the secondary effects of bone marrow depression, such as hemorrhage and infection which do cause changes in these organs.

Examination of each of the individual susceptible organs at critical intervals yields the following information. This account is necessarily quite brief, but will give the reader a chronological picture of the events occurring in the gaps in the human information. As far as can be determined, there is very little difference between the changes in animal and human, and such variation will be conspicuously pointed out. In this way, a more complete picture of the development of the degenerative and regenerative processes can be gained, and the dissimilarities between animal and human pointed out.

Bone Marrow (Dogs):

Following the depressing dosage of x-rays, the bone marrow shows conspicuous signs of degeneration of a progressive nature. First the early cells of the myelocyte series begin to lose their normal cellular and particularly nuclear detail. Cell walls become poorly demarcated, nuclei begin to shrink and later the former areas of complete myelopoesis appear somewhat as syncitiae of pyknotic cellular elements and what can be termed nuclear debris, which is dark staining with the basic dyes.

This process of disappearance of the granulocytes is associated with an inpouring of adult erythrocytes so that the marrow sinusoids become so filled with cells as to appear hemorrhagic in nature. This degenerative process continues up through the eighth to eleventh days, or more, and at its end the marrow appears to be a reticulum with occasional islets of dead cellular elements. There is no sign of activity at any portion. To follow this process, photomicrographs of dog rib marrow have been prepared. Plate II represents the control marrow with its abundance of all cellular elements. Plate III shows the above effect at the end of 14 days, with no sign of cellular activity.

A word must be said concerning the failure of erythropoesis as well. This process in the animal material studied is associated again with the early (3-5 days) disappearance of the nucleated cells which also assume a shrunken pyknotic appearance and gradually disappear from the marrow reticulum. It is evident also that the adult cells suffer little injury, inasmuch as the erythrocyte count is maintained through the normal life span of the cell, and hence shows only a very slow and gradual fall. This accounts for the absence of anemias in the early phases of radiation sickness.

Certain phenomena must be mentioned at this time which contribute to the difficulty in the gauging of the effect of a given dosage of x-rays, on the blood forming elements. Above a certain level of dosage (such as 100 r) the depressing effect on the marrow with the resultant effect on the disappearance of the white cell elements from

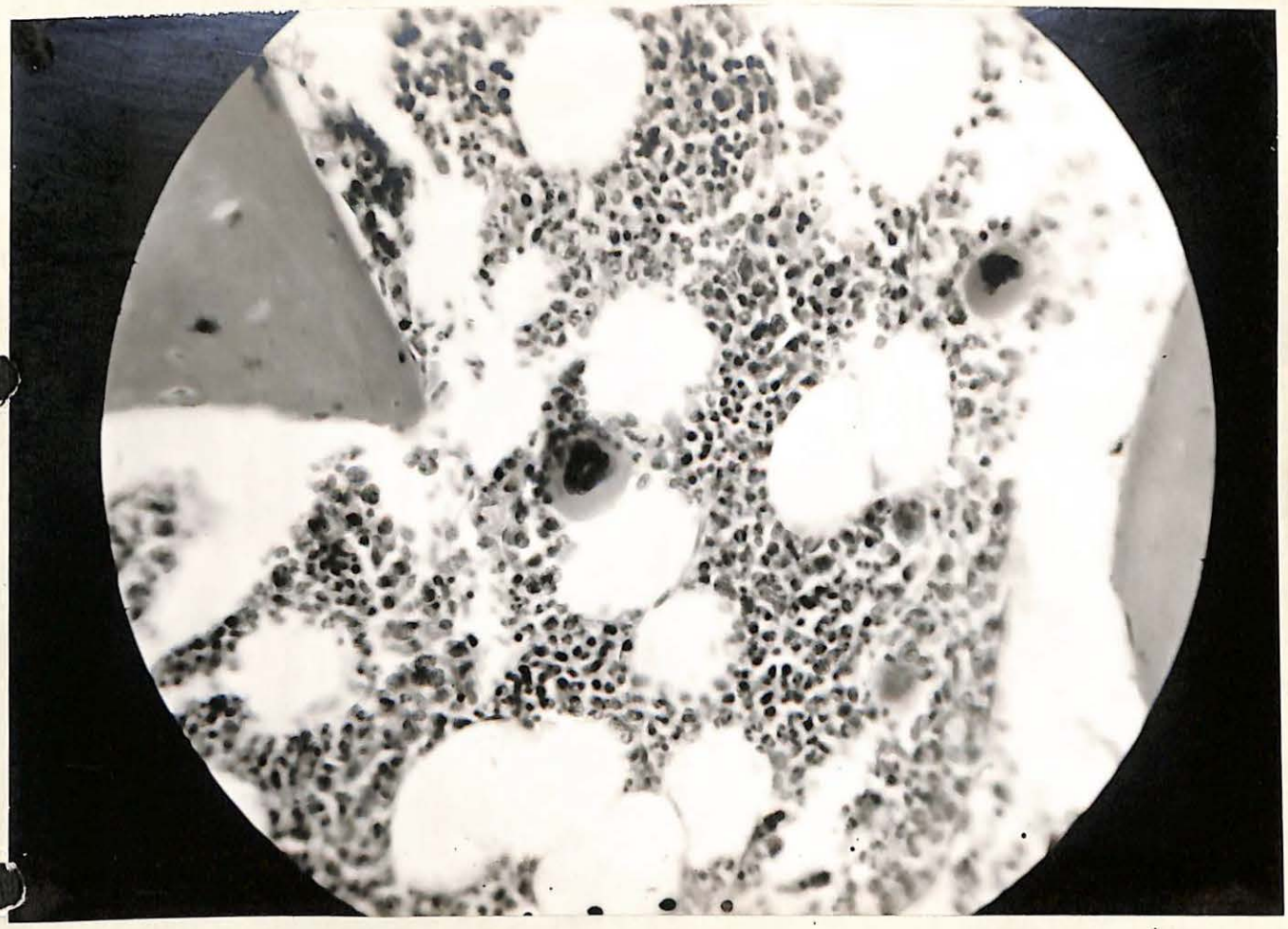

PLATE II. NORMAL RIB MARROW (DOG)

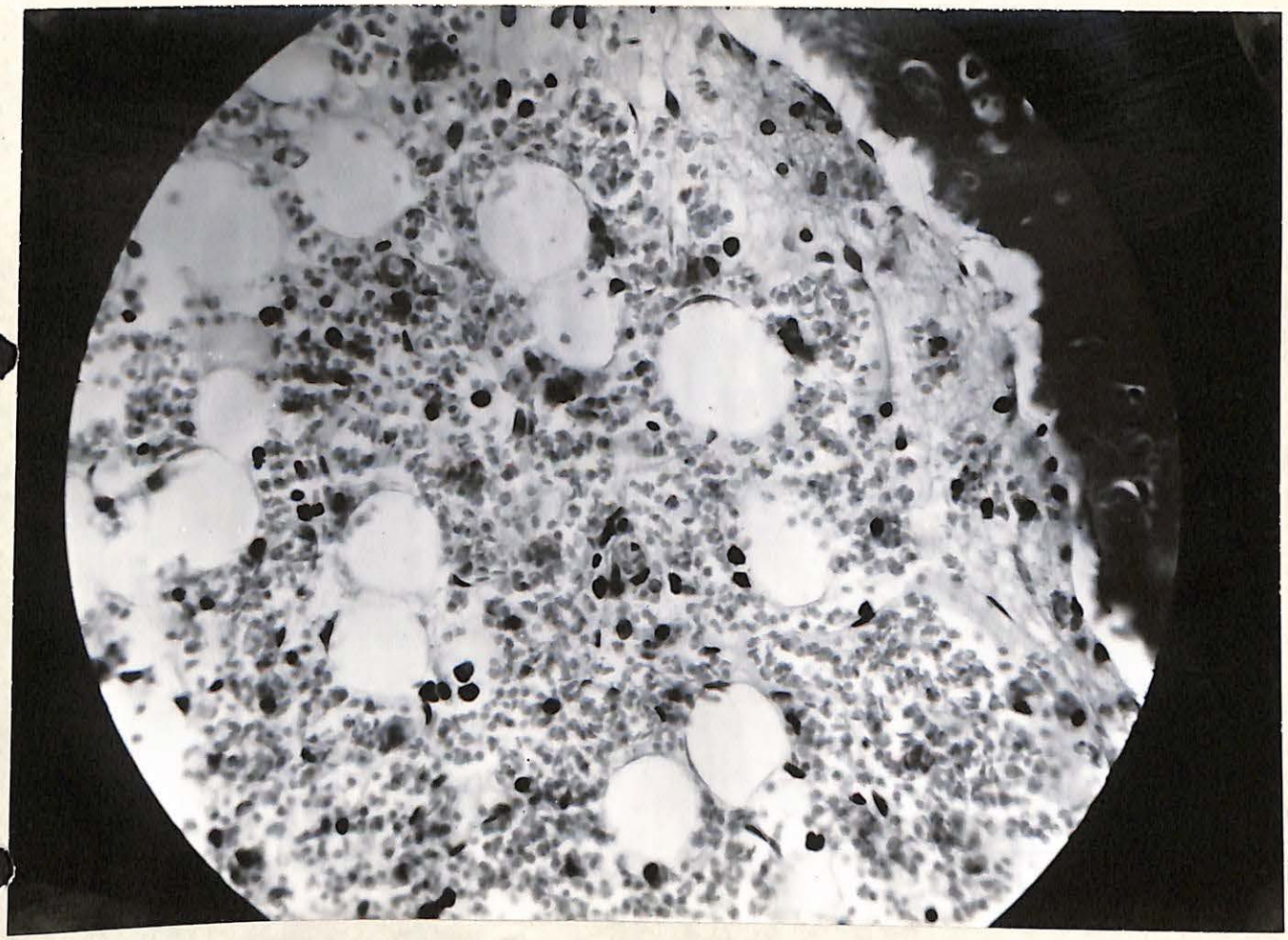

PLATE III. RIB MARROW (DOG)
14 DAYS AFTER TOTAL BODY RADITION (350 R)

the peripheral blood appears to be the same both as to time of development and extent of depression as it would with a lethal dosage. The stress of the increased dosage enters the picture only as an index to the severity of the involvement, i.e., the length of time the marrow remains depressed, the extent of the wiping out of the cellular elements, and the like. The explanation of this phenomena is not clear, and no attempt will be made to present the various potential possibilities which might underlie it.

A period of depression is noted in which the marrow remains relatively acellular, and in which the marrow spaces lose the cellular debris associated with the degenerative process. At the end of this time, new regeneration of cells sets up islands scattered through the marrow spaces. The period of onset of erythropoesis occurs in about the 4th to 7th day in the rat, and a little later than the 14th day in the dog, as far as can be determined from average figures. The cellular islands at first proliferate very slowly and the time of re-establishment of the new areas is slow. Myelopoesis is delayed by several days after the initiation of erythropoesis. The new cells appear normal although blood smears may show an increase in monocyte-like forms. The peripheral blood smears reflect the nature of this process with persistent leucopenia and a slow decline in erythrocytes. (Plate IV).

After this period in which cells are being formed slowly, a spurt in the production of new cells occurs. At the same time, allowing for

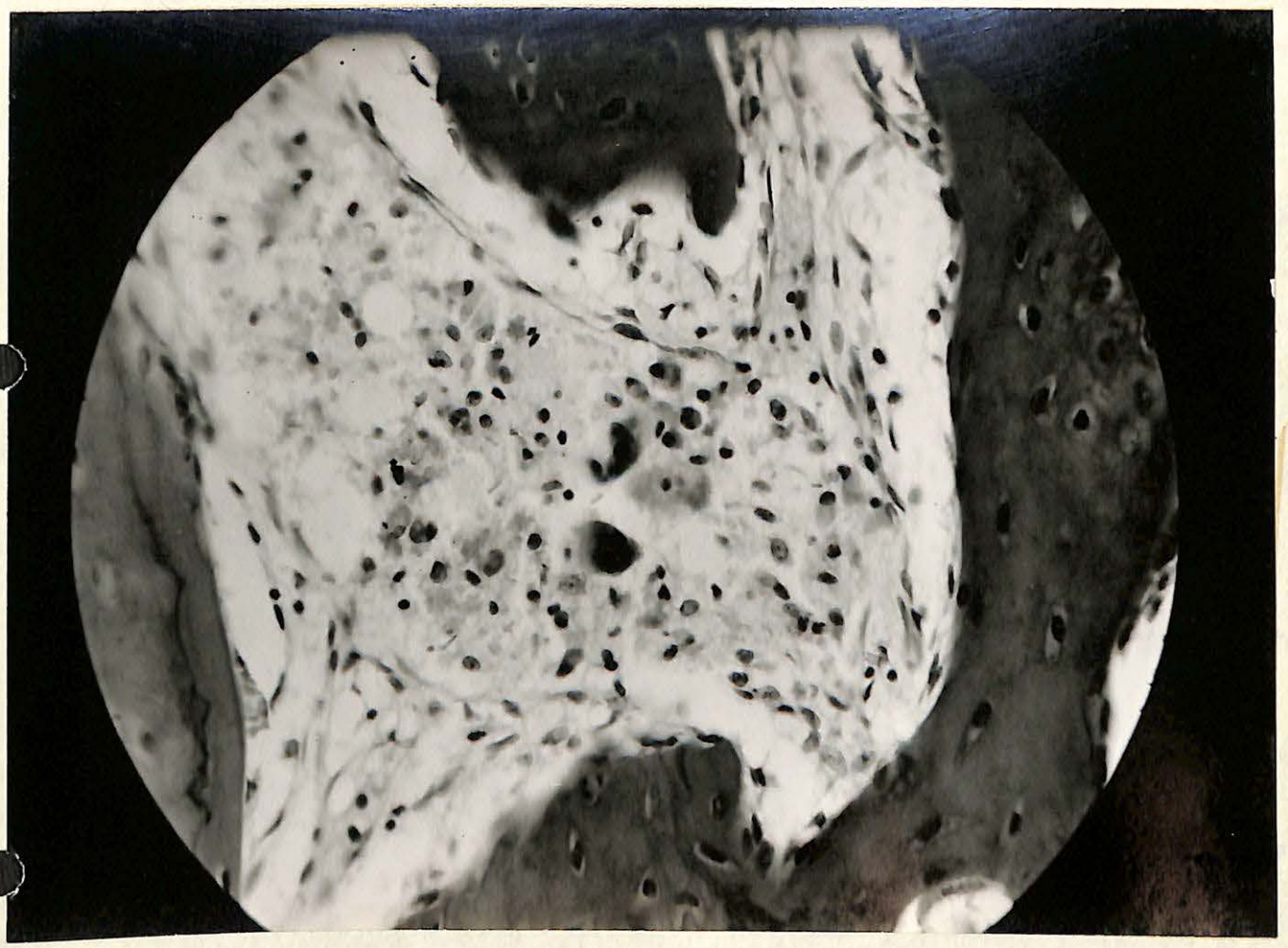

PLATE IV. RIB MARROW (DOG)
28 DAYS AFTER TOTAL BODY RADIATION (350 R)

a period of maturation, the peripheral blood reflects a change with appearance of new elements and proportional rises in leucocyte and somewhat later, the erythrocyte counts. This rise in the rat occurs about the 20th to 24th day on the average, and at about the 30th to 36th day in the dog.

Examination of marrows at this period may reveal a gelatinous appearance on gross examination due to the large numbers of formative cells occupying the marrow spaces, collapsing the blood vessels and rendering the marrow relatively free of adult red cells. (Plate V)

The giant cells or megakaryocytes, are worthy of mention, inasmuch as they are important as the site of platelet formation which is also depressed to low levels. These likewise disappear early from the marrow and are not reformed until relatively late in the regenerative cycle, the exact time being around the 20th day for the rat, and unknown for the dog.

Following the regenerative period, the proliferation may continue so that as much as twice the normal number of cell elements are observed in the marrow counts. In the dog this happens around the 55th day. As the respective need for blood cell elements is now solved, the marrow reverts to the normal state, this period being relatively unknown but perhaps about 100 days.

The Lymphatic System:

The effect of the radiation on the lymphatic system follows a

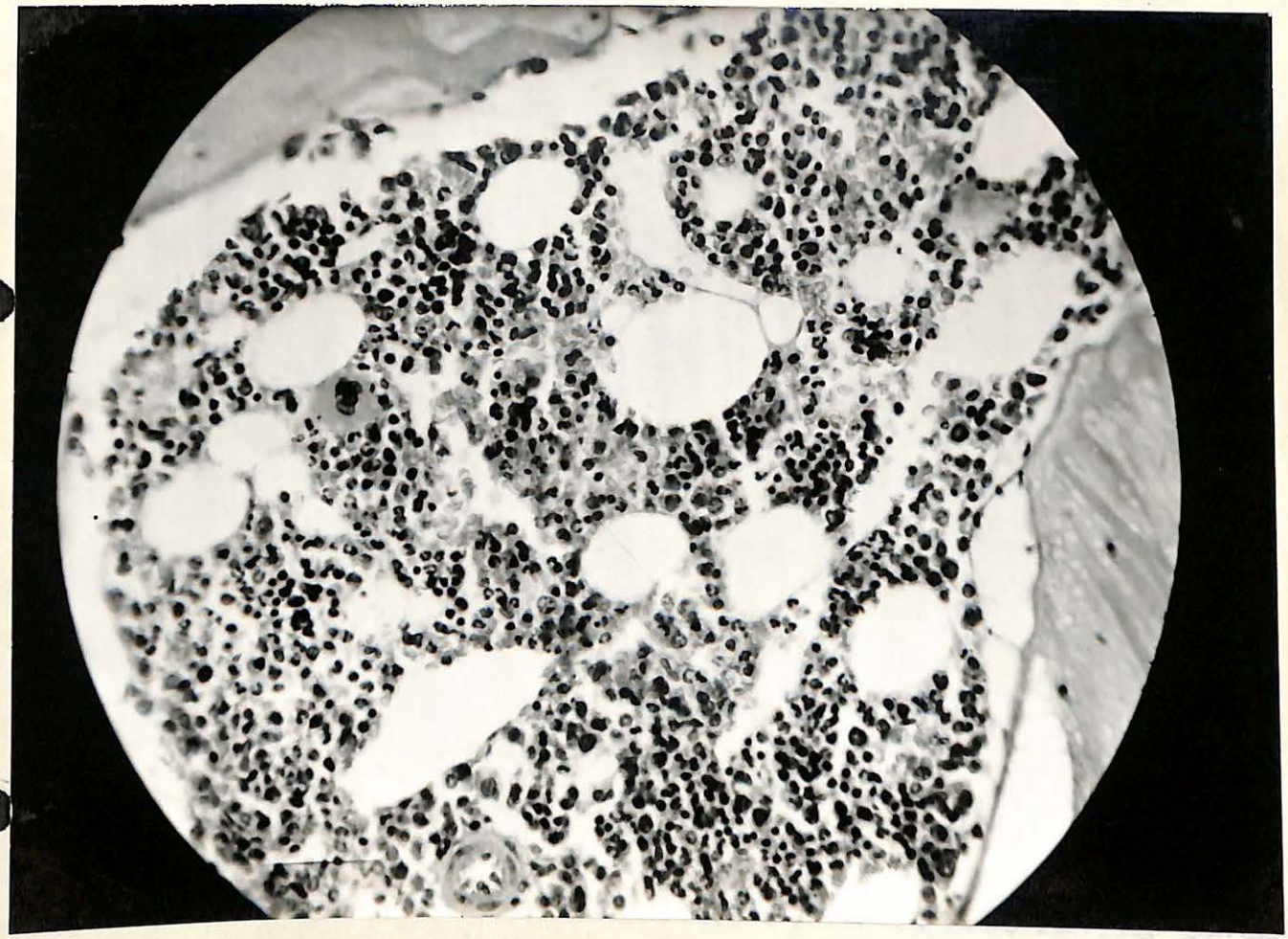

PLATE V. RIB MARROW (DOG)
60 DAYS AFTER TOTAL BODY RADIATION (350 R)

similar picture. Within a matter of hours after irradiation is given, the first signs of cellular degeneration with loss of cell detail, pyknosis and nuclear fragmentation is observed in the nodes. This continues throughout the following six to ten days with the wiping out of the germinal centers, leaving an apparently degenerate reticulum. This degenerative change is followed by a fall in the circulating lymphocytes to a very low level.

As in the bone marrow, signs of regeneration appear in the form of small islands of cells which start to reappear in four to six days after the period of complete depression. Again the process is very slow and gradual with the normal type of architecture of the node not being regained until some five weeks later in rat specimens, and considerably later in the dog.

The amount of destruction and the degree of damage are also proportional to the x-ray dosage employed, but as in the marrow, regardless of dose, the relative time factors are the same.

The Spleen:

The lymphatic structures in the spleen behave essentially the same as those described above, the period of regeneration appearing to be somewhat delayed over that observed in the lymph nodes. As late as 40 days, changes occur in the form of increasing cellularity of the pulp in the rat.

Islands of extramedullary myelopoesis have been reported in the rat as being formed during the reparative process. Such are not present

in the dog in the present study group.

An isolated finding in the healing and regenerative processes is the development of abundant iron pigmentation in the spleen following damage as shown by special stains. The possible explanation is the increased erythrocyte destruction during this period.

Stomach and Intestine:

The destruction of the epithelial tissue of the stomach and bowel has long been known to exist, as well as those physiological phenomena associated with it. This damage to the bowel in animals is again proportional to the amount of x-ray dosage. It occurs rapidly within a matter of hours and develops to a maximum extent in a matter of two to three days.

The changes observed following high exposure in dogs are an edema and hyaline appearance to the cells, engorgement with blood and in extreme cases actual desquamation of the mucous membrane in shreds. Hemorrhage into the involved area is not uncommon.

Healing is relatively rapid and is fully in progress within a few days after the initial damage. Residuals in the form of scarring are almost completely absent.

Some weeks after the initial damage, hemorrhage and subsequent ulceration into large areas of the bowel may occur (dogs), and be in themselves lethal.

Testis:

After a single lethal dose of x-radiation to the testis a gradual depression in sperm formation occurs. The first cells involved are the primary sperm cells which are adjacent to the walls of the tubule. These become swollen, lose their identity and disappear. They are followed in turn by the spermatogonia (spermatocytes), spermatids, and sperm which disappear by continuous maturation, so that for 20 to 30 days there is production of mature sperm. The Sertoli cells and stroma remain as the only remnants of the original active tissue. Later marked atrophy and shrinking of the entire organ occurs. The process is slow and gradual and requires weeks for its completion.

The time of regeneration or reformation is delayed, and, in a large number of instances, the complete return to normal function is not apparent.

Other Tissues:

As mentioned previously, the liver, lung, kidney, pancreas, heart, nervous tissue, skin, and muscle show no appreciable effect of a pathological nature except in those instances in which the dosage to a given area is extremely high.

C. Pathological Effects on Human Beings

The material presented below is subdivided into sections similar to those in the foregoing account. Much of the detailed description will be omitted due to gaps in the available information. For the

purpose of clarification a series of photomicrographs has been prepared illustrative of the changes described. Each group of pictures is preceded by a normal example for comparative purposes, so that the progression can be easily shown.

The radiosensitive tissues for the human are identical with those for the animal and consist of the bone marrow, lymphatic system, spleen, testis, and to a less conspicuous extent, the ovary. The primary changes in the bone marrow cause lethal effects elsewhere in the body in the form of infection, bleeding and anemia. Before starting on the descriptive account it can be generalized that aside from the immediate effects of burns, most of the early deaths (in the first three to four weeks) were caused by infection; during the next three to four weeks (with some overlapping of each series) deaths were related to hemorrhage and some infection; during the following time (up to several months) most deaths were related to severe anemia. With these generalizations in mind, descriptions of the changes in the various organs will now be made.

Bone Marrow:

Plate VI is a presentation of the normal state of resting femoral bone marrow. It consists essentially of a loose network of fat cells with interspersed islands of marrow cells in various stages of development. Both red and white cell series are represented. Occasional normal megakaryocytes are noted. There is no engorgement of the marrow by red cells. It must be again stressed that the femoral marrow as shown here has much more of a fat reticulum than the vertebral or rib

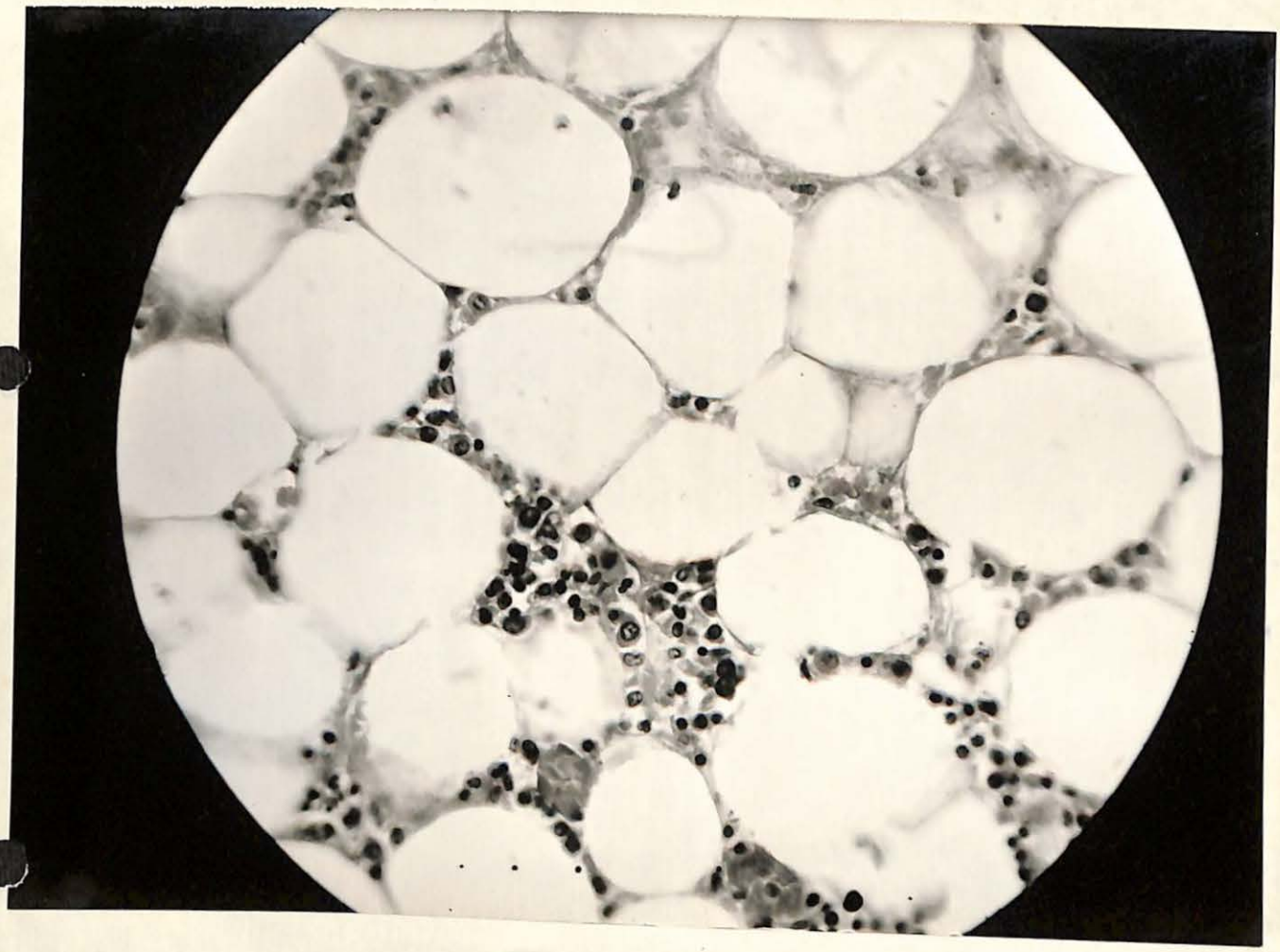

PLATE VI. NORMAL FEMORAL MARROW (HUMAN)

marrows seen previously in the dog slides.

Plate VII is the picture observed some 16 days after exposure. The reticulum seems to be the only persistent element being everywhere dotted with the pyknotic remnants of previously normal cells as well as nuclear debris. No active cell elements are noted. Shown also is some engorgement by red cells (much more conspicuous in other sections) actually at times being of hemorrhagic appearance. This picture compares with that shown in Plate III of the dog marrow at 14 days.

Unfortunately, there is no intermediate stage in this series showing the relative initial appearance of new islands of formative cells. This will be demonstrated in a subsequent report. For orientation, one should refer to Plate IV of the dog marrow taken at 28 days. This shows at first glance a degenerative appearance but on closer scrutiny small islands of what appear to be undifferentiated cells on the reticulum are seen.

Plate VIII shows the hyperplastic picture of the marrow during the recovery phase, and compares with the dog at 60 days. Note the return of abundant white blood cells of all types and descriptions, as well as islands of red cell formation. The fatty reticulum is almost completely replaced with marrow cells. Megakaryocytes are again present and blood platelets normal. One item of difference between the dog and human which must be mentioned is the relative decrease in the numbers of erythroid elements which are regenerated. This has not

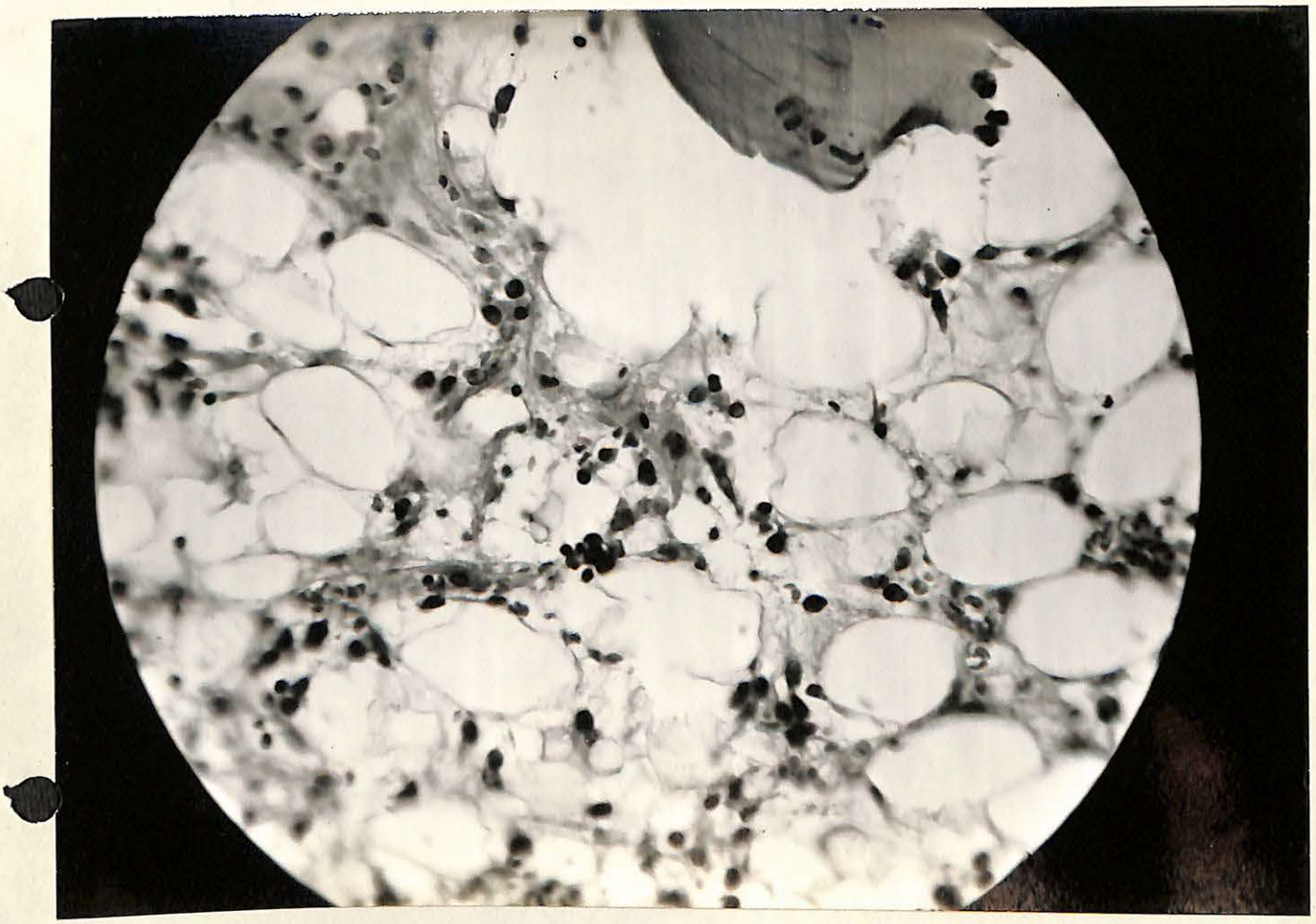

PLATE VII. FEMORAL MARROW (HUMAN)
16 DAYS AFTER EXPOSURE TO ATOMIC BOMB (HIROSHIMA)

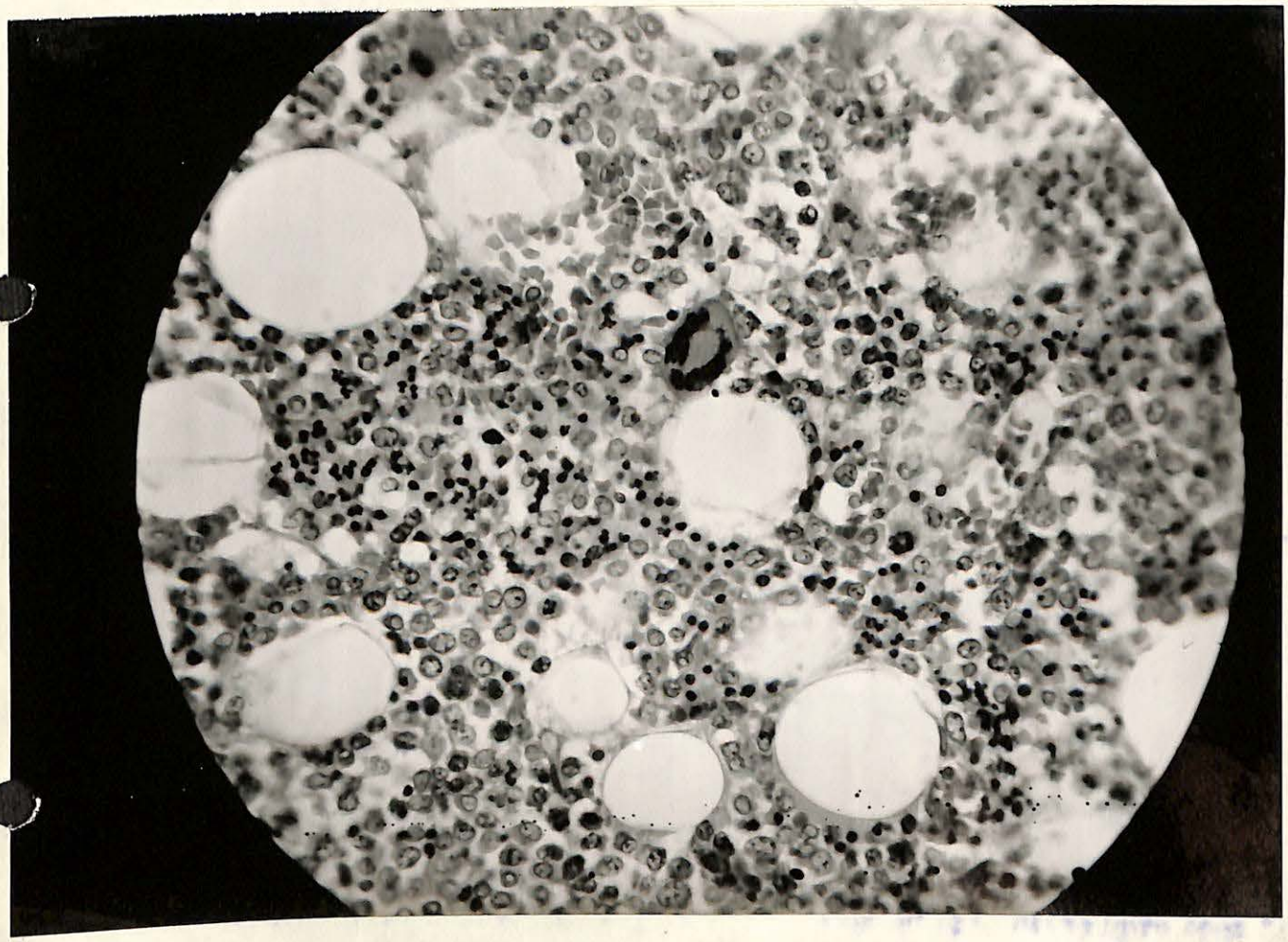

PLATE VIII. FEMORAL MARROW (HUMAN)
60 DAYS AFTER EXPOSURE TO ATOMIC BOMB (HIROSHIMA)

occurred in other species which have been studied to date (including the monkey). One might speculate that the lack of red cell formation in these people was related to a nutritional deficiency present prior to and during the radiation effect.

Effects Caused by Bone Marrow Depression:

First Period: During the early period (one to four weeks) following exposure, there is a depression of the leucocyte count from its normal of 8,000 cells per cubic millimeter to extremely low levels. This gives a chance for the development of infections in all parts of the body with the invasion of tissues by pathogenic and non-pathogenic bacteria. This will be discussed at some length.

Infections of the skin, particularly around the mouth, were described by Japanese physicians. These appeared in the form of shallow confluent ulcerations exuding greenish pus of a sweetish, fetid odor. Various types of buccal cavity ulcerative lesions were common, extending from a mild gingivitis with shallow ulceration to a complete aphthous stomatitis, tonsillitis, pharyngitis, and even to the involvement of the epiglottis, larynx, and trachea. Such a state is most commonly termed an agranulocytic angina. All types of this state were seen by the Japanese and pathological specimens of it preserved, but by the time of arrival of the American investigating party, only residual and recovering cases were noted. Several cases of noma or gangrene of the mouth were seen, some responding well to penicillin treatment. No pathological material suitable for photography is included in this series.

Frank sepsis with many forms of bacteria was also encountered. This was usually of a fulminating type. In subsequent slides of tissues, it is possible to distinguish numerous bacterial clumps with, however, almost complete absence of the normal leucocytic responses around them. Pneumonia, various types of ulcerative gastro-enteritis, and the like were found during this period.

Second Period: Following the period characterized by predominance of infections and coupled to some extent with it, was a more prolonged period in which bleeding into the various tissues and areas of the body was noted. This was associated with profound platelet deficiency related to the almost complete destruction of the megakaryocytes of the marrow. Hence the picture of a profound thrombocytopenic purpura is noted.

Petechiae and ecchymoses of various sizes were observed in all areas of the skin, serous surfaces, mucosal membranes and the like. Frank hemorrhage occurred in the lung tissues, the kidney, brain, bowel, etc., with symptoms of them being quite pronounced in the clinical picture. A few examples of these phenomena are shown in the following plates and description. Each tissue in turn is preceded by a normal example for comparison.

Plate IX shows a normal lung. Plate X shows a section of lung with the alveolar walls still well marked but copious amounts of serum and red blood cells have exuded into the cavities. Note the almost

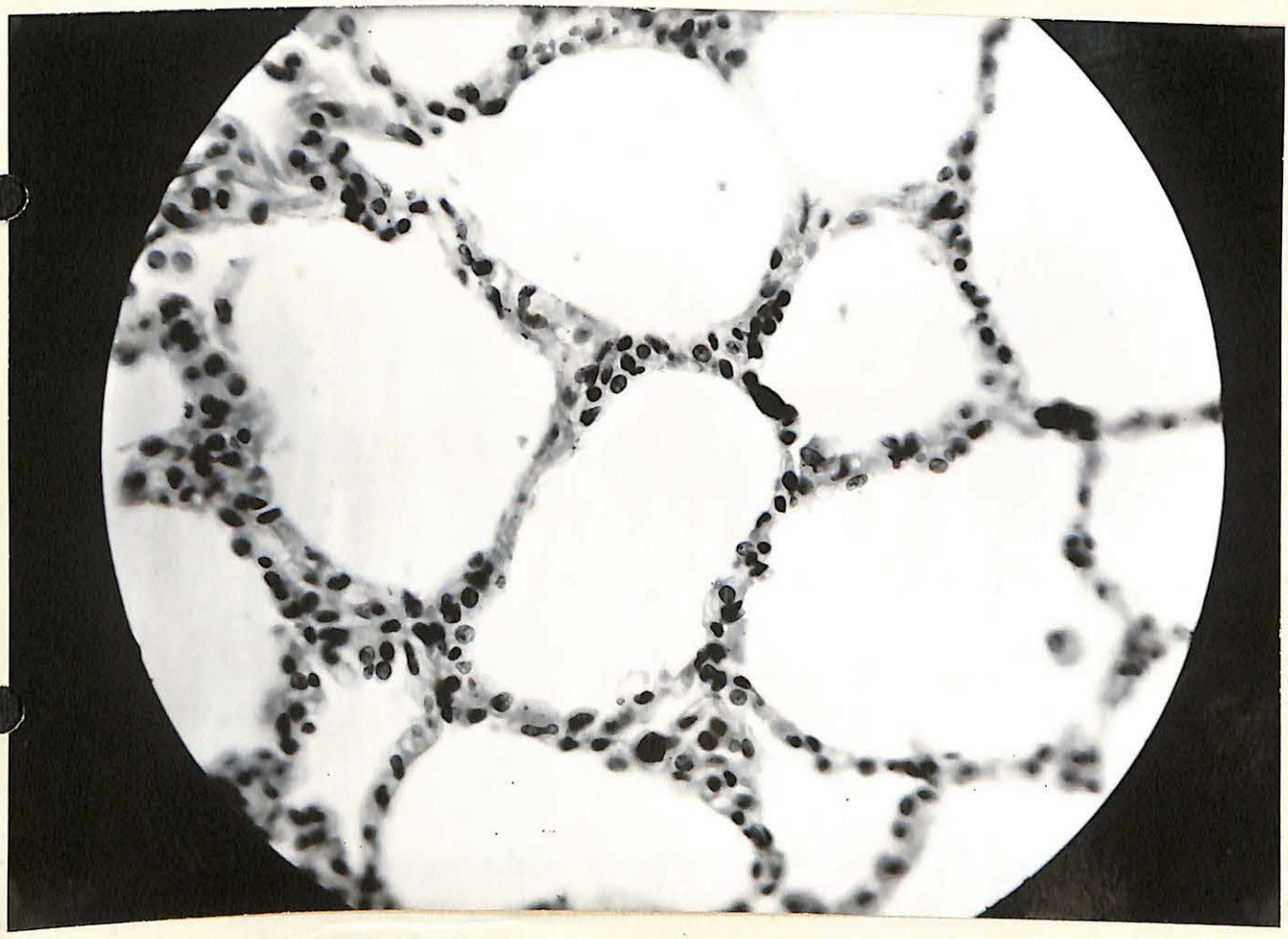

PLATE IX. NORMAL LUNG (HUMAN)

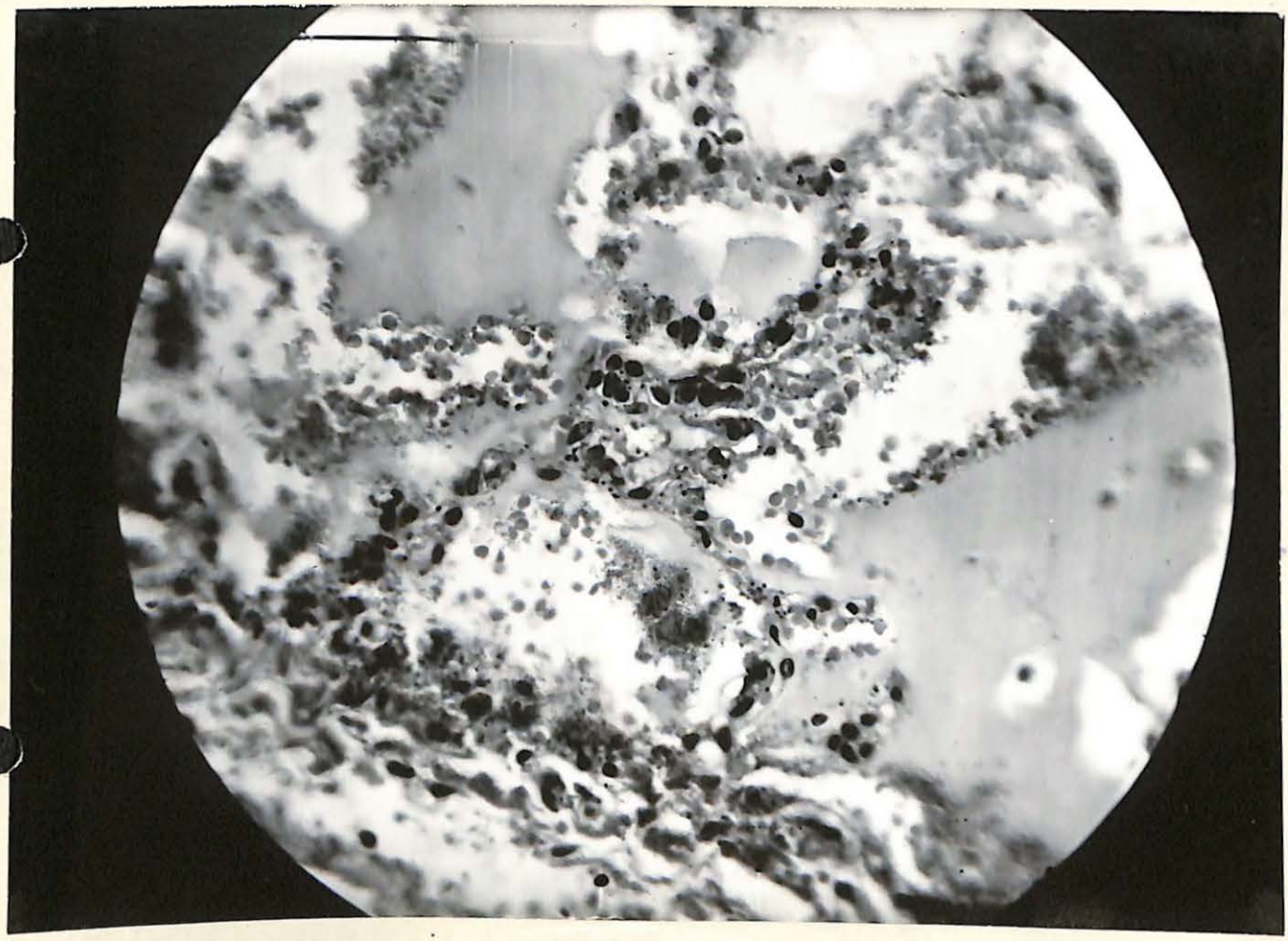

PLATE X. LUNG (HUMAN)
18 DAYS AFTER EXPOSURE TO ATOMIC BOMB (NAGASAKI)

complete absence of white cell elements. Clumps of bacteria are shown throughout as well. Plate XI shows a further process in the development of gangrene of the lung with complete loss of cellular detail and the entire area flooded with red blood cells.

Plate XII shows a normal stomach with the capillary arcades well marked out. Plate XIII shows hemorrhage into that area which consists of a liberation of red cells through the normal capillaries to form the overlying ecchymosis. Again note the absence of white blood cells. All sections throughout the areas of hemorrhage are similar, and when coupled with the leucopenia already in effect produce the picture shown above.

Third Period: Very little data are available on this so-called third stage of the series of pathological events following marrow depression, the stage of anemia. It is characterized by a failure of red blood cell formation, while at the same time, the white blood cell series and lymphocytes have returned to normal levels.

Individuals in this group develop a profound anemia and in spite of blood transfusions to which they react poorly, die with erythrocyte counts of less than one million per cubic millimeter.

Pathological examination of these individuals limits the picture to the bone marrow and the effects of anemia elsewhere. Tissues are markedly pale and bloodless. No bleeding tendencies are apparent.

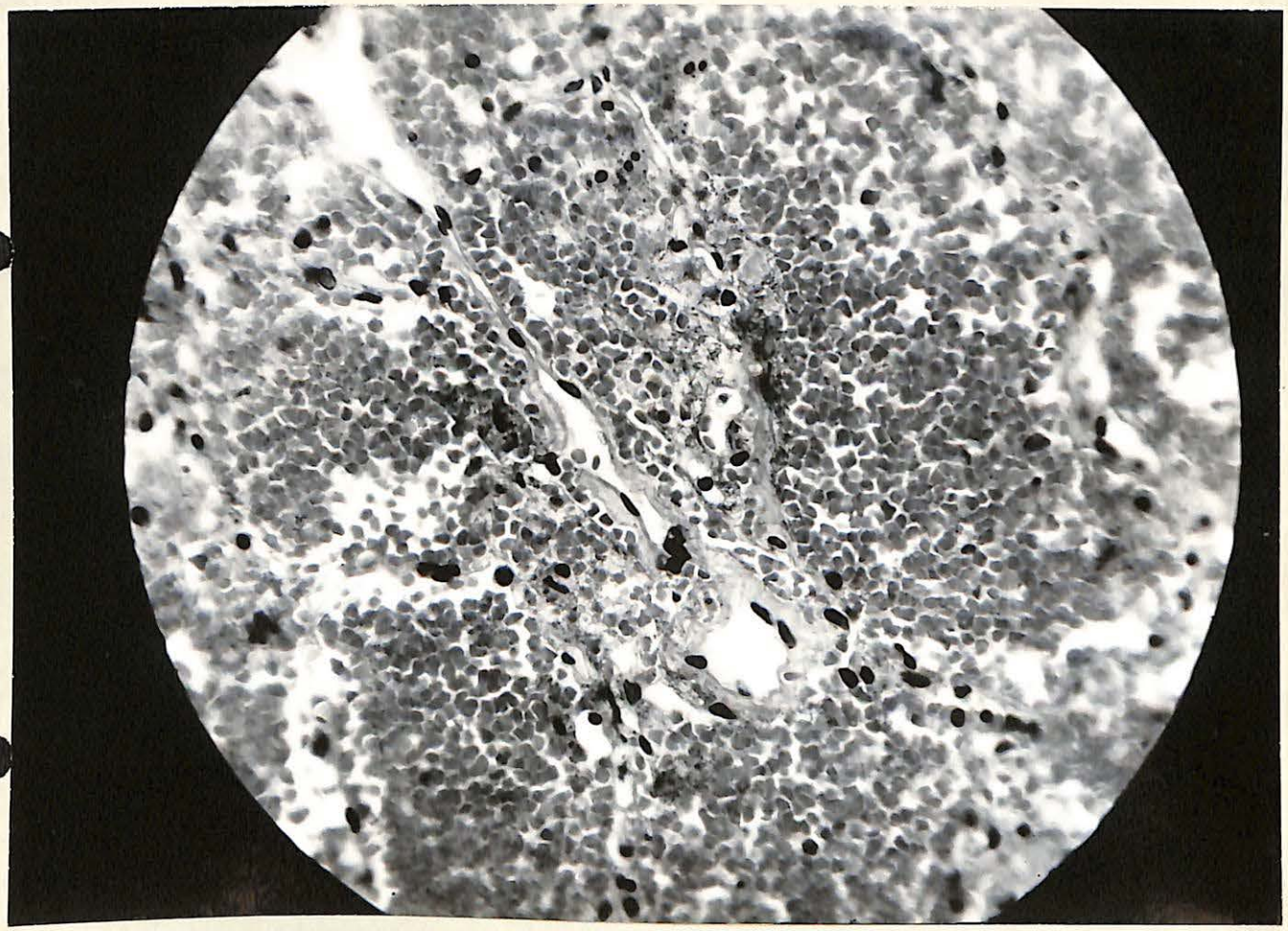

PLATE XI. LUNG HUMAN
16 DAYS AFTER EXPOSURE TO ATOMIC BOMB (HIROSHIMA)

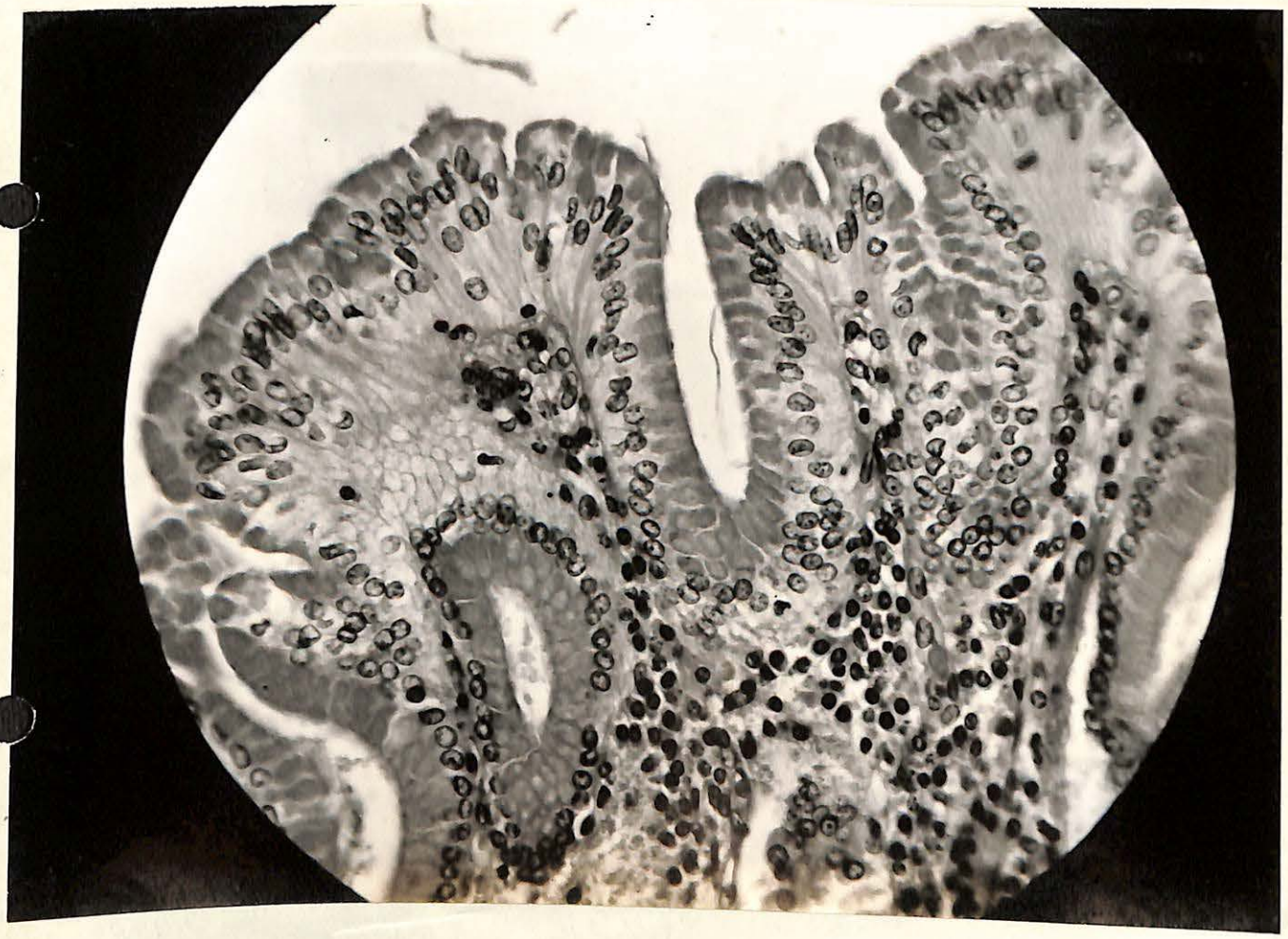

PLATE XII. NORMAL STOMACH (HUMAN)

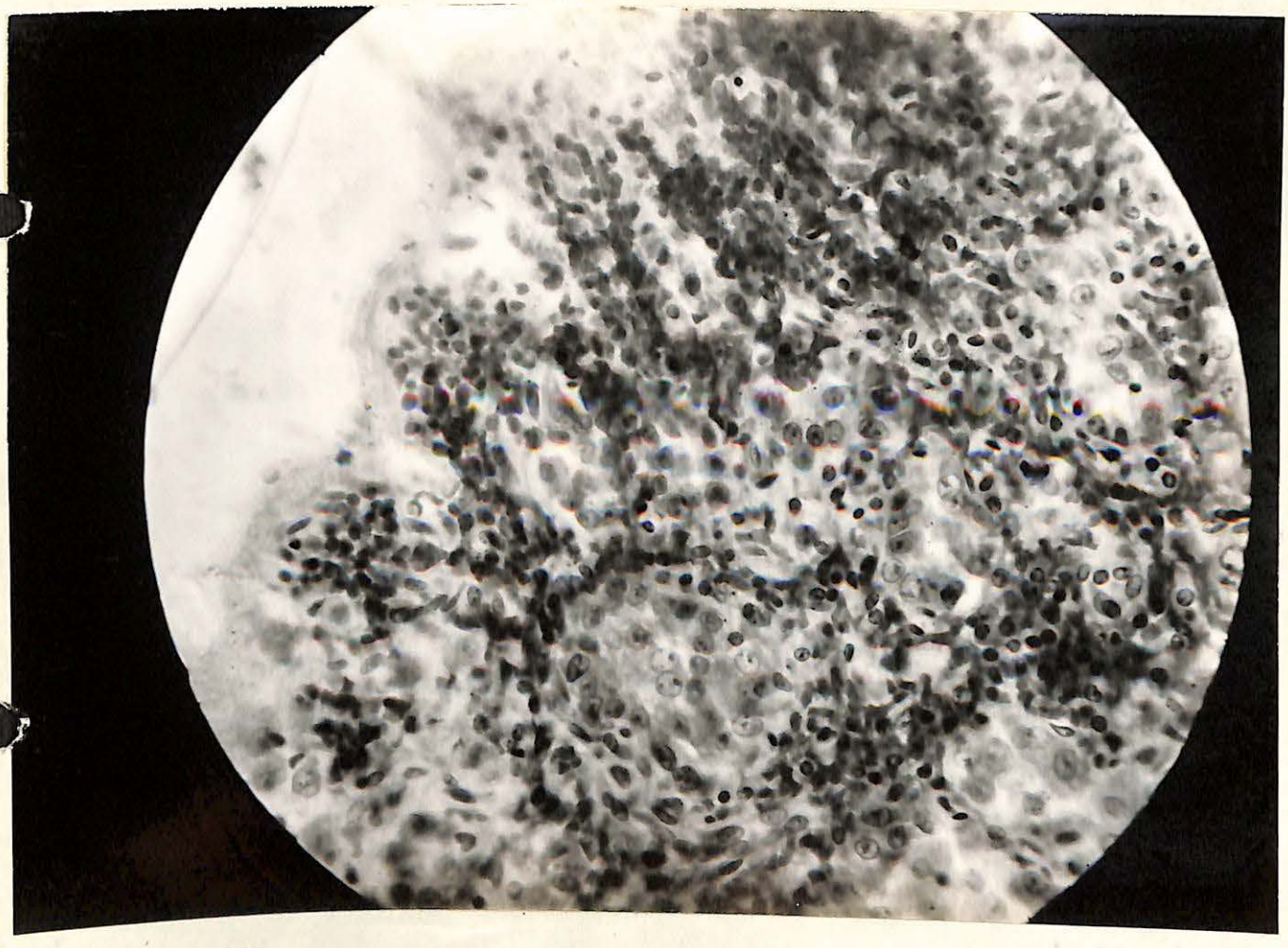

PLATE XIII. STOMACH (HUMAN)
28 DAYS AFTER EXPOSURE TO ATOMIC BOMB (HIROSHIMA)

The bone marrow is of a gelatinous or yellowish color and packed with all forms of the myelocyte series in apparently normal distribution. However, there is a conspicuous absence of erythroid forms. Marrow smears show a similar picture. Death is obviously due to the profound anemia. Speculation, as mentioned before, of a related nutritional deficiency must be raised due to the general nutritional status of the affected individuals. This phenomena has not been observed in animals.

Lymphatic Tissues:

As has been previously noted, the lymph nodes in various parts of the body are affected almost immediately following irradiation with a complete loss of cellular detail, leaving a stroma occupied with degenerating cells. Again, examples of this initial picture are absent, the earliest material showing the beginning of lymphopoesis.

The lymph nodes in the gross at approximately the two week period are soft and flabby with loss of structural detail. The microscopic picture is noted below.

Plate XIV shows a normal lymph node with well defined germinal centers and pulp filled with mixed red cells and adult lymphocytes. Plate XV shows a hypoplastic node without conspicuous follicles. In the cortical region there is some early indication of lymphocyte formation as indicated in blast forms and small and medium lymphocytes. The pulp is filled with erythrocytes in increased numbers and in some cases there is a hemorrhagic tendency. This slide (18 days) indicates the beginning of the reparative process. Plate XVI shows a little later

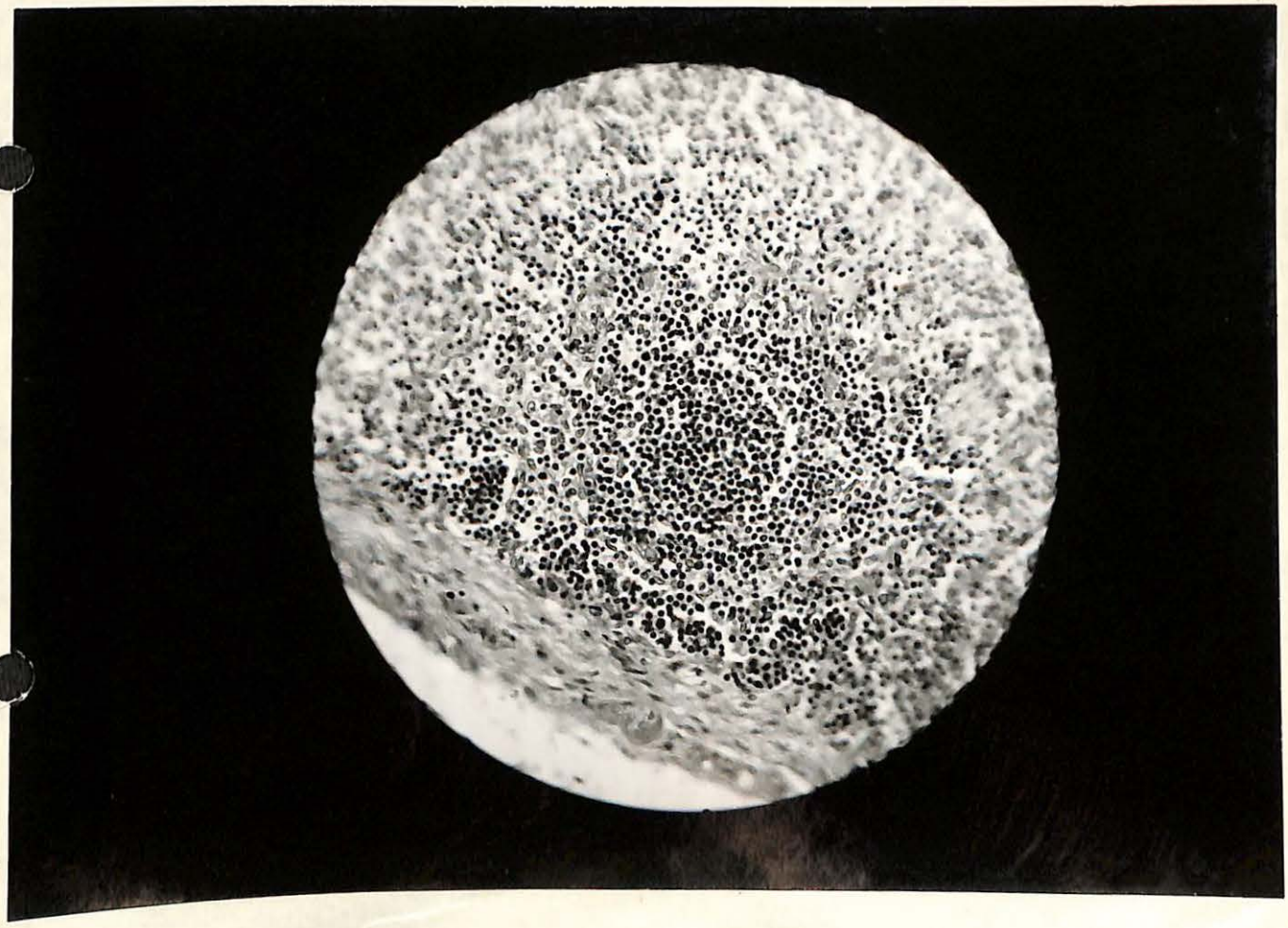

PLATE XIV. NORMAL LYMPH NODE (HUMAN)

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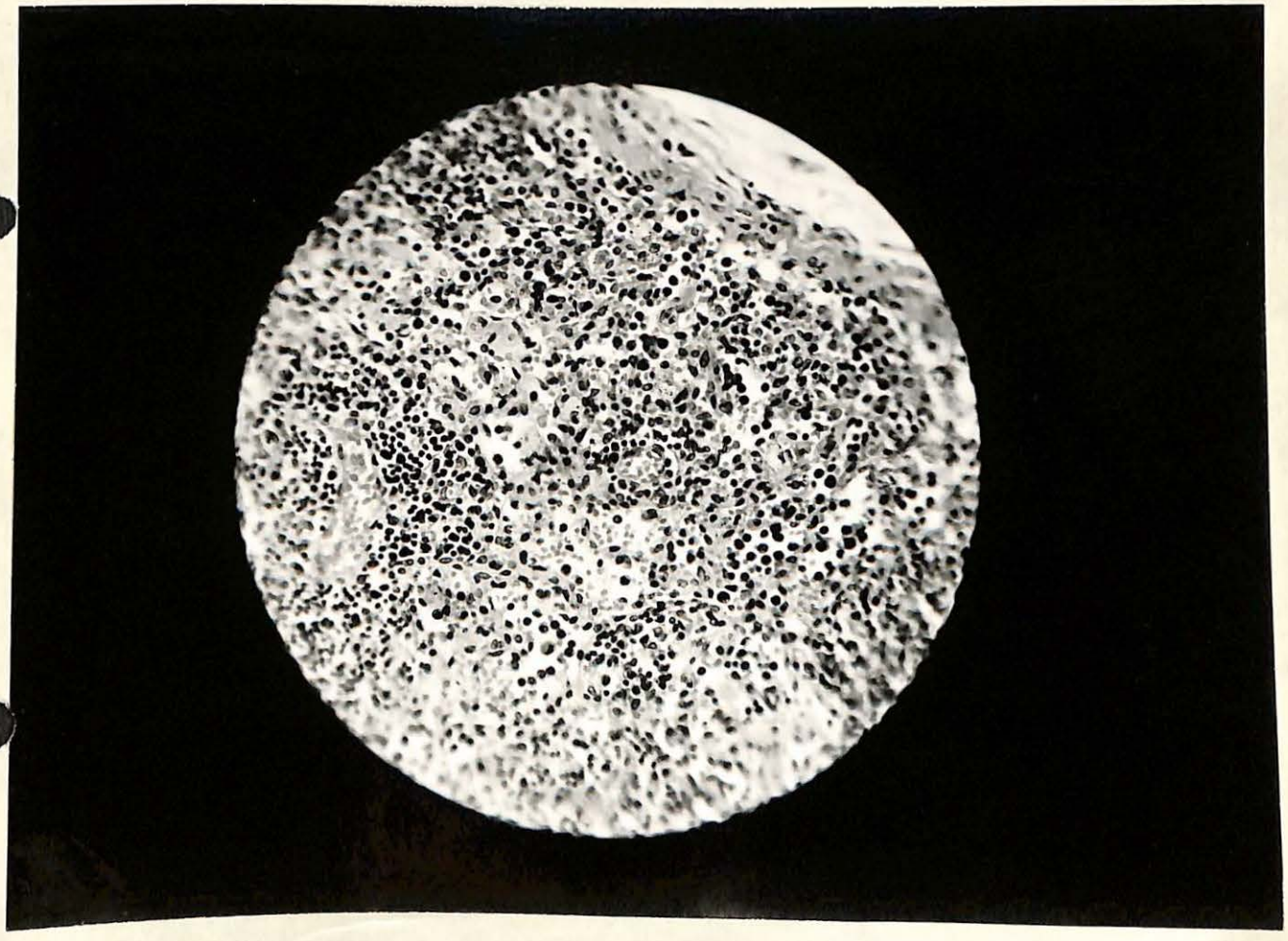

PLATE XV. LYMPH NODE (HUMAN)
24 DAYS AFTER EXPOSURE TO ATOMIC BOMB (HIROSHIMA)

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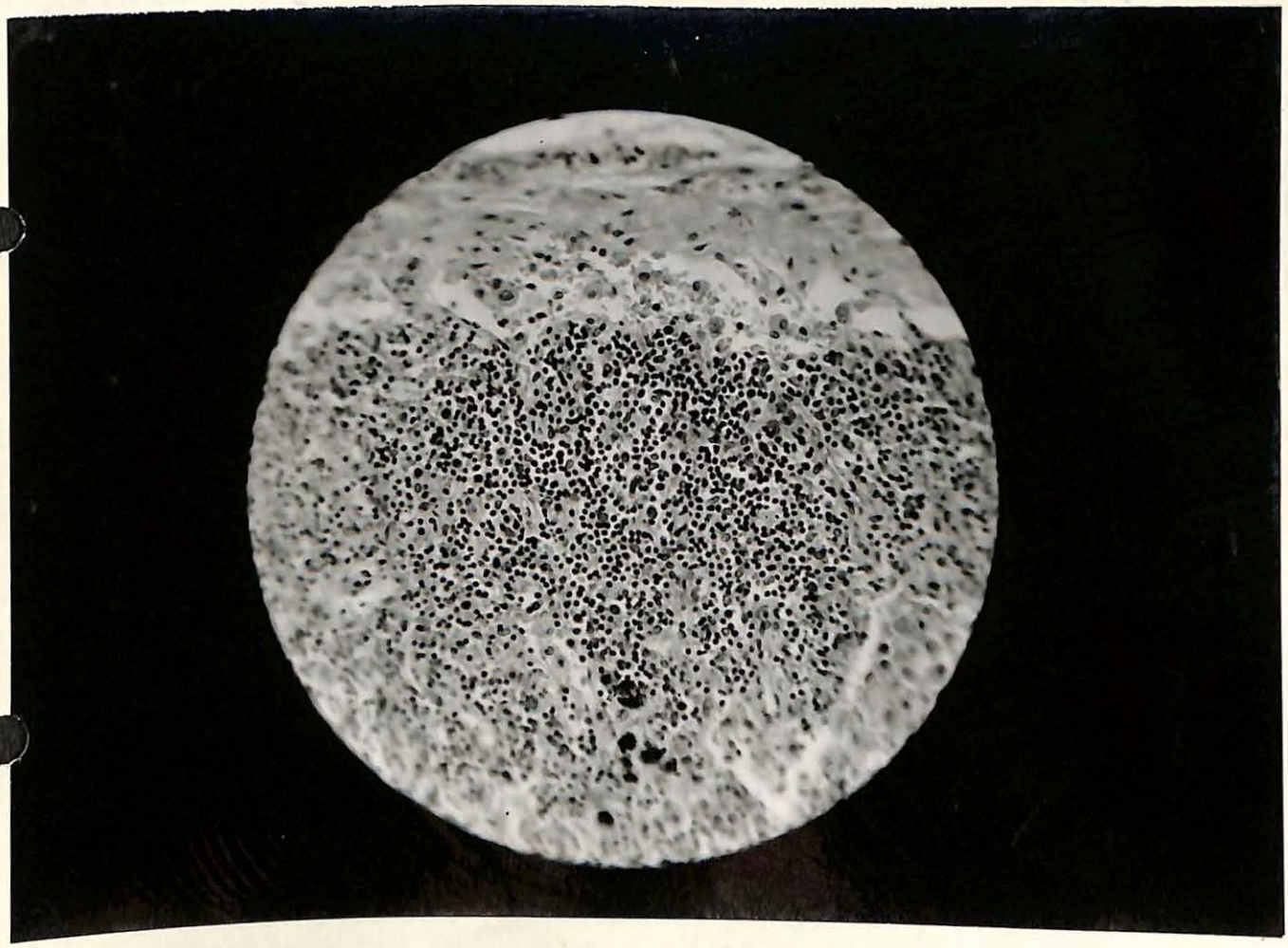


PLATE XVI. LYMPH NODE (HUMAN)
28 DAYS AFTER EXPOSURE TO ATOMIC BOMB (HIROSHIMA)

stage at 28 days, at which time the germinal centers are showing a tendency to round up the follicles with the development of mature forms. Later stages (60 days) show the presence of normal lymphatic structures.

During the first few weeks with the profound softening of the lymphatic areas in the intestine, some ulceration and infection was noted.

The blood picture as described reflects perfectly the pathological state of the lymph nodes at a given period. Complete early depression and reappearance of normal forms coincide with the degenerative and regenerative phases in the nodes.

Spleen:

The sequence of events in the spleen parallels that observed in the lymph nodes and is illustrated in the following plates. Plate XVII shows a spleen from a normal individual. Plate XVIII is a spleen 18 days after radiation. There is a pronounced lack of lymphoid elements here, and the follicles can be made out only with difficulty. An increased amount of blood is noted in the pulp. Around central vessels are a few cells which appear to be blast forms surrounded by small lymphocytes. An occasional larger cell of foreign appearance (? reticulum cell) is noted. Plate XIX shows the status at 28 days with the attempted rounding up of cells into follicles and the presence of mature forms. The large cells of questionable reticulum type are still in evidence.

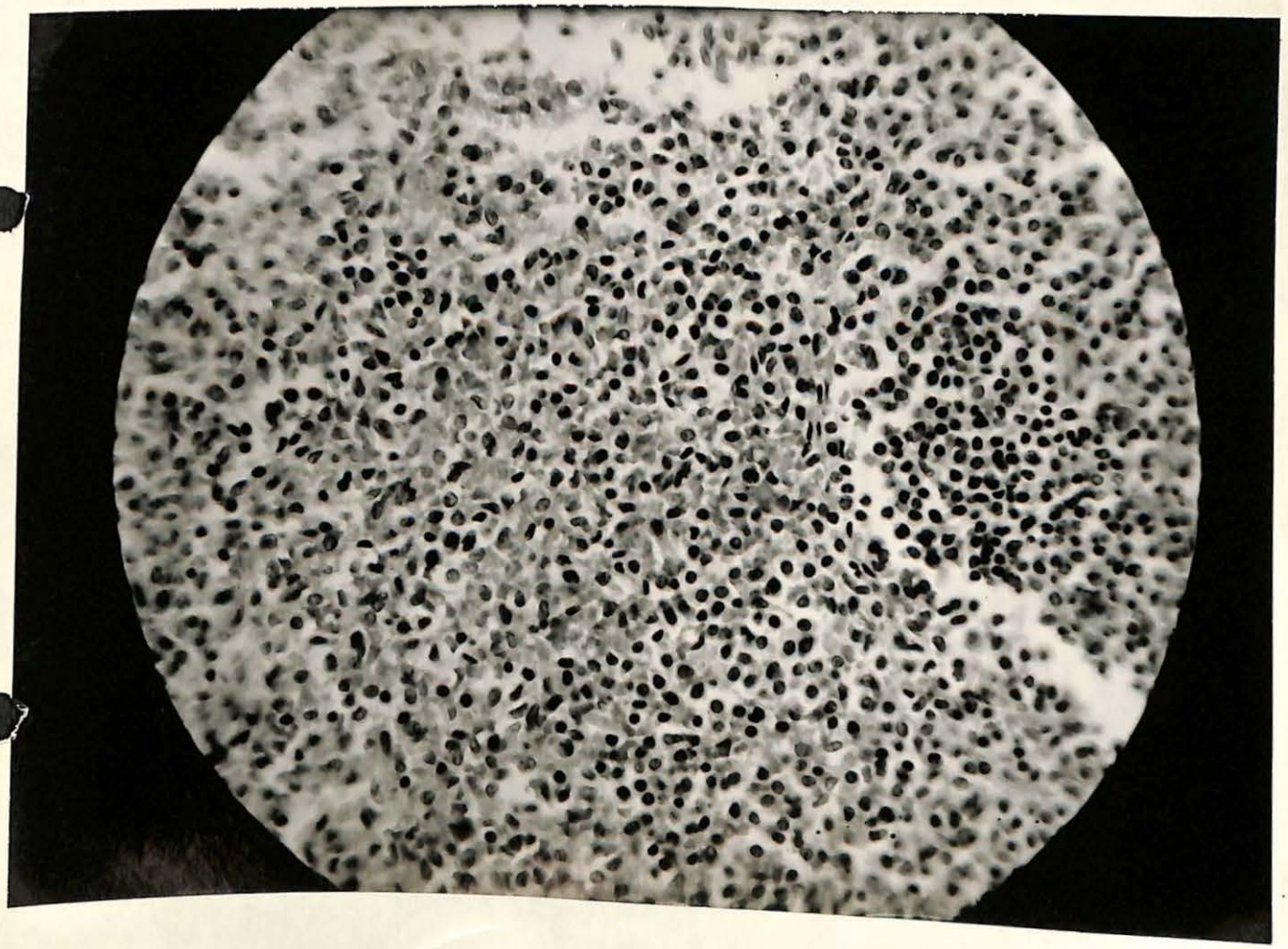


PLATE XVII. NORMAL SPLEEN (HUMAN)

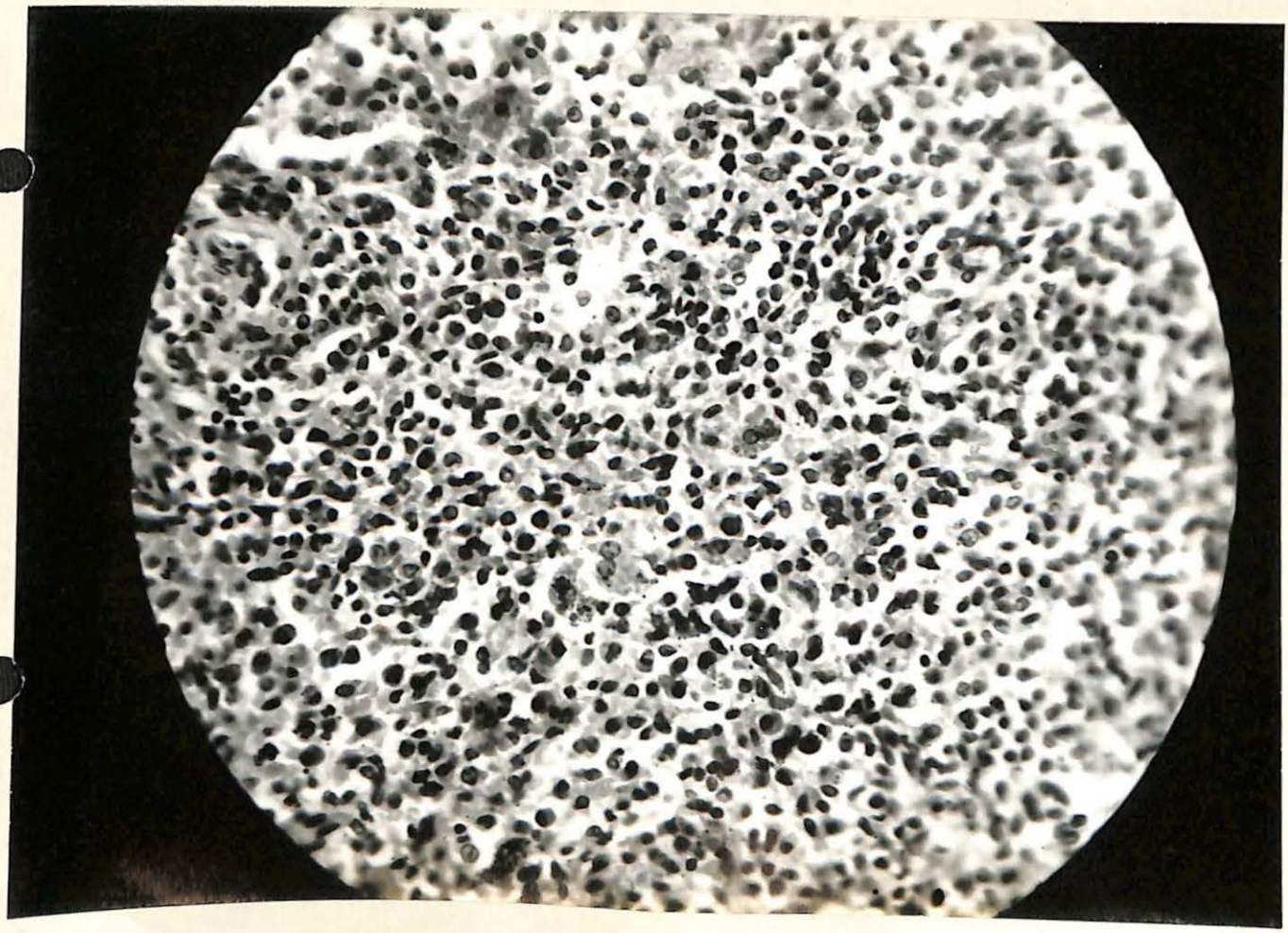


PLATE XVIII. SPLEEN (HUMAN)
18 DAYS AFTER EXPOSURE TO ATOMIC BOMB (HIROSHIMA)

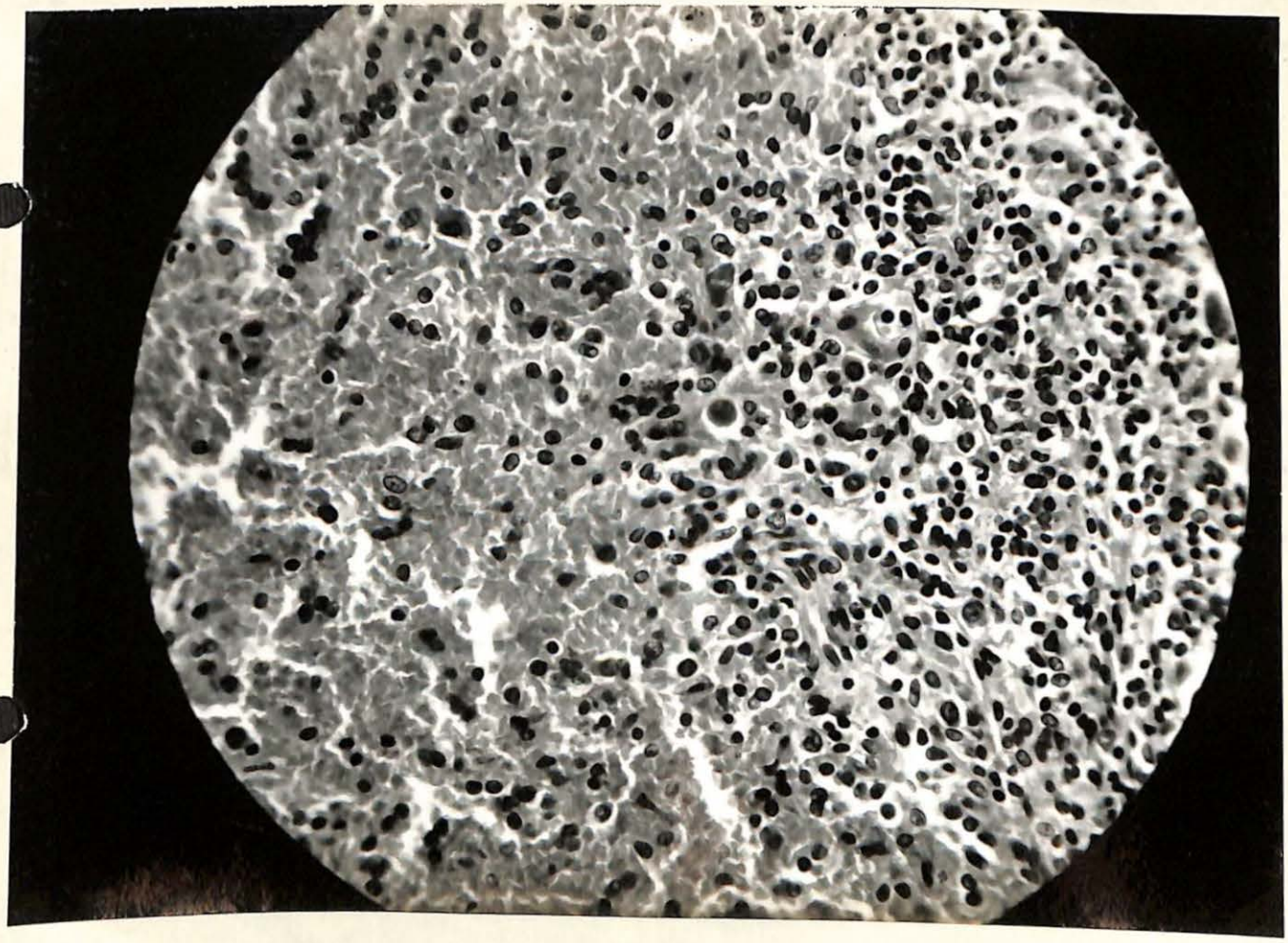


PLATE XIX. SPLEEN (HUMAN)
28 DAYS AFTER EXPOSURE TO ATOMIC BOMB (HIROSHIMA)

An additional finding in such spleens is the abundance of iron deposition in a large number of them. This is demonstrated conspicuously by iron stain and is probably related to increased red cell destruction in these individuals.

Testis:

Examination of the limited amount of testicular material in this series for profound effects is somewhat disappointing. For the nature of the progressive changes it is necessary to refer again to the animal data. One specimen at 18 days is worthy of comment and is illustrated below.

Plate XX shows a normal testis with all cellular elements intact. Plate XXI shows a specimen at 18 days in which the Sertoli cells appear healthy and active. The primary germinal elements appear somewhat degenerate and reduced in number. The spermatogonia, spermatids, and sperm appear normal, although reduced in amount.

Later specimens of testes not shown demonstrate marked atrophic changes with only active interstitial cells and reticulum.

Ovary:

The ovarian material is also limited. Sections examined showed the presence of an occasional small ovum, and it is impossible to interpret the findings. A better picture will be gained from the examination of the physiological effects as recorded elsewhere.

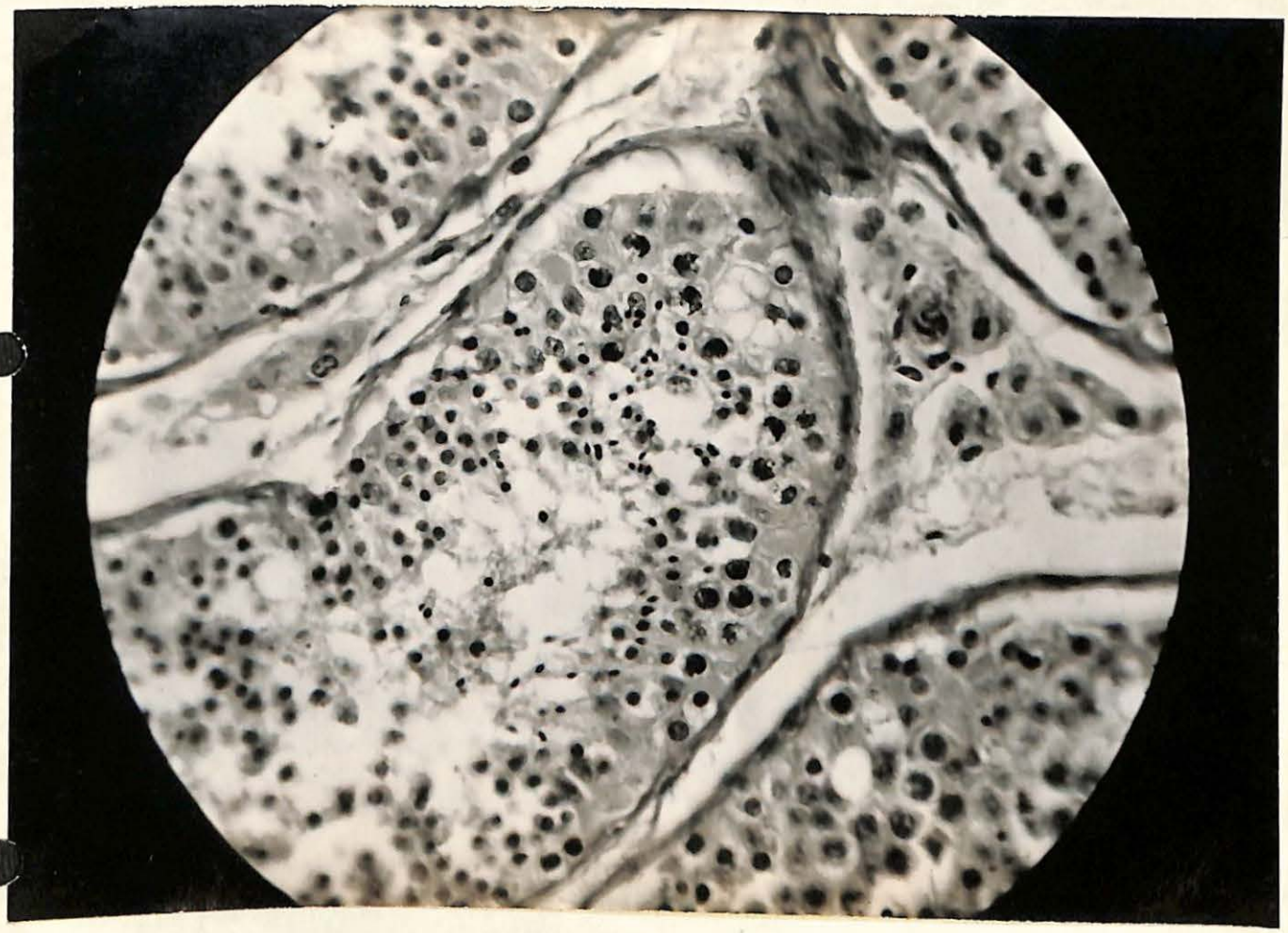


PLATE XX. NORMAL TESTIS (HUMAN)

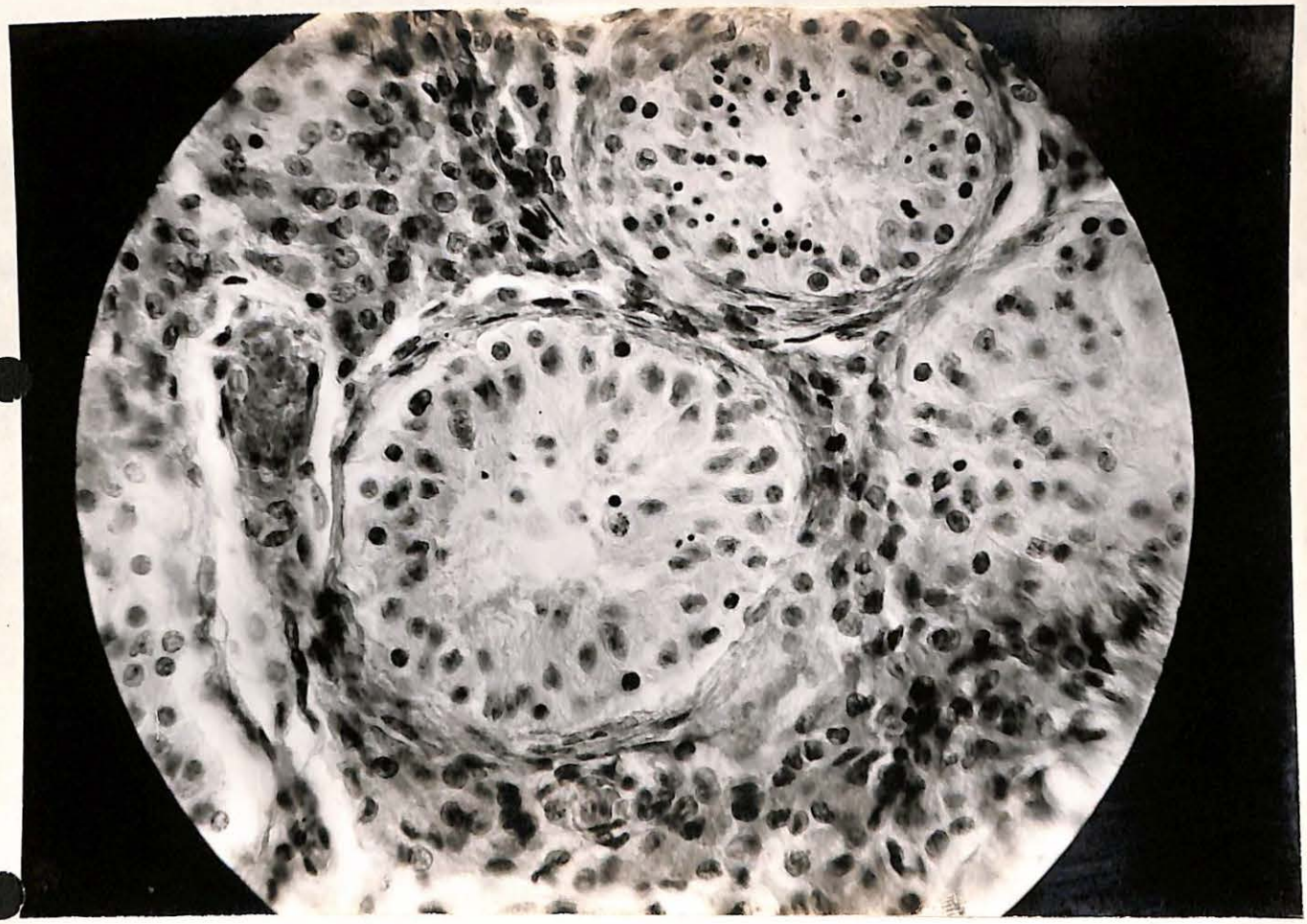


PLATE XXI. TESTIS (HUMAN)
28 DAYS AFTER EXPOSURE TO ATOMIC BOMB (NAGASAKI)

Stomach, Intestine and Colon:

The predominant observation in the bowel, aside from mucosal hemorrhage, is the appearance of superficial spotty ulceration with overlying membrane in the lower intestine (ileum), caecum, and colon. The sigmoid region was usually markedly involved. The process by which this ulceration appeared seemed to be that of an initial hemorrhage followed by erosion of the overlying ischemic mucosa. At times such ulceration gave a herringbone appearance. The microscopic sections examined invariably are too autolysed to allow accurate interpretation.

Changes are also described in the stomach, duodenum, and jejunum which may be related to atrophy with resulting reduction in the height of the columnar epithelium. From the sections studied, this change is admixed so completely with autolysis to render accurate opinion impossible.

Epilation:

This is a phenomenon characteristic of the human reaction long known to radiologists who have used x-ray as a depilitory agent. A brief description of the gross nature of this finding in the casualties is worth mention (see Photographs, Part I). In approximately 7 to 11 days following the explosions and later in many individuals, the loss of hair from the scalp, especially, face, arms, and legs became apparent. The loss is of a diffuse nature over the hirsute area, the individual hairs becoming loosened and dropping out. Interspersed are hairs of

greater viability so that particularly in women casualties with long uncombed hair, the entire mass of hair is held in place by sparse scattered long hairs, the areas of epilation appearing between them. The process develops with moderate slowness requiring some days for completion.

Sections taken through the epilated areas show atrophy and loss of conspicuous cellular identity of the sweat glands and hair follicles. Some edema appears in the skin and underlying connective tissue. Bacterial clumps may be present in cases having profound leucopenia. Only several sections are available of this material and it is difficult to formulate an accurate opinion of the nature of the process.

Gamma Radiation of the Skin:

The delayed effect of gamma irradiation to the skin is also well known to appear in the form of an erythema several weeks after exposure, and in some instances, as a burn. It must be stated at this time that no material is available which would indicate that such erythemas and burns did occur from the bomb explosions. All burned areas examined gave histories of radiation (heat) or fire burns to the body, an obvious casual relationship.

Other Pathology:

The previously mentioned pathological discussion deals rather completely with the specific findings of medical interest related to the atomic bomb. Other changes of possible nutritional, degenerative infections and parasitic nature were observed. In this brief report, however, all these are omitted for the obvious purposes of clarity and brevity.

CHAPTER IV

Conclusion

Chapter IV - Conclusion

In conclusion of this discussion, it is apparent that the positive pathological findings other than those associated with blast and heat burns are directly connected with the effect of gamma (and neutron) irradiation of tissues sufficiently sensitive so as to demonstrate rapid lethal or damaging effects. For comparative purposes, it is feasible to summarize the data recorded in the body of this report in tabular form. In the following chart, degeneration or pypoplasia is recorded numerically from one to four, the larger numbers indicating increasing severity of the reaction. Regeneration in turn is recorded in the same fashion with the larger numbers indicating more complete return to the normal state. Additional data on the monkey are appended for comparative purposes.

Days Following Exposure	Site: Bone Marrow	Lymph Node	Spleen	Testis
17 - 18 days				
Human	Hypoplasia 3 Regeneration 0	Hypoplasia 3 Regeneration 1	Hypoplasia 3 Regeneration 1	Degeneration
Dog	Hypoplasia 4 Regeneration 0	Hypoplasia 2 Regeneration 2	Hypoplasia 2 Regeneration 2	Degeneration
Rat	Hypoplasia 2-3 Regeneration 0-2	Hypoplasia 1-2 Regeneration 2-3	Hypoplasia 1-2 Regeneration 2-3	Degeneration 2-3
Monkey	Hypoplasia 2-3 Regeneration 0	No data	Hypoplasia 3 Regeneration 1	Immature
28 days				
Human	Hypoplasia 2 Regeneration 1	Hypoplasia 1 Regeneration 1	Hypoplasia 1 Regeneration 2	Degeneration 1-2
Dog	Hypoplasia 1 Regeneration 2	Hypoplasia 1 Regeneration 4	Hypoplasia 1 Regeneration 4	Degeneration 1
Rat	Normal	Normal	Hypoplasia 1	Degeneration 1-2
Monkey	Regeneration 3-4	Hypoplasia 1 Regeneration 3	Hypoplasia Regeneration 3	Immature
55 - 60 days				
Human	Normal ? erythroid elements	Hypoplasia 2 Regeneration 2-4	Hypoplasia 0-2 Regeneration 2-4	Degeneration 4
Dog	Normal	Normal	Normal	Degeneration 2
Monkey	Normal	Normal	? Hypoplasia	Immature

Appendix I - Report I

Preliminary Report Of Findings Of Atomic Bomb Investigating Groups At Hiroshima And Nagasaki

PRELIMINARY REPORT OF FINDINGS OF ATOMIC BOMB INVESTIGATING GROUPS AT HIROSHIMA AND NAGASAKI

Introduction

This report is based upon a preliminary evaluation of the data obtained by the atomic bomb investigating groups at Hiroshima and Nagasaki and upon impressions gained while doing the work. It contains some preliminary tables and some general conclusions which may be altered when a detailed analysis of the data is completed.

The data obtained fall generally into three distinct categories, which are, however, interdependent, and these are reported in three sections.

Section I. Medical report. A description of the effects of the bombings on the inhabitants of the two cities is given with a discussion of what caused the various effects insofar as this could be determined from the findings of this group.

Section II. Radioactivity measurements. Measurements of the intensity of radioactivity at the time of the investigation with delineation of the areas showing activity are shown on plots and the methods of counting and the significance of the findings related to the effects on patients are discussed.

Section III. Damage estimates. Estimates of the various degrees of structural damage in the two cities is shown on zone maps and the relation of these findings to physical injuries of patients is discussed.

SECTION I. MEDICAL FINDINGS IN HIROSHIMA AND NAGASAKI.

A. Purpose of study. To determine the actual effects of the atomic bombs on the people of Hiroshima and Nagasaki, and, insofar as possible, to determine to what the effects were due and how many people were injured.

B. Methods. Most of the data were derived from the following lines of investigation:

1. Examination of patients still living.

2. Analysis of records of patients who had died or were not available for examination for other reasons.

3. Autopsy material.

4. Tabulations of data and opinions of Japanese investigators who had studied the earlier patients.

C. Results. The results are given in the following paragraphs:

1. Symptoms and laboratory findings. The symptoms and laboratory findings in patients at Hiroshima and Nagasaki fall into two general groups. The first group includes the immediate effects due to burns and other physical injuries and will be discussed under F below. The second group of findings began after a latent period varying from 3 to 30 days. The important symptoms and physical findings were epilation, severe ulcerative lesions of the mouth and throat, hemorrhagic manifestations including petechiae, severe gastrointestinal symptoms, and rapid and extreme emaciation. Deaths occurred throughout a period extending from 1 week to 2 months after the explosion with the greatest number occurring about 1 month after. The important laboratory findings related primarily to disturbances in the hematopoietic function manifested by leucopenia, anemia, and thrombocytopenia. The most striking findings at autopsy were signs of destruction of the bone marrow and the lymphatics, ulcerative lesions of the colon and rectum; and signs of hemorrhage throughout the viscera. In these cases in general, the earlier the symptoms appeared the more severe was the case, and on this basis they can be divided into three groups. The details of the symptoms, laboratory data, and autopsy findings in patients of these three groups are shown in Table I, a,b, and c.

Table I,a.

Symptoms in Patients showing Delayed Effects.

Day after explosion	Most Severe (Patients usually within 1.0 Km. of center)	Moderately Severe (Between 1.0 and 1.5 Km.)	Mild (1.5 to 2.5 Km.)
1.	1. Nausea and vomiting after 1-2 hours lasting 1-2 days.	1. Nausea and vomiting after 1-2 hours lasting 1-2 days.	
2.			
3.			
4.	LATENT PERIOD		
5.	2. Bloody diarrhea		
6.	3. Vomiting		
7.	4. Fever	LATENT PERIOD	
8.	5. Rapid emaciation		
9.	Death		
10.	(Mortality probably		
11.	100%)	2. Beginning epilation progressing until death	LATENT PERIOD
12.			
13.			
14.			
15.			
16.			
17.			
18.			
19.		3. Loss of appetite and general malaise.	1. Epilation
20.		4. Fever	2. Anorexia and malaise
21.		5. Herpetiform eruption about mouth and on buccal mucus membranes progressing to necrotic stomatitis with hemorrhagic gingivitis.	3. Sore throat
22.			4. Pallor
23.			5. Petechiae
24.			6. Diarrhea
25.			7. Moderate emaciation
26.			
27.		6. Pallor	
28.		7. Petechiae, bloody diarrhea, epistaxis, and hematemesis.	(Recovery unless complicated by previous poor health or superimposed injuries or infections)
29.			
30.		8. Rapid emaciation	
31.		Death	
		(Mortality probably 50%)	

Table I,b

Laboratory Findings in Patients Showing Delayed Effects

FINDING	MOST SEVERE 3rd-5th	MODERATELY SEVERE Day of laboratory determination 20-30th	MILD 30th-60th
Leucopenia	Moderate	Extreme	Moderate
Anemia	None	Moderate	Severe
Thrombocytopenia	None	Extreme	Moderate
Hematuria	None	Frequent	Infrequent

Table I,c

Autopsy Findings in Patients Showing Delayed Effects

	MOST SEVERE	MODERATELY SEVERE	MILD
General aspect	Emaciation	Emaciation Petechiae Epilation	Emaciation Complicating findings (burns, etc.)
Mouth and pharynx	Ulcerations	Ulcerations	Swelling and edema
Bone Marrow	Grossly normal Early degenerative changes.	Myeloid degeneration	Myelois regeneration Erythroblastic degeneration
Colon and rectum	Necrotic ulceration	Necrotic ulcerations Hemorrhage	General hemorrhagic findings
Testes and ovaries	* * * * *	Atrophied	Atrophied
Other viscera	Terminal changes	Hemorrhage	Complicating findings (malnutrition; chr.dis,etc. worms)
Lymph Nodes	* * * * *	Moderate hyperplasia	No change

2. Cause of symptoms. That these symptoms and findings were primarily due to radiation was concluded from the following:

a. The theoretical calculations predicted an instantaneous discharge of high energy gamma rays and neutrons below the point of detonation which would have been expected to cause serious biological effects.

b. The symptoms and findings were those which would have been predicted from animal experiments and from known toxic effects encountered in clinical therapeutic application of radiation.

c. The existence of a definite latent period before the onset of symptoms and the correlation between the length of the latent period and the severity of the symptoms as shown in Table I,a, strongly suggested that the symptoms were due to radiation.

d. Induced radioactivity had been detected very near the center of the explosion. This could be attributed only to the effect of neutrons. Table II shows such induced radioactivity in bone phosphorus and the relation of its intensity to the distance from the center.

TABLE II

Activity of P in Bone. (Hiroshima)

No.	Distance from center Km.	Beta ray/min/gm. of ash* x 10^4
1.	0.00	20.3
2.	0.17	24.6
3.	0.25	16.9
4.	0.53	4.8
5.	0.60	0.126
6.	0.70	0.051
7.	1.28	-
8.	2.00	-

*1 gm. of ash corresponds to 6.4 gm. of bone.

(Data from Dr. Koiti Murati, Nuclear Research Laboratory, Institute of Physical and Chemical Research, Tokyo.)

3. Evaluation of symptoms. Of the symptoms and findings described, those which in themselves can be considered to be due to radiation are epilation, leucopenia with its accompanying symptoms, and thrombocytopenia with its accompanying hemorrhagic manifestations. These effects are due almost wholly to the gamma radiation. The additional role that neutrons may have played in the production of these symptoms can not be evaluated from the data. Any additional information on the biological effects of radiation which may be forthcoming from the data obtained must await more detailed analysis.

4. Evidence against effects from persistent radioactivity. That the symptoms from radiation were due to the instantaneous discharge of high energy particles and not to any persistent radioactivity deposited on the

ground was also concluded from several facts.

a. Theoretical predictions indicated that the height above the ground at which the bomb was detonated would not produce any dangerous amounts of persistent radioactivity.

b. The amount of radioactivity on the ground determined at the time of the study was very small and was not sufficient to account for any harmful amounts having been present since the explosion. This is more fully discussed in Section II of this report.

c. No persons coming into the areas after the explosion were found who showed any signs or symptoms of radiation effects.

These facts also apply to any effects from radioactive particles scattered along the path of the cloud.

5. Distribution of patients showing effects of radiation. Table III shows the relationship between the distance from the center of the explosion and the occurrence of epilation and hemorrhagic diathesis.

Table III

Relationship between Distance from the Center of the Explosion and the Occurrence of Epilation and Hemorrhagic Diathesis. (Nagasaki)

Distance from the center	No. of Cases	Percent
0.5 Km.	12	11.3
1.0	43	40.6
1.5	32	30.2
2.0	5	4.7
3.0	10	9.4
4.0	3	2.9
4.1 and over	2	1.9
Total - 107		

It is apparent that the majority of surviving cases showing the symptoms and findings due to radiation were between 1.0 and 1.5 Km. from the center at the time of the explosion. There were few cases studied who were within 0.5 Km. of the center since most of these must have died soon after the explosion. From the Japanese data there may be evidence that patients in Nagasaki as far away as 4.0 Km. did show effects of radiation.

6. Additional effects.

a. Physical injuries. Physical injuries other than burns included fractures, lacerations, contusions, and similar effects such as would be expected from blast directly and from the crumbling buildings and flying debris caused by the explosion. There were evidences of such injuries at least as far out as 3.5 Km. from the center. See Section III of this report.

b. Burns. The burns were of two types. The former were fire burns of the usual type. The latter, which comprised the majority of the burns, however, were distinctive in several respects. That they were due to infra-red rays was concluded from the following:

1. Clinically they resembled sunburns more closely than ordinary fire burns.

2. They were sharply delineated by lines representing the border of bare skin areas, and they were limited to those areas which were facing the center of the explosion. For instance, a patient who had been walking at right angles to a line drawn between him and the center of the explosion and whose arms were swinging might have burns on the outside of the arm nearest the center and the inside of the other arm.

3. Patients who were quite close to the center and who had on white and black striped clothes, may have had burns of the skin only in those areas under the black clothing.

4. Many patients recovered with as much as 2/3 of the total skin area so burned, which is most unlikely with ordinary burns if the burns are deeper than 1st degree, and is further evidence that these differed from the usual type of burns.

The majority of these burns were classified as second degree burns. They healed slowly, but without sloughing or many instances of secondary infection. The patients showing them were most frequently near the center, but with decreasing frequency and severity, they may have extended out as far as 4.0 Km. There was ample evidence of similar burning of physical objects.

7. Relation of other injuries to effects from radiation. The evaluation of symptoms and findings due wholly to radiation is complicated by the occurrence of the other types of injury described. The majority of patients who showed effects of radiation also had burns and other physical injuries since both types of injury occurred more frequently in persons near the center of the explosion. This is shown in Table IV, in which the depression of the leucocyte count can be considered as a measure of the extent of injury from radiation.

Table IV

Relationship between Leucocyte Count and Occurrence of Burns and other Physical Injuries.

W.B.C.	Uninjured	Burned	Other physical injuries
500			
1500	0	2	0
2500	3	1	10
3500	9	0	6
4500	2	2	12
5500	10	3	10

W.B.C.	Uninjured	Burned	Other physical injuries
6500	24	0	6
7500	13	3	6
8500	9	2	5
9500	5	0	0

8. Treatment. Treatment of the burns and other physical injuries was done by the Japanese by orthodox methods. Despite the inordinate number of patients and the poor facilities due in part to the gross destruction of medical installations, these injuries, and particularly the burns, did very well with very little infection in spite of the unbelievably poor conditions under which some of them were being treated.

Treatment of the radiation effects by the Japanese included general supportative measures such as rest and high vitamin and high caloric diets. Parenteral liver and calcium administration, thrombin preparations, and blood transfusions were used to combat hemorrhage. Parenteral vitamin preparations and pentanucleotide were used by American Army Medical Corps officers after their arrival. No definite effect of these measures on the course of the disease could be demonstrated. The use of sulfonamide drugs by the Japanese and of penicillin by the American physicians undoubtedly helped control superimposed infection, and appears to be the one known type of treatment which may effectively alter the course in these patients.

9. Casuality estimations. The total number of casualities with the percentage of deaths and the distribution of the casualities and death, particularly in relation to the effects of radiation, can only be roughly estimated at the present time and may never be accurately known.

a. Total casualities. A considerable proportion of the people known to have been in the two cities at the times of the explosions cannot be accounted for. Many of these were probably killed outright and not identified, but a large number may have found their way out of the cities, and there is no record of them. Death certificates are not routinely kept in Japan, and the vital statistics in general are not very complete. From what was found, the best estimates for total casualities in the two cities at the end of September were as shown in Table V.

Table V

Casuality Estimates

City	Total present at time of explosion	Dead	Wounded
Hiroshima	400,000	86,000	112,000
Nagasaki	270,000	40,000	50,000

b. Statistics or patients showing effects of radiation. The total number of patients who showed radiation effects and the percentage of these who died is even more difficult to estimate. An inherent defect in

this information which can never be overcome is the fact that many patients were killed immediately or died from other injuries before they had time to develop symptoms due to radiation. Records were not kept on the majority of the patients and many of those which were available were incomplete. This is particularly true of the records of patients admitted to the hospitals and who were discharged after their burns and wounds were healing, but before they developed symptoms due to radiation. Attempts to compare the amount of radiation received is made particularly difficult by the inability to estimate the amount of effective shielding in individual cases and this differed in general in the two cities. With all of these qualifications, and if one considers only those patients admitted to hospitals in the two cities, it can be estimated that of approximately 4000 patients admitted to hospitals, 1300, or 33%, showed effects of radiation and of this number approximately one-half died.

SECTION II. INTENSITY OF RADIOACTIVITY FOUND IN AND AROUND HIROSHIMA AND NAGASAKI

A. Purpose of study. To ascertain the presence of residual radioactivity in and around the bombed cities and to evaluate this activity in relation to possible physiological effects.

B. Instruments. Portable counters (Geiger-Mueller Type) with ear phone attachments were found to be the most practical instruments for this work. Landsverk and Wollan electroscopes were also used. Direct reading ionization chamber instruments were available but none were sensitive enough to detect the low intensity radiation present.

C. Calibration. The instruments used were calibrated against known radium sources brought for this purpose. The calibrations were performed before any readings were obtained and twice during their two week period of use.

D. Monitoring. Monitoring parties composed of physicians and technicians trained in this work explored the rubble of the bombed cities on foot and along roads into the environs. Readings were made by all in a prescribed manner and recorded. Water sheds and places of habitation in the vicinities of the town were investigated.

E. Results. The plots of radiation intensities are presented in the form of equi-intensity lines on the accompanying maps of the two cities; Fig. I, Hiroshima; Figs. II and III, Nagasaki.

F. Discussion. From a study of the results obtained, several salient features are seen.

1. In each city there are two distinct areas of low intensity radiation:

   a. One beneath the point of detonation
   b. Another separated from the first by several kilometers. These areas can be correlated with the wind directions reported directly after each bombinb.

2. Although the intensity of radiation is quite low, it is measurable with the very sensitive instruments used. From these measurements, simple calculations yield the highest radiation intensities which were present at any time after the bombings and also the total amount of radiation which would have been delivered during the whole period following the bombings. If the highest reading in each city is taken, the results of such calculations are shown in Table I.

Table I

City	Highest Reading mr/hr	date	Highest Intensity r/hr	time	Total Radiation R	# days
Hiroshima	0.4	6 Oct 45	0.576	0915 6 Oct 45	4.17	60
Nagasaki	1.8	26 Sept 45	2.02	1230 9 Aug 45	14.2	47

3. If we consider these intensities from a physiological standpoint, it is quite obvious that the residual radiation alone could not have been detrimental to the health of persons entering or living in the bombed areas after the explosions. Although "tolerance" is exceeded slightly (tolerance being defined as the amount of radiation a human being can take day after day indefinitely without influencing the course of his life or producing residual or latent effects), the total amount of radiation is so small and falls so rapidly that it is soon ineffective. This was confirmed by the fact that no one entering these areas after the explosion was found to suffer effects from radiation. (See Section I-D)

4. The measurements performed were in the main for gamma rays. These are the most penetrating type and the most important from the standpoint of general bodily reactions. Measurements of beta rays were also made but were not calibrated because of technical difficulties and inaccuracy in evaluating the readings. Alpha ray measurements in the field are almost impossible for the same reasons and their biological importance in these conditions is practically nil. No alpha radiation was found with the preliminary measurements. Therefore after spot checks were made for beta and alpha radiation (which were within the expected limits) the gamma radiation was concentrated upon as the most practical measurement from the technical and physiological viewpoints. There is no possibility that there would be any persistent neutron activity.

SECTION III. PHYSICAL DAMAGE IN HIROSHIMA AND NAGASAKI

A. Purpose of study. To observe and record residual evidences of physical damage in the bombed cities and to evaluate these observations in relation to physiological effects.

B. Methods. Army engineers and civilian physicists in both cities observed, photographed, and collected specimens for later tests. Statistics as to the number of buildings and types of construction were obtained. In the main, the physical damage will be reported under separate cover, but the effects of blast, flying debris, primary and secondary fires, and shielding from radiation are important from the casuality viewpoint.

C. Results.

1. Zones of various degrees of damage with an explanation of the type of damage are shown for the two cities in the attached maps; Fig. I, Hiroshima; Fig. II, Nagasaki.

2. The destruction of buildings and houses in Nagasaki is shown in Table I, compiled by Nagasaki Municipality.

TABLE I

Destruction of Buildings and Houses in Nagasaki

	Number	Percent
Total in Nagasaki (before bombing)	50,000	100.
Blasted (not burned)	2,652	5.3
Blasted and burned	11,494	23.0
Blasted and/or burned	14,146	28.3
Partially burned or blasted	5,441	10.9
Total buildings and houses destroyed or damaged	19,587	39.2
Undamaged	30,413	60.8

3. The following observations on the effects of the type of buildings on the casualties were obtained.

a. Wooden buildings. A very large portion of buildings severely damaged by blast were of wood construction, with tile roofs, typical of Japanese architecture. Nearly all of these buildings near the center of the blasts (principally dwellings and small factories) collapsed and burned. Casualties sustained by occupants of such buildings were mainly from secondary concussion (effects such as flying missles and falling walls and from fires.) Even though these buildings were of very light construction, persons in them were protected from the effects of infra-red and ultra-violet rays, unless they were situated in front of open windows or doorways. On the other hand, persons standing in the open at as great a distance

as 3 kilometers from the center of the explosion received "flash burns" to their exposed skin. Very little shielding from high energy radiation was provided by this type of house, however. Also in periphery of the damaged areas, secondary fires in these wooden houses were easily set by overturned charcoal stoves, short circuited electrical wiring, and direct spread of the conflagration.

b. Masonry buildings (brick and stone). A few small factory buildings were of this type of construction. Nearly all of them situated in the blasted areas were collapsed and the occupants of such buildings suffered from injuries of the same nature as did those in wooden type dwellings. These walls, although thicker than the wooden frames, did not protect appreciably from gamma and immediate neutron radiation.

c. Structural steel frame buildings with corrugated iron or asbestos roof and siding. This type of building housed most of the workers in large factories. Near the center of the blast, the frames were twisted and bent, a few were collapsed, but the heavier frames were only slightly injured. Injuries to occupants were almost the same as with wooden buildings except that fewer were totally crushed and burned.

d. Reenforced concrete buildings. While damage to buildings with heavily reenforced concrete frames was severe, the frames themselves were not destroyed and consequently such buildings did not collapse. Although lethal casualties were less in this type of building, serious injury was sustained by occupants from the effects of falling false ceilings and missles of metal, wood, metal-lath, plaster, and glass. This was the only type of structure which per se offered effective shielding against gamma radiation. Shielding against lethal amounts of gamma radiation was effected by ceilings and walls of reenforced concrete 6-7 inches thick at a distance of 1.2 Km. from the center; while persons in adjoining buildings with corrugated iron or asbestos roofs and ceilings were definitely injured. Walls and ceilings of concrete 4 inches thick provided effective shielding at a distance of 1.75 Km. from the center. Persons in such buildings standing in exposed situations were injured by the direct effects of long and short wave length radiations. The interior of these buildings were almost all completely burned out from secondary fires.

D. Discussion. Although the physical damage effects of the two cities and their resultant casualties were generally enormous and similar, there are some differences that are important to emphasize. The area destroyed and the total casualties suffered were greater in Hiroshima than in Nagasaki. Reasons for this are the following:

1. The bombing point or target at Hiroshima was in the center of the city which was geographically situated on a wide flat delta. The point of impact at Nagasaki was in the center of a narrow valley.

2. Hiroshima was composed mainly of Japanese type houses of wooden construction. The area bombed at Nagasaki contained large steel factory buildings and concrete buildings of modern construction.

3. Just previous to the bombing of Hiroshima plans were being made for the evacuation of unnecessary persons. The day of the bombing 40,000 extra people were brought into the center of the town for instructions on these evacuation plans. One week before the bombing of Nagasaki, such plans for the evacuation of unnecessary persons had been carried out and the population in the bombed areas had been reduced.

SUMMARY

The primary purposes of the atomic bomb investigating group sent to Japan by the Manhattan Engineer District were:

1) To protect occupation forces from exposure to radiation if any significant quantities of radioactivity persisted after the atomic bombings of Hiroshima and Nagasaki;

2) To investigate the Japanese reports that people were being harmed by "lasting effects" of the bombings; and

3) To gather information and data on:

a. The existence, if any, of persistent radioactivity;

b. The biological effects of the atomic bombs, and

c. General factors concerning physical damage and casualty estimates insofar as they related to the above.

The answers to the questions involved are presented in this preliminary report. The chief conclusions from it are:

1) No harmful amounts of persistent radioactivity were present after the explosion as determined by:

a. Measurements of the intensity of radioactivity at the time of the investigation; and

b. Failure to find any clinical evidence of persons harmed by persistent radioactivity.

2) The effects of the atomic bombs on human beings were of two main types:

a. Burns and other physical effects expected from large-scale explosions but exceptional in regard to the large area (14.3 square kilometers) over which they extended and in regard to an unusual type of burn due chiefly to infra-red radiation;

b. Delayed effects which indicated effects from radiation.

3) The effects from radiation were due to instantaneous discharge of radiation and not to persistent radioactivity.

The opinions expressed in this preliminary report are not in any sense final. For the most part they represent fairly unanimous opinions of those who took part in the investigation. The final results will be derived from a detailed analysis of the data obtained.

Appendix I - Report II

Ocular Injuries Produced By The Atomic Bombing At Nagasaki

John J. Flick, Major, M. C.

At the time of the visit to the atomic-bombed areas at Hiroshima and Nagasaki for the purpose of making a casualty study it was anticipated that some pathologic changes would be found in the eyes of those survivors who were near the site of the explosion. It was known that a large amount of light was produced by the explosion and it could be assumed that some detectable damage to the tissues of the eye might result. To the present date, 6 October 1945, no primary damage to the ocular structures has been observed that could be interpreted as the result of irradiation of any sort. The president of the Nagasaki Medical College, Dr. Yamane who himself died two weeks after the explosion from irradiation sickness is said to have treated a number of patients with purulent conjunctivitis occurring 3 or 4 days after the blast and lasting about a week. These lesions all resolved and did not involve the cornea or leave any permanent sequelae. No bacteria were found in the discharge. No evidence of such a disease was found by us and no patient questioned by us gave a history of such a disease. A number of patients with flash burns of the face, who must have been facing the exploding bomb were examined under a mydriatic at one of the hospitals in Hiroshima. No opacities were seen in the lens and no changes were present in the conjunctiva. The flash burns seemed to spare the eyelids in many instances as if the tight closure of the eyes had occurred quickly enough to hide that area of skin. Some patients were seen who had lost their lashes. although epilation of the eyebrows was rare.

Lesions arising from the secondary effects of the explosion are divided into three groups: mechanical injury, thermal injury, and irradiation injury. Lesions caused by mechanical factors differed in no way from those produced by other agents of warfare, such as bullets, fragments, and shells. Among those noted were penetrating injuries of the globe, leucome of the cornea, traumatic cataract, various deformities, including ectropion, ankyloblepharon, symblepharon, detachment of the retina and various syndromes involving fracture of the skull and walls of the bony orbit. Many ambulatory casualties were seen on the streets wearing eye patches.

Flash burns were pigmented and assumed a coppery color. There were large numbers of patients who exhibited extensive facial burns of the ordinary type with much dense cicatrix. These burns in some instances had involved the conjunctiva and cornea to such an extent that the red, lacrimating eyeball had only slight movement and seemed set in a dense mass of contracting scar.

Lesions associated with irradiation effects were limited to the retina. They consisted of hemorrhage and exudation. Of the patients exhibiting these retinal lesions, 75 per cent had one or more of the other clinical signs of irradiation. Of 37 patients whose leukocyte counts were available, 28 or 75.7 per cent gave figures at some time of 4,000 per cubic centimeter or below. Histories taken of patients presenting eye lesions numbered 46, comprising 42 from the Nagasaki area and 4 from the Hiroshima area. There were 23 patients under 25 years of age and 23 patients over 25 years of age. Of the four clinical signs found to be typical of radiation

reaction, namely, petechiae, gingivitis, angina, and epilation, the group under 25 years of age had an average of 1.52 while the group over 25 had an average of 1.22, a difference of about 20 per cent. This tends to throw light on the relationship of age to sensitivity to gamma irradiation.

All of the patients in this study were within 2 kilometers of the center of the explosion. Of 41 patients where the information could be obtained, only 8 or 19.5 per cent were outside of a building at the time of the blast. In these it must be assumed that some intervening absorptive material, i.e., concrete, must have protected them from gamma ray dosages that would certainly otherwise have caused them to die before our investigations began. Because of this unknown amount of shielding in any given case, it appears that a correlation of the distances from the explosion with the quality and intensity of the pathologic effects is impossible to compute in spite of the fact that doses received through the air by persons at equal distances were probably the same. It is evident, then, that in the case of any given patient at the time of our investigation we knew only that he had received a dose of irradiation that was either sublethal for him or lethal with a longer latent period than other cases had shown under similar circumstances. As noted in some of the case histories, serial leukocyte counts made by the Japanese before our arrival indicate that the depth of leukocyte depression probably took place near the first week in September in the patients alive and available for our clinical appraisal at the time this survey was made. The leukocyte counts recorded on the patients have no correlative value with the eye lesions and indicate simply the predominance of leukopenia in these instances.

The lesions observed in this disease appeared in the retinal tissues and were limited to that structure and to the nerve fibre layer as it overlay the nerve head. The hemorrhages were of four types. In order of frequency there were: flame hemorrhage, pre-retinal hemorrhage, "Roth" type hemorrhages, and vitreous hemorrhage.

Flame hemorrhage, of course, is situated in the nerve fibre layer of the retina. It is caused by the rupture of capillaries in that layer and the infiltration of cellular blood elements between the nerve fibres. These lesions were very numerous, being seen in 25, or 54.3% of the patients. They were nearly always situated close to the nerve head, never farther than 3 disc diameters distant. Some of the flame hemorrhages were very dense and had a deep maroon color while others were a very pale red, only slightly darker than the uninvolved retinal tissue and underlying choroid.

The term "flame hemorrhage" is used in this study to refer only to those lesions in which the reflexes from the internal limiting membrane revealed no change in level as they passed over the lesion. The location in the nerve fibre layer was often strikingly demonstrated by the extension of the lesion continuously onto the disc itself. Some of these took the form of narrow, splinter shapes often being situated parallel to and very close to a large vessel.

Pre-retinal hemorrhage occurred in 11 or 23.9% of the patients. These seemed to be a gross development of the flame hemorrhage in which the

blood had leaked into the subhyaloid space producing an elevated, rounded hematoma immediately adjacent to but not invading the vitreous. These lesions were often quite large (see drawing), and had straight-line borders due to sedimentation of the red cells. The surface of the hematoma was smooth and convex as determined by the character of the reflex. The granular appearance of these masses of blood was attributed to clotting which may have taken place. The distinguishing ophthalmoscopic features of these lesions were their extremely sharp margins and the tendency to form horizontal, straight-edged upper margins. The serum of the blood could be dimly seen above the straight edge and was usually clear enough so that underlying retinal vessels could be seen.

A rather unique type of hemorrhage was observed in this study. It resembled nothing so much as a Roth spot except that it was larger. These lesions were noted especially in 4 or 8.6% of the patients. They were larger than most flame hemorrhages and were almost invariably seen overlying a large artery, a branch of the first order. The portion toward the disc was smoothly and sharply outlined while that away from the disc was brush-like. The color was deep maroon and the lesion showed elevation of the retinal surface. Somewhere on the lesion, usually in the distal portion, was an irregularly round white area about $\frac{1}{4}$ of the diameter of the lesion itself, (see drawing). The pathogenesis of these spots could be made out from a study of the hemorrhage forming in association with exudates, (vide infra).

Vitreous hemorrhage was noted in two instances. There was an infiltration of the vitreous body itself by blood which had burst through the hyaloid. The view of the fundus was always more or less obscured in this type of hemorrhage.

Exudation into the retina was a most common finding in these patients (30 or 65.2%). They took the form of round, snow-white, slightly elevated lesions always within 3 disc diameters of the disc itself and were sometimes extremely numerous, 40 or 50 being seen in a single eyeground. The spots were scattered in random fashion over the polar zone of the retina without any reference to blood vessels. In some of the patients, however, it was noted occasionally a lesion situated near an artery would show a fine fringe of hemorrhage about its borders, particularly its peripheral or distal border. Some were seen in which this hemorrhage became large and came to surround the exudate. This led us to believe that such a hemorrhage about an exudate could develop into a hemorrhage of the so-called "Roth" type described above. The morphologic variations noted in these exudates were rather marked. The most common type was, as described, round and smoothly elevated with a feathered margin indicating that it was an involvement of the zone of the neural fibre. Elongated forms were also seen and a peculiar zig-zag formation in which the extension in length was in a direction perpendicular to the direction of the nerve fibres composing the lesion. Also in these the area of exudation would be not everywhere equidistant from the disc, producing a Z-shaped figure. In some cases this development became so marked that these exudates formed one or more rings or wreathes partially surrounding the disc. Subsequent observation of the lesions showed their borders becoming sharper as they absorb, in contrast to a hemorrhage in which the borders became more indefinite and irregular as absorption progressed. A late

residue of an old exudate is a small, waxy yellowish, sharply outlined placque associated with several much smaller satellite spots. In some instances rather large sharply outlined greyish speckled areas were seen surrounding a large artery. These could very well represent residual atrophy from absorption of one of the larger hemorrhages.

No changes were observed in the optic discs nor were any pathologic changes noted in the vessels themselves. Generalized retinal edema was a very common accompaniment of hemorrhages and exudates so that if edema was present a search for local lesions was pursued more intensively.

Case No. 1. 22, female.

This patient was dressed in a blue, one piece suit with long trousers and getas, no cap, and was in the Mitsubishi Weapons Factory, 1 kilometer from the center of the explosion, inside a concrete building. She suffered no burns or wounds. One hour after the explosion she vomited. The nausea continued for 2 or 3 days with loss of appetite. Beginning 13 August, there were frequent stools without blood. On 26 August, the hair began to fall. Throughout the entire first week of September she had sore bleeding gums, nose bleeds, and fever with tonsillitis. Since 15 September, she had complained of poor vision in the right eye. The last menstrual period was on 4 August, after which there was no bleeding until 25 September, when bleeding commenced and had continued unabated to the present (2 October). On 24 September, the leukocyte count was 8,600 and the sedimentation rate was 50 for the first hour and 64 for the second hour. On 14 September, ophthalmoscopic examination was done and the following description recorded:

"Examination of the ocular fundus of the right eye reveals an appreciable amount of retinal edema generally and particularly pronounced around the macular region. The veins and arteries are full and of good color. There are no pathologic changes in the optic disc. In the right foveal region is a deep red, pre-retinal hemorrhage ¼ DD in size and laterally oval in shape. The lesion shows marked bulging into the vitreous and the borders are very sharply defined. Above this is a very much larger, though similar lesion, about 3 DD in size. This lesion is elevated and the lower margin is very sharp. The upper margin is horizontally straight. The lesion is situated 1-2 DD from the papilla. Scattered about in the intervening retina are numerous small flame-shaped hemorrhages and several white, fluffy, elevated exudates, particularly on the nasal side. The left fundus shows no hemorrhage but numerous exudates of the soft white type."

On 5 October, the following note was made: "There is a large pre-retinal hemorrhage above the right macula 2½DD in size. There is little evidence of absorption of this lesion. The pre-retinal hemorrhage in the foveal region shows a moth-eaten appearance of the upper temporal margin indicating some absorption. Also it shows a greyish center. One small fresh exudate with no evidence of hemorrhage around it." (See drawing).

Case No. 28. 22, male.

Admitted 9 August 1945. Patient was at the Ohashi Arms Factory, 1,200 meters from the center. Bleeding of the gums began 13 September. The falling of hair began 19 August, and began to grow back 15 September. There was fever and black diarrhea the first week in September, and the patient volunteered that when he ate hard rice his stool was soft but when he took soft rice his stool was hard. He suffered no burns. On 26 September, the leukocyte count was 3,000. Ophthalmoscopic examination on 27 September, revealed in the right eye many small exudates scattered in the form of a wreathe around the disc, no hemorrhage. In the left eye there was formation of exudates as in the right and in addition a large flame hemorrhage in the lower nasal quadrant close to the disc. On 5 October, the exudates appeared unchanged and the hemorrhage in the left retina appeared to be absorbing.

Case No. 29. 43, female.

Patient had been standing outside the Arms Factory at the time of explosion. She was wearing a black kimono with trousers. She received burns of the left face, left neck, and right hand. Falling of the hair began 16 August. Patient had some genital bleeding 14 August, none since. On 23 August, the leukocyte count was 800, red count 4.04, hemoglobin 55%, and color index 0.68. On 12 September, the leukocyte count was 4,300. Ophthalmoscopic examination on 27 September, revealed the right vitreous to be cloudy with two small, soft, white exudates below the right disc. In the left eye many small, soft, white exudates were seen, one of which had a fringe of hemorrhage about it. On 5 October, there were no lesions seen in the right eye and the vitreous was clear. The left showed numerous absorbing hemorrhages of the lower fundus but no exudate.

Case No. 30. 18, female.

Patient was admitted on 9 August. At the time of the explosion she was in a wooden house at the Ohashi Factory. She wore a khaki coat, white shirt, and blue trousers. She suffered cuts by glass and burns of the right forearm and wrist. She states that at the time of the explosion she was blinded and could not see for three days. On 15 August, she began to run a fever up to 40 degrees C. and the cuts she had received which had partially healed became infected. She had sore, bleeding gums during the first week in September, for one week, also a sore throat, nausea, and much watering of the mouth. The leukocyte count was 3,000 on 26 September. Ophthalmoscopic examination on 27 September, revealed in the right eye many white, elevated, radially striated exudates up to 3 DD from the disc with one flame hemorrhage and retinal edema. In the left eye there were exudates as in the right with several fine splinter-like hemorrhages. On 5 October, no hemorrhages were seen in the right eye, but three small exudates were present in the upper nasal quadrant. In the left eye one small Z-shaped exudate was seen; retinal edema was much improved.

Case No. 31. 18, male.

Patient was at Urakami in a wooden house 800 meters from the center of the explosion. The upper half of the body was naked, the lower half covered with a blanket. He received burns on the face, right chest, right arm and hand. On 1 September, he suffered an infection of the right wrist with much swelling. On 26 September, the leukocyte count was 2,600. On 27 September, one small hemorrhage of the Roth type was seen in the left lower fundus. On 5 October, no fundus lesions could be found.

Case No. 32. 25, female.

Patient was near Mitsubishi War Plant and was wounded in the falling building. She wore black trousers, half sleeved, white, blue-striped shirt. At the time of the explosion, she was 3 months pregnant. Abortion occurred on 1 September. She received multiple wounds by glass. Her gums bled for 5 days beginning 20 September. On 20 September, the leukocyte count was

Case No. 35. 59, male.

Admitted 26 September 1945, having received burns on face, with bruises and cuts. He wore thin white coveralls. He had a period of unconsciousness on the way to the hospital. At the time of the explosion he had been 400 meters west of the Ohashi Arms Factory or at a distance of 1,200 meters from the center of the explosion. He had suffered from weakness and ringing in the ears since the explosion. For a period of one month prior to admission to the hospital he had been suffering from sore, bleeding gums. From 25 August 1945, to 3 September 1945, he had had fever which ranged as high as 41 degrees C. He had had some acute chest pain associated with breathing. There was a large slough involving all the soft tissue of the anterior one-third of the hard palate. On 1 September, the sedimentation rate was 84 the first hour and 136 the second hour, the leukocyte count at that time was 7,200. On 27 September, ophthalmoscopic examination under full pupillary dilation revealed many soft, white exudates scattered about in both fundi and a splinter-shaped flame hemorrhage extending onto the right disc. Re-examination on 5 October, showed no exudates in the right eye. The splinter hemorrhage was smaller. There was a small exudate temporal to the left disc.

Case No. 36. 23, male.

The patient was at the Mitsubishi Weapons Factory in a wood building at a distance of 2 kilometers. He was dressed in a soldier's uniform. He received no burns but suffered minor cuts and abrasions about the right side of the face, scalp, right elbow, both forearms, and right side of chest. He had a sore throat and nose bleeds for about two days about 8 September. On 21 September, the sedimentation rate was 115 for the first hour and 146 for the second hour. The leukocyte count at that time was 7,200. Ophthalmoscopic examination on 27 September, revealed one small flame hemorrhage. On re-examination on 5 October, no fundus lesions could be found.

Case No. 37. 31, male.

Patient was at the Mitsubishi Arms Factory, inside, dressed in all white clothes, sitting down, at the time of the explosion. Had suffered from weakness, fever, and falling hair since 17 September, and also had a sore throat during that time. The gums had been sore and bleeding since 4 September. He received no burns and only minor wounds at the time of the explosion. During the first week in September his skin was covered with petechiae. On 26 September, the sedimentation rate was 142 for the first hour and 163 for the second hour. The leukocyte count at that time was 7,000. On 27 September, many flame hemorrhages, pre-retinal hemorrhages, and exudates were found. On 5 October, the following note was made, "Hemorrhages very numerous in both fundi, both flame and pre-retinal. There are a few exudates. There are several Roth-type spots related to the left inferior temporal artery. There is one exudate just temporal to the right disc. There are two large pre-retinal hemorrhages one related to each of the temporal branches of the right fundus."

Case No. 38. 34, female.

Patient had been inside a wooden house at a distance of 1.5 kilometers at the time of explosion. She was barefooted and wore a black shirt, short sleeves, long trousers, and she received burns of the left knee, arm, forearm, and hand. There were minor wounds of the head, face, and back. She has had more or less bloody diarrhea ever since the explosion. She had not menstruated since the day before the explosion. Her hair has been falling since 22 August. The sedimentation rate on 21 September was 131 for the first hour and 160 for the second hour. The leukocyte count at that time was 2,000. Ophthalmoscopic examination on 27 September, revealed hemorrhage and exudates. Another examination on 5 October, revealed one exudate nasal to the left disc and an area of absorbed hemorrhage around the proximal part of the superior nasal artery. No lesions were seen in the right fundus.

Case No. 39. 49, male.

Admitted 10 August 1945. He had been at the Ohashi Weapon Factory, 1,200 meters from the center of the explosion, standing outside, wearing white shirt, green trousers, and gaiters. He suffered burns of the forearms, left side of face and neck. He also sustained a fracture of the left patella. Since the explosion, he had had two attacks of tonsillitis and fever up to 39 degrees C. On 5 September, petechiae appeared on his left thigh. From 23 August, till 10 September, he had profuse falling of hair. Since 22 August, he had had sore, bleeding gums. The following is a table of serial blood estimations:

	6 Sept	8 Sept	10 Sept	13 Sept	16 Sept	20 Sept	24 Sept
RBC	3.7	3.3	2.7	2.2	2.2	2.6	3.0
WBC	600	500	700	1100	3400	3600	3000
C. Ind	0.89	0.91	0.9	1.2	1.0	0.96	0.96
Bl. Time	3½	12	12	10	7	6	5
Cl. Time	3.16	3.15	3.16	3.15	3.14	3.14	5
HBG	65%	60.9%	50%	55%	48%	50%	58%

Ophthalmoscopic examination on 27 October, revealed many exudates scattered over both retinae, also flame hemorrhages and Roth spots. On 5 October, no hemorrhages were seen. An exudate with sharp borders, indicating absorption, was seen in the upper temporal quadrant of the right eye and below the disc in the left another similar lesion was present.

Case No. 40. 42, male.

Admitted 9 August 1945: At the time of the explosion he was sitting, naked to the waist and wearing khaki trousers, inside a wooden building at the Ohashi Weapons Factory, 1,200 meters from the center of the explosion. He had been suffering from sore bleeding gums and his hair had been falling since 19 August 1945. He complained of some loss of hearing in the left ear. Ophthalmoscopic examination 27 September, revealed many exudates in both fundi but no hemorrhage. On 5 October 1945, the exudates were still present but were smaller and more waxy with sharper borders and exhibiting tiny satellite spots as if the absorption in those areas was not complete. These changes were seen in both fundi.

2,500. On 27 September, many exudates and flame and pre-retinal hemorrhages were found. On 5 October, the right eye showed a large pre-retinal hemorrhage below related to the right inferior temporal branch of the arteria centralis. There was also a large bulging pre-retinal lesions medial to the disc. There were a few exudates in the upper portion of the fundus. The left fundus appeared the mirror image of the right with two large pre-retinal hemorrhages, one above and one below. No exudates were seen.

Case No. 33. 30, female.

Patient was in a wooden Japanese house wearing a one-piece coverall. She was 500 meters from the center of the explosion. She vomited five or six times on the day of the explosion. On 9 September, hair began to fall. On 20 September, the leukocyte count was 2,400. Premature menses occurred on 12 August, and lasted three days. There has been no genital bleeding since 2 October. On 27 September, the only ophthalmoscopic lesion was a broad, thin, pinkish, flame hemorrhage in the upper temporal region of the left fundus. There were no lesions in the right fundus. On 5 October, the appearance of the lesion was the same.

Appendix II - Report I

The Effect of the Explosion of the Atomic Bomb on the Human Body.

Masoa Shiotsuki
Omura Naval Hospital

10 September 1945

Translated by: David Fukuda

I treated a number of patients brought to the Omura Naval Hospital who were injured by the atomic bomb dropped on Nagasaki on 9 August '45. I realized that the unusual effects, clinical and otherwise, could not be solely the result of mechanical forces and thermal radiation, but also of incredibly strong radiation of another type. I presumed that when atomic disintegration occurred, radiation which might have important effects on the human body could be produced. I have accordingly set down my observations regarding the effects.

At the time that the bomb was dropped, I was in the clinic as usual treating patients. The 9th of August was a bright sunny day and there had been no rain for several days. Suddenly I saw a white flash something like that of burning magnesium (by some said to have been of a bluish-yellow color). I had heard that an unusual type of bomb had been dropped on Hiroshima on the 6th of August, and I spent an uneasy 60 seconds until I heard a thunderous roar, as if all of the anti-aircraft guns in the vicinity had gone off at once. I then experienced a sensation of pressure. The pressure wave broke many windows in the hospital. Most of these were on the northeast side of the hospital, the side away from the blast. Some panes of glass in interior doors were also broken.

While hurrying outside to an air raid shelter, I kept watching the sky for enemy planes. I saw a large white cloud in the shape of an opened umbrella with a pink (or light orange) shadow in the inner under part, gradually spreading. Below this were three white parachutes drifting eastward. We awaited the all clear signal with peculiarly uneasy feeling. Figure I, shows the cloud which formed after the explosion of the atomic bomb. It disappeared forty minutes later. (Taken by Lt. Nihara of the Japanese Navy, Chief of Pharmacy of the Omura Naval Hospital, from the rear of the Hospital).

Site of explosion:- North of Nagasaki at the western end of Ugami (about on the center of a line connecting the city commercial school and the Yamazato Grammar School. Near Ohashi.

Height of explosion:- 500 M.

Distance from Uragami:- From Nagasaki to the Omura Naval Hospital is about 24 Km. (This is the average of figures given by the fort near the hospital, Omura Aviation Supply Depot, Uragami Arsenal, Headquarters of the Regimental District.)

Meteorological conditions at noon on 9 August '45:-

Weather:	Clear
Barometric pressure:	763.5mm Hg.
Temperature:	28.00
wet bulb:	21.00
Rel. humidity:	71%

About 600 wounded patients were sent to the Omura Naval Hospital between 2000, 9 August, and about 0100, 10 August. These were transported to Omura Railroad station by train, and from there to the hospital by trucks. The appearance of the patients on that night was horrifying. Their hair was burned, their clothes torn to pieces and stained by blood, and the naked parts were all burned and inflamed. Their wounds were contaminated by filth. Many among them had numerous pieces of glass and wood projecting from the skin of the face and back. Many were in such a state that they were with difficulty recognized as human beings. (See Figure 2).

As can be imagined, it was an appalling scene of confusion. Nearly ten hours had passed since the injuries had been received, and in spite of their severe injuries, the majority of the patients were quiet as though in a collapsed state. Many were covered with black blobs, which we at first thought to be coagulated blood from their wounds mixed with smoke from the train. Later, however, we learned that after the explosion there had been a "Black rain" throughout the city. The patients were given routine burn treatment and we finished about 0500, 10 August '45.

Case 24 (See Figure 3): 25 year old male. Wounds of the body from ricocheting fragments of glass. 20 August healed; discharged.

Notes: Most of the burns were of second degree severity and then in order of frequency, 3rd degree and 1st degree.

Burns were rare on parts covered by heavy clothing. Among those who had on caps (such as military caps) there was a clear cut line of demarkation corresponding to the lower border of the cap. The injury was very slight in parts protected by white clothing. Burns occurred under black clothing, however. There were some clothes in a material patterned with white and black stripes, and in these we found linear burns beneath the black stripes.

There seemed to be an unpleasant smell associated with the radiation burns. This odor mixed with that of the fish liver oil used in dressing produced a nearly unbearable stench.

Local Conditions (as remembered by patients):

Factory worker: "It was just after the all clear signal had been given and we had returned to our place of work. Suddenly a flash occurred; I felt very hot, and the roof of the factory came tumbling down. When I recovered consciousness, I was beneath the ridge of the roof with smoke and flame all about me. How I got out, I don't know."

Factory worker: "Since I had been working the night shift, I was sleeping upstairs in my lodgings with only my trousers on. I was near an open window, and suddenly felt as though a hot wind were blowing on me. I was thrown down."

Clerk: (had thermal radiation burns on face, neck, chest, and both upper extremities). "I was in front of a warehouse, supervising the loading of a truck. I felt as though fire were thrown on me from overhead. I was thrown to the ground."

All the others told similar stories in describing their experience at the time. At the time we thought that the atomic bomb caused a terrific pressure-wind and then an intense burst of thermal radiation which gave rise to the burns. Our treatment was at first based upon this concept.

Damage at Uragmi, Nagasaki: Later (31 August) I went to Nagasaki to view the damage which was beyond description. It resembled closely a picture published in the paper of 23 August entitled: "Hiroshima Catastrophe". All the buildings were crushed. Telephone poles were uprooted. Even reenforced concrete buildings were crushed like paper boxes, but, in general, masonry buildings were standing, but with the interior ruined as though a Titan had been playing there. Leaves of trees on surrounding mountains had been scorched up to 8 Km. away, and it looked as though autumn had come. The local people describing the condition of the people instantly killed by the blast told of corpses with eyes torn from their sockets, some eviscerated, some burned to ashes. Many were blown from factory buildings across the road and into the river. It must have been a dreadful scene.

TABLE I

A Statistical Study of 208 Patients Admitted to Omura Naval Hospital: Situation at the Time of the Explosion

Location		Type of Building		Damage to Building		
Indoors	Outdoors	Reinforced concrete	Wood	Completely destroyed	Partially destroyed	Concrete destroyed
147	61	17	191	137	67	4

Sound of Explosion:	Heard by: 187; Not heard by: 19.
Color of Flash:	Blue-red: 57; blue-yellow: 20; pale blue-white: 109; white: 29.
Position:	Sitting: 113; standing: 47; lying down: 48.
Clothing:	White: 78; colored: 130; short sleeved shirt and short trousers: 12; short sleeved shirt and long trousers: 112; half naked: 58; one piece women's clothes: 1; others: 25.
In Direct Sunlight:	78.
Original Burns:	Flash: 197; fire: 11.
Degree of Burns:	1st degree: 29; 2nd degree: 148; 3rd degree: 31.

TABLE II.

Statistical Study of 431 Patients Admitted to Omura Naval Hospital

Location		Clothing		Source of Injury	
Indoors	Outdoors	Clothed	Naked	Primary; by Bomb	Indirectly; by Fire
81%	19%	63%	37%	97%	3%

(Tables I and II from information from Lt. Com. Nobuhita Fukuhara of the Omura Naval Hospital).

The damage in the city seems to have been the greatest where the sun was shining. This was apparently not always the case with human beings (patients).

Condition of patients after admission: On the next day, 10 August, 71 patients were admitted to ward 8. These were transported by train on the night of the 9th and were treated by the Emergency Corps at the Matsumura Elementary School, Omura. They were then transferred here by truck. I was assigned to this ward and from this time on my observations were largely confined to these 71 patients. As on the day before, we continued to treat these patients as ordinary burns.

Patients with burns of the entire body and ones severely wounded by flying fragments died in two or three days. Examples:

1.) Factory worker, male, 45 years old. Wounds over entire body. Died 0500, 11 August. (Figure 4).

2.) Student, female, 19 years old. Wounds of both lower extremities with considerable hemmorhage. Died 1040, 11 August.

3.) Student, female, age unknown. Flash burns of face, both upper extremities, back, right knee, and right thigh. Died 0500, 12 August.

4.) Factory worker, male, 29 years old. Flash burns of face and both upper extremities. Wounds of back and both thighs by flying fragments of glass. Died 1510, 12 August. (Figure 5).

5.) Clerk, male, 30 years old. Flash burns on back and both upper extremities. Died 2105, 12 August.

6.) Fuyoko Araki, housewife, 41 years old. She received flash burns on face and both upper extremities; contusions and abrasions of both lower extremities. At the time of the explosion, she was nearly in the middle, Okamachi, Nagasaki, which is about 300 M from Ohashi. This is about 500 M from the vertical descent point or within 750 M of the explosion in direct line.

At the time of admission she had a temperature of 39.0 C, dysentery-like diarrhea and an herpetiform eruption about the mouth with an unusual odor. On the morning of 14 August, eyesight suddenly failed. Koernig's sign, ankle clonus, 3 plus; and opisthotonus, 2 plus, were noted. Spinal puncture revealed the cerebrospinal fluid to be turbid and admixed with dark red blood. Patient died at 1700, 14 August.

Shortly after death, necropsy was performed. The usual finding was petechiae of the mucous membranes of the intestinal tract, especially the rectum, varying in size from that of a grain of rice to a bean. In patient (Number 1) there were also changes found at the point of branching of the anterior and middle cerebral arteries, and also at a branch of the posterior cerebral artery near the fusiform gyrus of the right temporal lobe. At these points were clots were hemorrhage had occurred. He thought that these arterial ruptures may have been the result of inflammation from lodgement of emboli, secondary to histamine intoxication from the burns. They may have been purely of traumatic origin, or other mechanisms may have been responsible.

On the pia mater and also in the brain substance are blob-like spots the size of a millet seed, which show a tendency to become agglutinated into masses the size of the tip of the little finger. These resemble the spots we see on the pia in epilepsy.

7.) Factory worker, 19 years old; male. Had flash burns of the right upper extremity and left lower extremity. He was discharged 15 August, after his burns had healed. According to information which we secured later, he became ill about two weeks after his discharge, with symptoms of fever, loss of appetite, fatigue, loss of hair of the scalp. He developed petechiae, a mucoid diarrhea, and died.

8.) Hatsuko Ikei, female, 17 years old. She was within 1150 M. of the center. She received flash burns of the left upper extremity. She had fever up to 40.0 C, loss of appetite, herpetiform eruption about the mouth, cerebral symptoms and disturbances of eyesight. Petechiae, which appeared first on the arms and legs on 11 August, became generalized on 14 August and ranged in size from that of a grain of rice to that of the thumb. A blood count done on the afternoon of 14 August showed: Erythrocytes, 1.5M; leucocytes, 300; Hb, 37%. She died at 1630 on 15 August. The spinal fluid was similar to that in Case 6. Necropsy was performed shortly after death.

The positive findings were petechiae the size of a rice grain throughout the alimentary tract. Other changes were as before, that is, hemorrhage in the left posterior portion of the cerebellum in the vicinity of the posterior inferior cerebellar artery. The spots on the pia previously mentioned were also seen in several places.

9.) Male, age not stated. He suffered from a contusion of the scrotum. Starting on the 11th, he began to have fever. The contusion was about 1 cm. in diameter with practically no bleeding. On 14 August, he began to lose his hair in patches. The individual hairs could be pulled out without resistance. On 15 August, petechiae began to appear and also the peculiar eruption about the mouth. He died at 0015 on 16 August.

Three more patients showed epilation and the herpetiform eruption about the mouth. Fever developed reaching 40 to 41 C at the time of death. These also showed petechiae and the dysentery-like diarrhea.

These patients were treated by transfusions of 100 to 200 cc. of blood and the parenteral administration of Vitamin B complex and Vitamin C, intravenous glucose, and liver extract. The patients got worse in spite of treatment. The fact that patients with relatively slight wounds and burns showed the most severe symptoms is worthy of note.

At this time, on another ward (ward 12), there was a female patient, Chizuko Yamada, age unknown, with abrasions of the left arm and chest and a contusion of the hip. She developed herpes, hair loss, fever, and numerous petechiae. She died 20 August. Necropsy was performed. Findings:

The body is that of a female corpse of average size showing moderate emaciation. Both corneas are cloudy and the pupils contracted. There is no swelling of the superficial lymph nodes of the body. Crusted herpetic lesions are present about the lips. The oral mucosa has a gray coating. The subcutaneous fat is moderately well developed. Post mortem lividity is present in the dependent portions. Rigor mortis is present throughout. The left dome of the diaphragm reaches the level of the left sixth rib; the right diaphragm is at the level of the fifth right interspace. In the pericardial sac are 15 cc. of straw-colored, clear, fluid. The cardiac chambers are filled with liquid and clotted blood. The heart is slightly enlarged. The right lung is bound down by easily separated fibrinous adhesions; it is blue-violet in color, and is filled with blood and air. The left lung is of similar appearance except for the absence of adhesions. The thymus shows degeneration and is atrophied to the size of the little finger. The peritoneum is shiney and light yellow in color. The liver measures 30x18x7 cm., and weighs 1160 Gm. with the gall bladder. It is partially adherent to the diaphragm. The color is dark purplish-red. The surface is smooth, but there is a torn area on the posterior surface of the right lobe, 10x0.3 cm. The torn surface is yellowish to reddish-brown in color and the hepatic lobules can be distinctly made out. Stomach: A portion is adherent to the spleen and pancreas. It is about normal in size. The mucosa is quite hyperemic and shows numerous petechiae. It contains bile-stained viscous material. Gall bladder: Size of a hen's egg. Exterior is glossy. Contains about 10 cc. of yellowish-green bile. Spleen: Purplish-red in color. The surface is smooth and glossy except for a tear 4 cm. long by 0.5 cm. deep running horizontally across the center. The follicles are not prominent. Pancreas: Of a pink color. The cut surface is gray. Acinic are distinctly visible. Kidneys: Both light reddish-purple in color. The capsule strips easily. The line of demarcation between medulla and cortex is clear. The kidney pelves are of normal capacity. The small intestine and colon are markedly hyperemic and on the serous surfaces are petechiae varying in size from that of a grain of rice to that of a pea. On the mucosa are many ulcerated areas varying in size from that of a rice grain to that of a red bean. In the large bowel there are patches in rows or arborizing patterns covered with grayish membrane which can be readily stripped away, revealing a hyperemic base in the sigmoid and rectum, but not in the rest of the colon.

Todachi Kusumoto, a patient on ward 6, was admitted on 25 August. He was a 14 year old male student who had been 1 Km from the flash. He had no burns or wounds. He complained that in the past few days he had had fever

and loss of hair. On the morning of 25 August, he had fever of 40.4 C, pulse, 140. He died the same morning. The following notes were made at the time of admission: "The patient is of about average size and development. The nutrition is rather poor. The body temperature is 40.4 C and the pulse 140. Pupillary reaction sluggish. The lower lip is eroded and partly crusted. The lips are swollen. The submaxillary nodes are enlarged to the size of the terminal phalanx of the index finger and are tender. The tongue is dry and covered with a brown coat. The pharyngeal mucosa is reddened. The tonsils are covered with white exudate. There are petechiae over the entire body. Scalp hair is completely lost. There is cardiac palpitation. Breath sounds are harsh. The liver can be felt 3 cm. below the costal margin. The spleen is not palpable". Findings at autopsy:

The body is that of a middle-sized male. The nutrition is quite poor. The cornea are slightly clouded. Pupils are moderately dilated. The oral mucosa is of a grayish color. Tongue is heavily coated. The teeth are carious; the gums necrotic and covered with exudate. Fat could be found in every joint. Post mortem lividity is present in the dependent portions. There are numerous petechiae of the skin from the size of a millet seed to that of a red bean. The hair is noteworthy in that it pulls out very easily, so that large amounts come away when touched with the wet hand. The diaphragmatic domes are at the level of the fifth rib on both the right and the left. There are adhesions between the visceral and parietal pleura, especially on the right side. The pericardium was smooth and glistening and contained 20 cc. of clear, serous fluid. The peritoneum was glistening and did not appear abnormal. The liver was strongly adherent to the diaphragm. Heart: No abnormalities except a few petechiae on the epicardium. Lungs: Filled with blood and air. A few petechiae beneath the visceral pleura. Liver: Surface glossy, dark purplish-red. The cut surface appears essentially normal, though the liver lobules are rather indistinct. Spleen: Dark purplish-red. Cut surface appears normal. Follicles indistinct. Right kidney: Surface purplish-red and glossy. The cut surface is normal with a clear line of demarcation between cortex and medulla. There are a few petechiae under the kidney capsule. The renal pelvis is normal. Left kidney: Similar to right except for the presence of clots in the pelvis. Pancreas: Rather small. The acini are distinctly visible on the cut surface. Stomach: No abnormalities except petechiae on the mucosa. Bladder: Normal mucous membrane. Intestine: Portions are hyperemic; petechiae are numerous. Colon: Numerous petechiae. Esophagus: Numerous petechiae. Diaphragm: Petechiae under the parietal pleura of the right leaf. Pia mater: Blob-like areas the size of a millet seed. Brain: Cut surface shows no abnormalities.

We did 10 autopsies up to 31 August. Eight of these patients had epilation. In general, petechial spots were numerous in the internal organs.

1.) Distribution of petechiae:

From esophagus to rectum	3 cases
In intestine only	6 cases
of above, in rectum only	2 cases
of above, in colon only	2 cases
In spleen, kidney, etc.	8 cases
In brain only	1 case

2.) White sloughs in alimentary canal.....3 cases

3.) Hemorrhage from vessels at base of brain.....6 cases

4.) Ruptured viscera:

liver	3 cases
spleen	2 cases
lung	2 cases

Noteworthy features: Three cases with sloughs of the intestinal mucosa had similar lesions of the oral mucosa. Six cases had the small cysts between the pia and brain surface similar to those seen in epilepsy. Changes in the bone marrow and other blood forming organs were not studied.

The illnesses resulting from the atomic bombing of Nagasaki (excepting those killed outright as previously described) can be classified in several rather well-defined groups:

1. Burns
2. Wounds from debris hurled about by the blast wave.
3. Cases with hemorrhagic diathesis:
   a. those with dysentery-like symptoms starting shortly after the bombing
   b. those with symptoms starting after a latent period.

The cause of the 3rd group is presumably radiation given off by atomic disintegration.

Incubation period: This seems to be inversely proportional to the distance from the center. For example:

Patient 6 - Distance less than 750 M; symptoms appeared the same day.
Patient 8 - Distance 750 M; symptoms appeared the same day.
Patient 12- About 1000 M; symptoms appeared 4 days later. (6 other similar cases.)
Patient from ward 6 - Distance about 1000 to 1500 M; symptoms appeared 10 days later.

These data are derived from 25 out of the 758 cases admitted. No further data is available on this point at the time of writing.

Symptomatology: Those who received no wounds and were quite well immediately after the attack, developed symptoms of fatigue, anorexia, and high fever even to 40 C. At this time swelling and tenderness of the cervical lymph nodes appeared in many, together with sore throat and hoarseness. One or two days later, there appeared diarrhea, with a watery, mucoid, bloody stool. Hematuria appeared. Alopecia began to develop, spreading from points of pinhead size. Then petechiae developed over the entire body and simultaneously, bleeding from the mouth and gums and epistaxis. Many developed an unusual herpetiform eruption around the mouth; as death draws near the area becomes gangrenous and the fetor becomes marked. No cardiac disturbances were seen except a drop in blood pressure in the terminal stage. Many developed symptoms of a terminal pneumonia. Many complained of stomach ache, but these did not always have vomiting. Ascaris was present in most. Terminally, central nervous system symptoms appeared with loss of vision (inability to count fingers at 30 cm.). Those who showed no central nervous system symptoms remained mentally clear even terminally, in spite of severe anemia and high fever. Among those whose wounds had been healing well, the granulations gradually became gangrenous and foul smelling. The sites of needle punctures also became infected and necrotic.

Laboratory findings: On examination of the urine, albumin and urobilinogen were found. Blood findings: RBC, 1.0 to 2.0 M; WBC, 200 to 500; Hb, 30 to 50%. Bleeding time: 20 minutes to 2 hours or more. Throughout a smear, only one or two leucocytes might be seen. These were all lymphocytes.

Fever gradually became higher and reached a maximum terminally, dropping slightly at death. (Plate V). During the prodromal period, bullae varying in size from a thumbprint to a hen's egg appeared in various places. These may be comparable to Roentgen-ray erythemas, or may be the result of radioactive material adherent to the skin.

Prognosis up to 10 September: Mortality, 100%.

Diagnosis: Presents no difficulties.

Treatment:

1.) Intravenous administration of 20% glucose mixed with Vitamin B Complex and Vitamin C.
2.) Blood transfusions of 100-200 cc. at one time.
3.) Liver extract.

No special benefit was noted from any therapy given.

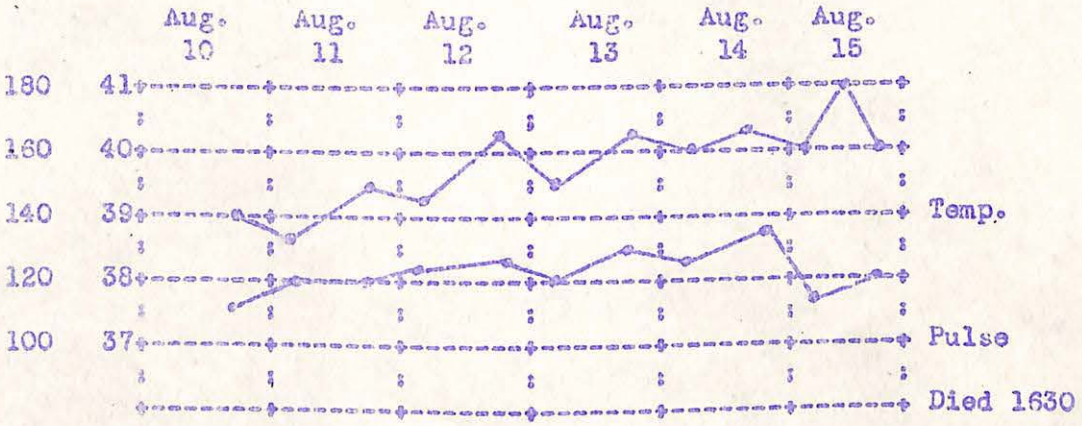
Postscript: The distance from the source seems unbelievably great for these effects to have been the result of exposure to radiation from radioactive material. However, the magnitude of the radiation effects may be far greater than anything previously conceived of in the science of radiology.

Amont the foresaid 758 cases admitted to this hospital, there were only 3 cases of tetanus. This is quite remarkable when we consider conditions

At the site of injury and the condition of the trains and for transportation.

Therefore in treating these patients, I think it best to attempt to support the function of the blood-forming organs. However, in six out of ten cases autopsied, there were lesions in the pia mater for which this treatment would have been of no avail. No final statement as to the ideal treatment can be given at this time.

Plate 6.- Patient 8, female; 17 years old.



Appendix II - Report II

Research on the Symptoms Caused by the Atomic Bomb

Professor Toichiro Sawada
Committee

September 28, 1945

A. Effect on the human system of those who were at the scene of disaster.

On August 31, in front of the Nagasaki Medical University, we were able to locate nine persons who were not victims of the explosion, but who came here afterwards and have been living in self-made huts about 500 meters from the center of the explosion. Some of these people rushed down to Nagasaki from such distant places as Shikoku and Kyoto-Prefecture. We carefully selected only those of whom we had reasonable assurance of their not having been exposed to the explosion. The leucocyte count of these people was taken (see Table I). Tests revealed that the lowest was 4400, the highest 8200, and the average 6550.

For comparison, we found ten persons who were in Nagasaki or its vicinity at the time of the explosion and have since been living near the scene of disaster. We have also taken their leucocyte counts. The results are as shown in Table II, the lowest 3000, the highest 7320, and the average 4650

A comparison of the two averages showed the former in the 6000's and the latter in the 4000's (which had smaller counts), but we were unable to determine any physical differences between the two groups.

From these results we have obtained a general impression that unless a person is directly exposed to the explosion, no physical disorders of any import develop even if he does live at the scene of disaster afterwards.

Later, we examined the leucocytes of those people who have remained at, or passed through, this area as members of relief and restoration parties. Table III shows the results of the examination to date. In almost all cases the leucocyte count is close to normal and no physical disorders have come to our attention.

Looking into the aforesaid results, we found cases of fatigue and diarrhea among people who were not victims of the explosion, but who had been living at the scene of the disaster afterwards. The patients suspected that these symptoms were caused by radioactive substances remaining at the scene of disaster, and they also feared that their leucocyte count had decreased, but re-examination of these people showed that their leucocyte count was absolutely normal. It is impossible for us to conclude that such aforementioned symptoms as fatigue and diarrhea were caused by the actions of radioactive substances remaining at the scene of disaster. It is perhaps more proper to say that the causes of these symptoms were from overwork, neglect of health or neuropathy.

B. Nature of the symptoms caused by the atomic bomb.

When the effects of the atomic bomb on the human system are analyzed, they can be classified into the following three types:

1. "Mechanical effects"
   (Possibly external wounds caused by flying objects, falling debris, etc.)
   Caused by the blast
   (Literally, "explosion wind")

2. Burns caused by the heat waves and ultra-violet rays.

3. Effects caused by a great amount of radioactive rays.

The "mechanical effects" caused by the blast are similar to those caused by ordinary bombs. Burns caused by heat are similar to those caused by incendiary bombs, but burns caused by ultra-violet rays have a special trait of healing rather rapidly. It can be said that the reactions caused by radioactive rays are special features of the atomic bomb. For instance, people are taken ill several weeks after the explosion, and the death rate is very high. From the viewpoint of internal medicine, they are special symptoms and should be classified separately as symptoms caused by the atomic bomb.

In looking into the symptoms caused by the atomic bomb one should always keep in mind that they are symptoms caused by a great amount of various radioactive rays to the human system.

It is by these rays that the various cells in the human system are affected, and the degree of damage depends largely upon the sensitivity of these cells. The maematopoietic cells and the generative cells are considered most sensitive. It is also believed that the cells of the various internal organs and internal secretion organs are also affected.

Judging from the internal symptoms (to be discussed later) it is believed that the medullary tissues are mainly affected. In order to verify this fact, aspiration of the bone marrow has been performed on many patients to study the medullary cells. The result of the examination showed that the cells were severely affected.

The normal percentage of erythroblasts is 19%, but according to Table IV in Matsuda's case, for example, it is 0, and in Murata's case, 6.5%. The hematoblasts are also 0.

The normal percentages of leucoblast and leucocytes are 59.8%, but they have decreased to 15.5% in Matsuda's case and to 5% in Murata's case.

Practically no change occurred in the lymph corpuscles. The reticular cells and adipose cells are normally about 1%, but in Matsuda's case it increased to 63% and in Murata's case to 60.5%.

These facts show that the bone marrow tissues were severely affected, and is evidently due to panmyelophthisis (or agranulocytosis, which is a common clinical term). It is believed that the impaired functions of

the bone marrow are the chief causes for the symptoms caused by the atomic bomb. The histological examination of a piece of bone marrow has also proved these facts.

C. Clinical Symptoms.

This Medical Relief Party has diagnosed and observed about 400 patients at the Shinkozen National School in Nagasaki during a period of two weeks from September 1 to September 14.

Table V shows the dates on which the symptoms occurred. Among them the most frequently complained of symptom was fever, which is followed by epilation, anemia, headache, systemic fatigue, etc., in that order of frequency.

During the first week the most complained of symptoms were nausea (28 cases out of 32), vomiting (23 cases out of 25), anorexia (15 cases out of 23), and headache (17 cases out of 44). Symptoms such as nausea, vomiting, systemic fatigue, and headache are believed to be caused directly by being exposed to the radioactive rays. Besides these symptoms, fever (12 cases out of 70), systemic fatigue (7 cases out of 35), and diarrhea (6 cases out of 35) also occurred during the first week. Table V shows that fever, epilation, spotted hemorrhage of the skin, anemia, systemic fatigue, sore throat, tonsillitis, odontalgia, maculas on the skin, stomatitis and icterus occurred most often during the fourth week than during any other preceding week. Among these, fever, epilation, hemorrhage, sore throat, and stomatitis should be considered as chief symptoms which developed in the late stadium, and with the exception of epilation these are considered as symptoms of bone marrow consumption. These symptoms and blood changes indicating symptoms of bone marrow consumption developed in most patients about three or four weeks after the explosion.

Table VI has been prepared by classifying the reactinns caused by radioactive rays into early and late stadia, and also by examining the patients who were within 3 km. from the center of the explosion. Of the 169 patients examined, 27.2% showed absolutely no sign of illness, while the majority (72.8%) had some symptoms of which more than half occurred in the early stadium.

Epilation, hemorrhage (spotted hemorrhage of the skin, gingival hemorrhage, intestinal hemorrhage and epistaxis), stomatitis and fever are considered the chief symptoms which developed in the late stadium. Table VII shows the relationship of these symptoms to the distance from the center of the explosion. The relatively small percentage of these symptoms within 0.5 km. radius, is, perhaps, because most victims in that area died within a short period of time after the explosion. The largest percentage of these symptoms is found between the 1.0 to 1.5 km. radius, but beyond 2.0 km. radius there is a marked decline (a few exceptional cases occurred beyond 4.0 km.). In other words, those who were taken ill up to September 14, were chiefly persons who were within 1.5 km. from the center of the explosion, while only a few were taken ill beyond a distance of 2.0 km.

This coincides with the fact that the completely destroyed areas in Nagasaki were within 1.5 km. to 2.0 km. from the center of the explosion.

Examination of the leucocytes revealed that a sharp decrease of them occurred in many patients. Table VIII has been prepared for the purpose of determining whether the leucocyte count will return to normal or not with the lapse of time. According to this Table, patients with leucocyte counts below 1000 during the first period (9/1 - 9/4) came to 25.6%; the second period (9/5 - 9/9) 8.2%; and the third period (9/10 - 9/13) only 2.9%. As a result of these changes, patients with leucocyte counts of 5000 to 6000 in the second period increased to 23.7%, and during the third period 17.5% of the patients had counts of 6000 to 8000. It is therefore evident that the lost leucocytes are gradually replaced with the lapse of time.

Table IX is an observation of these changes in relation to the distance from the center of the explosion. From September 1 to 4, persons who were close to the center of explosion (within 1 km.) show a remarkable decrease in their leucocyte count, but the farther the distance the less conspicuous is the decrease. The leucocyte count of many patients who were about 3 km. from the center of the explosion especially was almost close to normal. This relationship became more distinct with the lapse of time. For instance, from September 10 to 13, even among those who were close to the center of the explosion, those who suffered from leucopenia became few. Among normal patients whose leucocyte count was returning to normal, some even had a count exceeding the average number of 8000. This fact was especially noticeable among those who were within the radius of 3 km. (There were actually more persons with an increase of leucocytes.)

The changes in the erythocyte count are shown in Table X. During the early part of September there were relatively few patients with a noticeable decrease in the erythrocyte count, and most of them maintained the normal number of 4 million to 5 million. However, as time went by a gradual decrease in the number of erythrocytes became evident. During the period from September 10 to 13, 34.6% of the patients had a count of 3 million or below. This indicates that contrary to the increase in the leucocyte count, the erythrocyte count decreases. Clinically, this coincides with the fact that many patients have recently developed anemia.

Furthermore, due to the recent increase of leucocytes, myeloblasts and medullary cells were found in the blood and cases which showed medullary reactions were noticed. The change of the hemoglobin, the decrease of hematoblasts, and the delay of bleeding time were also noticed.

Albumin in the urine was detected in a few cases. During the early part of September, many patients had positive urobilinogen in their urine, which indicated defective functioning of their liver, but this condition gradually disappeared. Other clinical reports will be made available on some other occasion.

D. Prognosis

Among the main symptoms which develop in the late stadium, the more serious the degree of fever, epilation, pharyngitis and hemorrhage of the skin, the poorer the prognosis, but some patients with serious main symptoms are gradually recovering after being considered hopeless. It is also true that the greater the decrease of leucocytes, the more serious is the condition of the patient, but in some cases patients with a leucocyte count of 1000 or below have recovered.

In general, the earlier the symptoms develop, or the shorter the latent period, the poorer the prognosis; the longer the latent period the better the prognosis. Whether or not the patients had external wounds or burns, these symptoms developed several weeks after the explosion. Those who overworked themselves instead of remaining quiet when no abnormal symptoms developed at first, are the ones who later developed symptoms and in many cases the prognosis is bad.

It is very reasonable to say that the death rate is proportionate to the extent of exposure to radioactive rays, while the extent of exposure to radioactive rays is in inverse ratio to the square of the distance from the center of the explosion. Therefore, the closer a person is to the center of the explosion, the earlier the symptoms develop, which also explains the high death rate; and the closer a person is to the center of the explosion, the easier it is for him to receive external wounds and burns. Many people have died from these causes. Thus, it is very difficult to compile accurate statistics. Moreover, two persons may be at an equal distance from the center of the explosion, but it is important to take into account the extent of cover (whether they were under cover or not) which further complicates the whole situation. An investigation is being held on these matters at present.

E. Medical Treatment

It is needless to say that complete rest, nutrition, and a supply of vitamins are important. Besides these, I believe the injection of grape sugar is very effective.

From our experience, occasional blood transfusions for serious anemia patients have invigorated their feelings or revived their spirits, and the results have been good.

Since the liver contains hormone that reacts to the blood-making action of the medulla, we have used it at every opportunity; the results seem to be good.

We have in our internal medicine department about 38 patients with symptoms caused by the atomic bomb. Among them are patients with the combination of high fever, epilation, spotted hemorrhage of the skin, and pharyngitis, who were considered hopeless in the early part of September, but most of them are recovering after application of the treatments mentioned above. Only three deaths occurred.

Judgment as to the efficacy of the treatments is very difficult.

TABLE I

The Leucocyte Count of those Living in the Center of the Bombed Area
(Not in the area at the time of the bombing)

Name	Sex	Age	Leucocytes
Eguchi	female	18	8,200
Ogawa	female	32	6,260
Takubo	male	39	7,800
Kanaya	male	39	5,460
Tajima	male	21	6,660
Eguchi	female	20	5,460
Takeshita	male	7	8,000
Mitsutake	male	37	4,400
Kubo	male	44	6,600
Average			6,550

TABLE II

The Leucocyte Count of those Living in the Bombed Center (victims)

Name	Sex	Age	Leucocytes
Hoshika	male	14	4,720
Inao	male	38	5,100
Okabe	male	21	4,400
Hamada	female	30	3,200
Yashima	male	42	5,850
Mabuchi	female	30	3,060
Hasezaki	male	33	3,000
Otsuka	male	53	5,200
Matsuo	male	53	7,320
Average			4,650

TABLE III

The Leucocyte Count of the Members of the Kyushu University Relief Party
(Remained at the Scene of Disaster from Aug. 14 to 23rd)

Name	Sex	Age	Leucocytes
Inouye	male	25	7,300
Kuroki	male	24	6,400
Sawa	male	25	5,800
Morimoto	male	36	5,700
Watanabe	male	30	5,600
Takagishi	male	25	6,800
Nakajima	male	27	6,000
Nagaoka	male	25	5,800
Fukushige	male	25	6,100
Noda	male	24	7,600
Ikeda	male	25	8,200
Maruoka	male	25	5,500
Okazaki	male	25	7,000
Average			6,440

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TABLE IV

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Microscopic analysis of the Marrow Afflicted with Symptoms Caused by the Atomic Bomb

Kind of Cells		Normal Percentage for a Japanese		Matsuda		Murata	
Megaloblast	formation of erythrocytes	0.1%	19.0%	0%		0.5%	6.5%
Macroblast		2.9		0		4.0	
Erythroblast		16.0		0		2.0	
Hematoblast		0.1%		0		0	
Myeloblast	Granuloleukomatose (Ger.)	1.8%	59%	5.5%	16.5%	1.5%	5.0%
Neutrophil premyelocyte		3.8%		3.5		1.0	
Neutrophil myelocyte		5.1		4.5		1.5	
Neutrophil post myelocyte (leucocytes)		7.8		1.5		0	
Neutrophil "Staff form" nucleus		16.6		0.5		0	
Lobulated Nucleus (leucocytes)		20.2		1.0		0	
Eosinophil cells		4.2		0		1.0	
Basophil cells		0.3		0		0	
Monocyte		3.1%		0		2.0%	
Lymph corpuscles		16.8%		16.0%		22.5%	
Lymphoid	Reticular cells		ABOUT 1.0%	24.5%	53.0%	28.5%	60.5
Plasmatic				30.5%		26.0%	
Phagocytic				5.0%		5.0%	
Fatty				3.0%		1.0%	
Cells which are difficult to classify				4.5%		3.5%	
Total				100%		100%	
Non-nucleated cell	non-nucleated cells / Nucleated cells			46/200		21/200	

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TABLE V

	Symptoms	Total No of Patients	1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week
1.	Fever	70	12	5	10	36	7	
2.	Epilation	69	6	5	20	31	7	
3.	Spotted Hemorrhage of the skin	51	4		10	22	15	
4.	Anemia	46			12	27	7	
5.	Headache	44	17		8	16	3	
6.	Systemic Fatigue	35	7		4	11	13	
7.	Gingival Hemorrhage	33	3	1	8	12	9	
8.	Nausea	32	28		1	3		
9.	Sore throat	31	2	1	4	17	7	
10.	Tonsillitis	27		2	4	12	9	
11.	Vomiting	25	23			1	1	
12.	Diarrhea	25	6	1	2	12	4	
13.	Dropsy	23	2		6	14	1	
14.	Anorexia	23	15		2	6		
15.	Vertigo	15		2	13			
16.	Odontalgia	13	3		1	6	3	
17.	Haematuria	10	2	3	4		1	
18.	Macula	9				5	4	
19.	Tinnitus	6			4	2		
20.	Epistaxis	5	1		3	1		
21.	Stomach ache	4				1	3	
22.	Stomatitis	4				3	1	
23.	Icterus	4				3	1	
24.	Constipation	3			2	1		
25.	Haematemesis	2	2					
26.	Chest ache	2	1		1			
27.	Dyspnoea	2				1	1	
28.	Lung ulcer	2				1	1	
29.	Hemoptysis	2				2		
30.	Insomnia	1				1		
31.	Hard of hearing	1				1		
32.	Drivel	1			1			
33.	Frequent urination	1	1					
34.	Blood stool	1				1		
35.	Mouth ulcer	1				1		
36.	Emaciation	1			1			

TABLE VI

	No. of People	%
Those who developed symptoms only in early stadium	16	9.5
Those who developed symptoms only in late stadium	48	28.4
Those who developed symptoms in the late as well as the early stadium	59	34.9
Those who did not develop symptoms in the early or late stadium	46	27.2
Total	169	100.0

TABLE VII

Distance	Towns	No. of Cases	%
0.5 Km	Shiroyama, Yamazato, Takao	12	11.3
1.0	Mezame, Uragami, Shigesato, Sakamoto, Takenokubo	43	40.6
1.5	Ohashi, Zeniza, Nishizaka	32	30.3
2.0	Inasa, Mifuna, Saiwai	5	4.7
3.0	Nagasaki Station, Hiradokoya(?), Motohara, Oi	10	9.4
4.0	Mizunoura	3	3.4
4.1 & over	Showa	2	1.9

TABLE VIII

Leucocyte Count	No. of People	%
0 - 1000	13	12.3
1001 - 2000	15	14.2
2001 - 3000	24	22.6
3001 - 4000	14	13.2
4001 - 5000	8	7.5
5001 - 6000	13	12.3
6001 -10000	12	11.3
Over 10,000	7	6.6
Total	106	100.0

TABLE VIII

Leucocyte Count	No. of People	%
0 - 1000	13	12.3
1001 - 2000	15	14.2
2001 - 3000	24	22.6
3001 - 4000	14	13.2
4001 - 5000	8	7.5
5001 - 6000	13	12.3
6001 -10000	12	11.3
Over 10,000	7	6.6
Total	106	100.0

TABLE IX

White Corp. / Date	Below 1000	Below 2000	Below 3000	Below 4000	Below 5000	Below 6000	Below 8000	Below 10000	Over 100000	Total
1	8	6	4	2	6	4	8	1		39
2	2									2
3										
4	1	1								2
	11 (25.6)	7 (16.3)	4 (9.3)	2 (4.6)	6 (13.9)	4 (9.3)	8 (18.6)	1 (2.3)		43
5-6	2	2	1	2	5	11	9	2	1	35
7		2	1	3	5	5	4	1		21
8	3	1	6	3	4	6	3			26
9	3	2		2	2	1	3	2		15
	8 (8.2)	7 (7.2)	8 (8.2)	10 (10.3)	16 (16.5)	23 (23.7)	19 (19.6)	5 (5.2)	1 (1.0)	97
10	2	4	6	5	3	5	4	6	7	42
11	1		3	9	2	3	2	3	2	25
12	1	1	2	1	11	9	9	9	5	48
13	1	4	4	7	6	4	15	10	5	56
	5 (2.9)	9 (5.3)	15 (8.8)	22 (12.9)	22 (12.9)	21 (12.3)	30 (17.5)	28 (16.4)	19 (11.1)	171

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TABLE X

Sept. 1-4

White corpuscles / Distance	Under 2000		Under 5000		Under 7000		Under 8000	
0 - 1.0 Km	9	45%	7	35%	2	10%	2	10%
1.1 - 2.0	5	37%	6	40%	4	27%	0	-
2.1 - 4.0	2	30%	0	-	4	40%	4	40%
Sept. 5-9								
0 - 1.0 Km	4	28%	3	21%	5	37%	2	14%
1.1 - 2.0	10	23%	20	47%	10	23%	3	7%
2.1 - 4.0	1	5%	7	33%	12	57%	1	5%
Sept. 10-13								
0 - 1.0 Km	1	7%	3	21%	2	14%	8	58%
1.1 - 2.0	8	10%	40	50%	19	24%	13	16%
2.1 - 4.0	1	2%	13	22%	12	20%	32	56%

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TABLE XI

Number of Red Blood Corpuscles.

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Date	Below 2 mil.	Below 3 mil.	Below 4 mil.	Below 5 mil.	Over 5 mil.	Total
Sept. 1		3	10	12	7	32
2		1		3		4
3						0
4		1	2	1		4
	0	5 (12.5%)	12 (30.0%)	16 (40.0%)	7 (17.5%)	40
5		3	12	6	1	22
6		1	1	8	1	11
7 - 8		4	22	16	1	42
9	1	3	6		2	13
	1 (1.1%)	11 (12.5%)	41 (46.5%)	30 (34.0%)	5 (5.6%)	88
10	1					1
11		8	7	1	2	18
12	3	4	3		3	13
13				17		17
	14 (8.1%)	12 (26.5%)	10 (20.4%)	18 (34.6%)	5 (10.2%)	49

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