

**THE MEDICAL SEQUELAE OF THE ATOMIC BOMB EXPLOSION**

原子爆弾による医学的後遺症

GEORGE V. LeROY, M.D.

**HEMATOLOGY OF ATOMIC BOMB CASUALTIES**

原子爆弾被爆者の血液所見

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ATOMIC BOMB CASUALTY COMMISSION

国立予防衛生研究所—原爆傷害調査委員会

JAPANESE NATIONAL INSTITUTE OF HEALTH OF THE MINISTRY OF HEALTH AND WELFARE

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ATOMIC BOMB CASUALTY COMMISSION  
HIROSHIMA AND NAGASAKI, JAPAN

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## HEMATOLOGY OF ATOMIC BOMB CASUALTIES

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As a practical generalization, it may be said that sufficient irradiation of tissues with either radium or roentgen rays will cause a reduction in the number of cells of all series in the circulating blood. The greater the dose, the more profound is the blood damage, the more rapidly it develops and the more slowly it is repaired. The blood response remains quite consistent qualitatively over a wide range of dosage, although massive exposures may obscure the early changes, and small doses sometimes fail to evoke the complete response. —Minot and Spurling.<sup>1</sup>

During the period Aug. 6 to Dec. 16, 1945, a large number of hematological studies was performed on Japanese injured by the atomic bombs exploded over Hiroshima and Nagasaki, Japan. These studies were conducted by Japanese physicians and by medical officers of the United States Army and Navy attached to the Joint Commission for the Investigation of the Effects of the Atomic Bomb in Japan. The results of the studies were submitted in the Medical Report of the Joint Commission<sup>2</sup> and have not been published in their entirety up to the present. Because of current interest in the syndrome of radiation injury from the standpoint of national defense, permission has been granted for the publication of these detailed hematological

「現実的な一般論としては、ラジウムあるいはX線によって身体組織が十分な放射線照射を受けると、循環血液中のすべての血球系の細胞数が減少するといえるであろう。線量が多いほど、血液損傷は顕著で、急速に出現し、回復もおそい。血液反応は、大量照射で初期変化が隠蔽されたり、小量照射ですべての反応が誘発されなかつたりする場合もあるが、質的には、広範囲の線量にわたりかなり一定している。」——Minot および Spurling.<sup>1</sup>

1945年8月6日から12月16日までの期間に、広島、長崎の上空で炸裂した原子爆弾の日本人被爆者について多数の血液学的調査が行なわれた。これらの調査は、日本の医師や原爆影響に関する日米合同調査団に所属する米陸海軍の軍医によって実施された。これらの調査の結果は、合同調査団の医学的報告書<sup>2</sup>として提出されたが、今日までにその全体が発表されたことはない。現在は、国防の見地からも放射線傷害症候群について関心が持たれているため、これらの詳細な血液学的調査の発表が許可された。ここに示した資料の出所は、合同調査団の医学的報告書の第6章の血液学的領域および第9章の統計学的解析である。この資料は、原爆による電離放射線を種々の程度に受けた多

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*This article is derived from the Medical Report,<sup>2</sup> the preparation of which was the joint responsibility of Drs. Ashley W. Oughterson, New Haven, Conn.; Shield Warren, Boston; Averill A. Liebow, New Haven, Conn.; L. Cuyler Hammond, New York; Henry L. Barnett, New York, and George V. LeRoy, Chicago.*

*The Medical Illustration Department, Naval Medical School, Navy Medical Center, prepared the figures.*

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本報告書は, Dr. Ashley W. Oughterson (Connecticut 州New Haven市), Dr. Shield Warren (Boston市), Dr. Averill A. Liebow (Connecticut 州New Haven市), Dr. L. Cuyler Hammond (New York市), Dr. Henry L. Barnett (New York市) および Dr. George V. LeRoy (Chicago市) の共同責任で作成された合同調査団医学的報告書<sup>2</sup>に基づいている。

図表は, 米海軍医学センター海軍医学校医学図表部で作成した。

studies. The source of the material here presented is Section 6, hematological aspects, and Section 9, statistical analysis, of the Medical Report. The data are of unusual interest as the authoritative record of the changes in the blood of a large group of persons exposed to varying amounts of ionizing radiation from atomic bombs. They are of especial interest when compared with the report of Snell,<sup>2</sup> of the United States Atomic Bomb Casualty Commission. In the preparation of the latter report many of the Japanese studied were the same persons discussed in the present paper.

A large body of literature is available describing the hematological changes that occur in laboratory animals after exposure to ionizing radiation, and it is not necessary to review it at this time. The interested reader is referred to the monographs of Dunlap<sup>4</sup> and Bloom.<sup>5</sup> This report will be restricted to a description of changes that were observed in the peripheral blood. An interpretation of the changes in the bone marrow is in preparation. The clinical features of radiation injury were discussed by Warren and Bowers.<sup>6</sup>

#### MATERIAL AND METHODS

The material on which this study is based was obtained from three sources:

1. Blood examinations performed by Japanese physicians prior to the formation of the Joint Commission (about Sept. 15, 1945). Some of these studies were made by medical aid and research groups recruited from various medical schools. Others were carried out in the wards of medical schools and military hospitals to which casualties had been admitted. Few of such studies were systematic, and most were done under extremely unfavorable conditions.

2. Routine blood counts performed on survivors in each city as a part of the program of the Joint Commission. An attempt was made to obtain a reliable "sample" of persons from all parts of the bombed cities. The study included the completion of a questionnaire, a physical examination and a routine blood count by American and/or Japanese technicians.

数例における血液変化の信頼すべき記録として特に興味がある。この資料を米国原爆傷害調査委員会における Snell の報告と比較すれば興味深いであろう。後者の報告に用いられた日本人調査対象者の多くは、本報告書における対象者と同一である。

動物実験で電離放射線照射後に生ずる血液学的変化を記述した文献は多いが、ここでその再検討を行なう必要はないであろう。関心を有する読者は、Dunlap<sup>4</sup> および Bloom<sup>5</sup> の論文を参照していただきたい。本報告書では、末梢血液に観察された変化を記述することとどめる。骨髄変化の解釈についての報告書は、準備中であり、放射線傷害の臨床的特徴については、Warren および Bowers の報告がある。<sup>6</sup>

#### 材料および方法

今回の調査に用いた材料は、次の三つの出所から求めた：

1) 合同調査団の結成(1945年9月15日ごろ)以前に日本の医師によって行なわれた血液検査。その一部は、各大学から派遣された医療班や研究班によって行なわれた。そのほか、被爆者を収容した大学病院や陸海軍病院で実施されたものもある。検査が系統的に行なわれたことは少なく、その大部分はきわめて悪い条件のもとで実施された。

2) 合同調査団の調査プログラムの一環として両市の被爆者について実施された常用血球計算。両被爆都市の全地域における人々の信頼すべき「サンプル」を求める努力が行なわれた。その調査では、調査票への記入、全身検査、米国人ないし日本人の技術員による常用血球計算などが実施された。



3. Special hematological studies conducted by members of the Joint Commission in the casualty hospitals to which they had access.

The tabular data which follow will be identified as follows: *JAP*, Japanese data, and *JC*, data from the Joint Commission statistical study. In most instances the material from the Medical Report<sup>2</sup> has been revised to facilitate presentation, and new graphs have been prepared.

The laboratory methods employed were as follows:

Erythrocytes and leukocytes were counted with standard hemacytometers. Some of these were of American manufacture, and the others were of Japanese or German make. None of the equipment was certified by the National Bureau of Standards. When time permitted, counts were made in duplicate, but these were an exception.

The hemoglobin concentration was estimated with the Haden-Hausser or the Sahli hemoglobinometer (American and Japanese models) and by the copper sulfate ( $\text{CuSO}_4$ ) method. The hemoglobinometers were standardized against the  $\text{CuSO}_4$  method, and, for the Japanese, 14.5 g of hemoglobin per 100 ml was taken as 100%. The standard  $\text{CuSO}_4$  solutions were checked by the pycnometer method. The hematocrit determinations (for mean cell volume, etc.) were done by Wintrobe's method.

Differential counts of 50 to 200 cells were made from films prepared on slides or cover slips stained with Wright's stain. Most of these films are now filed at the Armed Forces Institute of Pathology.

Thrombocyte (platelet) counts and clotting studies were performed by a variety of methods and, generally speaking, were not reliable.

The exigencies of the situation were such that the usual niceties of clinical research could not always be observed. In spite of this, there was remarkably good agreement between the findings obtained by various groups in each city.

3) 合同調査団員が災害救助病院を訪れて行なった特別血液学的調査。

以下に示す集計表は次のように表示して区別した：  
*JAP* すなわち、日本側の資料，ならびに *JC* すなわち、合同調査団の統計学的調査の資料。掲載の便利を計るため、合同調査団の医学的報告書<sup>2</sup>の材料の多くを訂正して新しい図表を作成した。

使用した検査方法は次のとおりであった：

赤血球数および白血球数は標準的な血球計算盤を用いて求めた。その一部は米国製であり，そのほかに日本製やドイツ製の血球計算盤も用いられた。器具は，米国基準局の検定を受けたものではなかった。時間に余裕のある際には，重複測定を行なった場合もあるが，それはほとんど例外的であった。

血色素濃度は，Haden-Hausser または Sahli 血色素計（米国製あるいは日本製）を用いて硫酸銅 ( $\text{CuSO}_4$ ) 法に従って測定した。血色素計は  $\text{CuSO}_4$  法に対して規格化し，日本人では，血色素量 14.5g/100ml を 100% とした。 $\text{CuSO}_4$  標準液は比重瓶法によって検定した。ヘマトクリット測定（平均血球容積など）は Wintrobe 法に従った。

鑑別血球計算は，スライド・ガラスまたは載せガラスを用いて作成した塗抹標本に Wright 染色を施し，血球 50 ないし 100 個を検査して行なった。これらの塗抹標本の大部分は Armed Forces Institute of Pathology で保管されている。

栓球（血小板）数計算および凝血検査が種々の方法で実施されたが，一般に信頼できるものではなかった。

当時の緊迫した状況のもとでは，臨床調査で通常要求される正確性が常に守られたとは限らない。それにもかかわらず，両市で種々の調査班によって得られた所見は，驚くほど一致した。

## SELECTION OF DATA

The large number of blood counts available for analysis and the variation in the amount of radiation received by persons throughout the bombed cities forced me carefully to select the data for presentation. The questionnaire used in the Joint Commission study yielded information on the approximate location of each person with respect to zero (the point on the ground directly beneath the bomb), his position (i. e., outdoors or inside a building), his clinical symptoms, the extent of his injuries, if any, and the results of physical examination and blood examination. The material on the questionnaires was transcribed to International Business Machine (IBM) cards for statistical analysis.<sup>7</sup> Of the 13,545 questionnaires suitable for analysis, approximately one half contained some hematological data. In selecting material to demonstrate the effect of atomic bomb radiations on the blood picture, two groups of persons were used: (1) patients in whom the diagnosis of "radiation injury" was made and (2) persons exposed to comparable amounts of ionizing radiation who survived 20 days or more. It is desirable to define these two groups precisely, so that the reader may appreciate both the significance and the limitations of the hematological studies of atomic bomb casualties.

*1. Radiation Injury.*—One of the objectives of the Joint Commission was to establish criteria for the diagnosis of radiation injury in men. From the 14 clinical signs and symptoms recorded on the questionnaires it was possible by analysis to define two as specific symptoms of radiation injury, epilation and purpura, and three as suggestive symptoms, vomiting on the day of the bombing, oropharyngeal lesions (such as pain, ulceration, necrosis and gingivitis, occurring within 39 days after exposure) and hemorrhagic manifestations other than purpura. The correlation of these criteria with the blood changes and with the estimated dose of radiation was excellent. In the tables that follow, "persons with radiation injury" have been selected on the basis of the foregoing specific and/or suggestive symptoms. The interrelationship between the various clinical

## 資料の選択

解析に利用できる血球計算の件数が非常に多く、また、両被爆都市における人々の受けた放射線量も一様ではなかったため、今回の報告の資料を注意深く選定する必要があった。合同調査団の用いた調査書から、各対象者のゼロ地点（原爆直下の地点）に対するおおよその位置、場所（すなわち、屋外または屋内）、臨床症状、外傷があった場合はその程度、全身検査および血液検査の結果などの資料を求めた。調査書の資料から IBM カードを作成して統計学的解析を行なった。<sup>7</sup> 解析に利用できた調査書 13,545 枚中の約半数になんらかの血液学的資料が記載してあった。血液像に対する原爆放射線の影響を調査するための資料を選定するにあたって対象者を次の 2 群に分けて使用した：(1)「放射線傷害」の診断を受けていた者、ならびに、(2)同程度の電離放射線を受けて 20 日間以上生存した者。原爆傷害に関する血液学的調査の意義および限界を理解するためには、この二群に対する定義を明確にすることが望ましいであろう。

**1. 放射線傷害** 合同調査団の目的の一つは、ヒトにおける放射線傷害の診断基準を確立することであった。調査書に記入してあった他覚的徴候や自覚症状 14 項目の解析により、脱毛および紫斑の二つが放射線傷害の特異的の症状であり、被爆当日の嘔吐、口腔咽頭部病変（たとえば、被爆後 39 日以内の疼痛、潰瘍形成、壊死、歯齦炎など）および紫斑以外の出血性症状の三つが示唆的の症状であると定義された。この基準と血液変化および放射線推定線量との相関はきわめて良好であった。以下の図表における「放射線傷害を有する者」は、上記の特異的ないし示唆的の症状に基づいて選ばれた。放射線傷害の各臨床分類間の相関を表 1 に示した。放射線傷害ありと分類された者は、明らかな傷害を、調査時に、または、その以前に呈した者ばかり

types of radiation injury is shown in Table 1. It should be noted that all the persons classed as having radiation injury had been or were obviously ill at the time they were studied.

2. *Persons Exposed to Comparable Amounts of Radiation.*—In the evaluation of the Japanese casualties, it was desirable to divide the patients into groups, as homogeneous as possible, in respect to their probable exposure to radiation. If the exact amount of shielding material between each person and the bomb had been known, as well as the exact distance, it would have been theoretically possible to make precise classifications. While such a procedure could not be applied, it was practical to make reasonably homogeneous groupings from the information available on the influence of shielding (by heavy building construction, shelters, etc.) on the incidence of symptoms. Within the same distance, persons outdoors or in wooden buildings were most exposed to radiation, persons in heavy-type buildings were less exposed and persons in bomb shelters and tunnels were least exposed. It was observed that roughly, the incidence of the more important symptoms among persons in heavy buildings was about the same as the incidence of the same symptoms in persons outdoors who were about 550 yards (500 m) farther from zero. On this basis, eight exposure groups, lettered A<sub>1</sub> to H, were made up by collating the IBM cards. The location of the persons in these exposure groups is shown in Table 2.

Exposure group A consisted of the most exposed patients, and exposure group H, presumably of the least exposed. It is assumed that all persons in each exposure group received about the same average dose of radiation. It is apparent that within any exposure group the persons who did not manifest radiation injury (as defined) either had greater resistance or were better shielded.

In the data labeled JAP, there has been a considerable, but unknown, amount of selection. Blood counts were made only on the critically ill or on patients who presented the syndrome which the Japanese came to recognize as radiation injury. It is fair to assume that patients so designated had

りであることを指摘したい。

2. 同程度の放射線量を受けた者 日本における被爆者を評価する場合、推定被曝線量ができる限り一様になるようないくつかの群に、対象者を分類することが望ましいと考えた。各被爆者と原爆との間に介在した遮蔽物の量あるいは被爆距離が正確にわかったならば、理論的には、厳密な分類が可能であろうがそのような方法は適用できなかった。しかし、遮蔽物（重構造建築物、防空壕など）の症状発生に及ぼす影響について現在判明している情報を用いてかなり均質的な分類区分を設けることができた。同一距離区分内にあっても、屋外または木造家屋内にいた者の被曝線量が最高であり、重構造物内にいた者の被曝線量は、それよりも少なく、防空壕やトンネル内にいた者の線量が最少であった。全般的に見て、重構造物内にいた者における主要症状の発現率は、それよりも約550ヤード（500m）遠方の屋外にいた者とほぼ同じであることが認められた。この事実に基づいてIBMカードを照合してAからHの8組の被曝群を設けた。各被曝群に属している者の被曝場所を表2に示した。

被曝群Aは最大に被曝した者であり、被曝群Hは被曝が最小の者であると考えられる。それぞれの被曝群内における者はすべてほぼ同程度の平均線量を受けたと仮定した。いずれの被曝群においても、(ここに定義したような)放射線傷害を発病しなかった者は、抵抗力がより大きかったか、より大きい遮蔽があったのであろう。

日本側の資料にはかなりの選択性があったが、それがいかなる程度であったかは不明である。重症の者や日本側が放射線傷害と考えた症候群を呈した者のみについて血球計算が行なわれていた。このように放射線傷害ありとされた患者の大部分は、実際に傷害があっ

radiation injury in most instances. Only those reports concerning the validity of which I have no doubt are included.

In the data labeled *JC*, there has been no selection in the usual sense of the term. The data are presented in relation to distance, to exposure group, to other injuries and to the time trend. Because of the manner in which the data were collected, relatively few of the persons had serial blood examinations. For this reason, it was necessary and proper to deal with pooled blood counts to demonstrate the time trend of the changes in the blood picture. All the blood counts recorded on the questionnaires for which a date was noted are included in the tabulations. Differential counts were excluded if the percentages added up to less than 95 or more than 105. All the blood count data are presented in terms of weeks after the bombing. In the Medical Report<sup>2</sup> week 1 is defined as the first seven days following the day of the bombing, week 2 the next seven days and so on. The data have been combined in various ways (i. e., weeks 2 to 5; exposure groups *A* and *B*, etc.) to obtain large enough numbers of counts for analysis, to demonstrate significant trends, etc. The number of white blood cell counts available for analysis is shown in Table 3.

たとえてよいであろう。ここでは、記録の確実性を疑う余地の全くない例のみを含めた。

合同調査団の資料に通常の意味での選択性はない。この資料と被爆距離、被爆器、その他の傷害および時間的傾向との関係を示した。資料収集方法の関係上、連続的な血液検査を受けた者は比較的少なかった。このため、血液像における変化の時間的傾向をみるために各例の血球計算の結果を合計して検討する必要があり、これは妥当な方法であると考えられた。調査票に検査年月日が明記されている血球計算の結果をすべて使用して製表を行なった。白血球百分比の合計が95未満または105以上のものは除外した。血球数の資料は、原爆後の経過を週単位で示した。合同調査団の医学的報告書<sup>2</sup>では、第1週は原爆後の最初の7日間、第2週はその次の7日間というように定義してある。解析に十分の例数を求めるため、また、有意な傾向を証明するためなどの目的で、資料を種々に組み合わせしてみた（たとえば、第2から第5週、被爆器AおよびB合計）。解析に利用できた白血球計算の件数を表3に示した。

TABLE 1 CLASSIFICATION OF CLINICAL TYPES OF THE SYNDROME OF RADIATION INJURY\*

表1 放射線傷害症候群の臨床的分類

Pathological group†	I	II	III	IV
Clinical designation	Very Severe	Severe	Moderately Severe	Mild
Approximate mortality, %	100	50	10	Nil
Time of death, wk.	1-2	3-6	6+	Nil
Exposure group	A	A, B	C, D	D, E, F, G
Approximate distance, yd. from zero, for persons outdoors, unshielded or in Japanese buildings.....	1, 100	1, 100-1, 650	1, 650-2, 750	2, 200+
Symptoms and Signs				
Vomiting, day of bombing‡	+	+	+	+
Epilation	±	‡	+	±
Purpura	+	‡	‡	+
Leukopenia	‡	‡	‡	+
Other suggestive signs of radiation injury	+	‡	‡	+

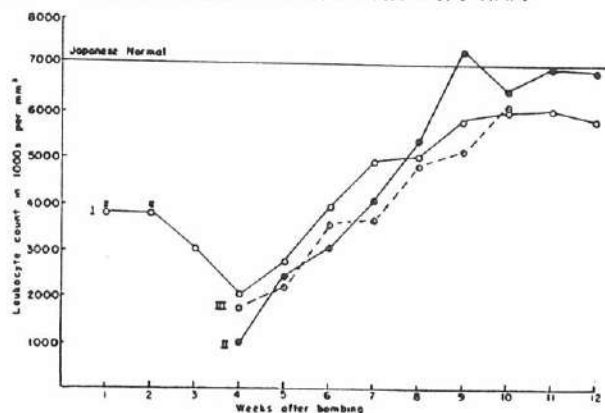
\*Source: Table 1, Section 6, Medical Report.<sup>2</sup>

†These designations are the ones used by Liebow, Warren and deCoursey (Am J Pathol 25: 853-1027, 1949).

‡Vomiting on the day of bombing is placed in the first rank of symptoms because of its obvious usefulness in triage and early evaluation of individual patients.

**FIGURE 1** Time trend of leukocyte count in severe radiation injury. Curve I shows data for exposure groups A and B, pooled (1,057 persons); curve II, for exposure groups A and B, pooled, of 287 persons with specific signs of radiation injury, and curve III, for 16 patients with severe radiation injury from Misao Clinic. Stars indicate average of less than 10 counts.

図1 高度放射線傷害における白血球数の時間的傾向



**TABLE 2** COMPARISON OF EXPOSURE GROUPS ACCORDING TO DISTANCE FROM ZERO, YARDS\*

表2 各被爆群のゼロ地点からの距離別比較 (ヤード単位)

Exposure Group	Persons Outdoors or in Wooden Buildings	Persons in Heavy Buildings	Persons in Bomb Shelters and Tunnels
A .....	0-1, 100†	.....	.....
B .....	1, 100-1, 650	0-1, 100	.....
C .....	1, 650-2, 200	1, 100-1, 650	0-1, 100
D .....	2, 200-2, 750	1, 650-2, 200	1, 100-1, 650
E .....	2, 750-3, 300	2, 200-2, 750	1, 650-2, 200
F .....	3, 300-4, 400	2, 750-3, 300	2, 200-2, 750
G .....	4, 400-5, 500	3, 300-5, 500	2, 750-5, 500
H .....	Beyond 5, 500	.....	.....

\*Source: Page 50, Section 9, Medical Report.<sup>2</sup>

†For simplicity of calculation, 1, 100 yards is considered equal to 1, 000 meters.

### OBSERVATIONS

The fact that radiation injury of varying degrees of severity occurred complicates the presentation of the hematological findings. It is desirable, however, to present the apparently typical blood pictures for the two types of the syndrome which were the most serious, very severe and severe radiation injury. Although it is not strictly correct to do so, it is probably a fair generalization to assume that most of the survivors who were included in the Joint Commission study had sustained radiation injury which could be graded as moderately severe or mild. Actu-

### 観察結果

発生した放射線傷害の重篤度はさまざまであり、このことのために血液所見の記述は複雑となるが、前記の二つの症候群に基づいて放射線傷害が「最も高度」「きわめて高度」および「高度」の別に、定型的と考えられる血液像を示すことが望ましいであろう。厳密には正しくないが、合同調査団の調査に含まれた被爆者の大部分は、一般に中等度ないし軽度の放射線傷害を受けていたと考えてよいであろう。事実上、集団としての放射線傷害の程度が決定できないので、調査票で求めた資料を臨床的見地で利用することはできな

TABLE 3 SUMMARY OF DATA\*  
表3 資料の総括

Exposure Group	Hiroshima		Nagasaki	
	No. of Person.	No. of White Cell Counts†	No. of Persons	No. of White Cell Counts
A .....	570	387	376	161
B .....	1,119	670	1,465	592
C .....	1,817	955	1,630	554
D .....	1,604	794	702	156
E .....	711	286	663	132
F .....	575	145	1,091	157
G .....	267	77	500	70
Total.....	6,663	3,314	6,427	1,822
H .....	219	112	194	94
Grand Total.....	6,882	3,426	6,621	1,916

\*Source: Tables 23H, 23N, 33H and 33N, Section 9, Medical Report.<sup>2</sup>

†These are single blood counts on different persons, living 20 days after the bombing, who were examined at any time between weeks 1 and 12 inclusive.

ally, it is not possible to use the data from the questionnaire study in a clinical sense, since the severity of radiation injury cannot be determined for groups of persons. With reference to Table 1, however, it is reasonable to assume that most of the persons in exposure groups A and B sustained severe radiation injury if they survived 20 days or more, and that the persons in exposure groups C and D and E, F and G sustained moderately severe and mild radiation injury, respectively. However, this assumption is less valid than the clinical evidence.

First the Japanese data reported for patients who are certainly identifiable as examples of very severe and severe radiation injury are considered. It may be seen in Figure 1 that the time trend of pooled white blood cell counts for exposure groups A and B correspond closely with serial counts for patients in well run hospitals who had severe radiation injury. The similarity of these curves is a reasonable basis for accepting the clinical conclusions of reliable Japanese physicians with respect to severe radiation injury. As a matter of interest, it should be noted that the median lethal dose in 90 days of ionizing radiation for man was delivered at about 1,100 yards (1,000m).

い。しかし、表1を見ると、被爆群AおよびBに属している者のうちで20日間以上生存した者の放射線傷害は高度であり、被爆群CおよびDならびにE、FおよびGではそれぞれ中等度および軽度であると仮定してもよいであろう。しかし、この仮定は、臨床所見よりも確実性が劣る。

まず、放射線傷害がきわめて高度および高度であったことが確実である患者について日本側の報告した資料の考察を行なう。図1に示したとおり、被爆群AおよびBにおける合計白血球数の時間的推移は、円滑に運営されている病院で行なわれた高度放射線傷害者の連続的検査の結果とよく一致する。これらの曲線が類似することは、信頼できる日本側医師の高度放射線傷害についての臨床的結論が信用できる合理的な根拠である。興味ある事実として、ヒトが電離放射線照射で90日以内に死亡する致死線量の中央値が約1100ヤード(1000m)の地点に相当することを指摘したい。

VERY SEVERE RADIATION INJURY

All the hemograms of patients with very severe radiation injury were obtained from the Japanese. Because of the chaotic conditions in each city, few valid studies are available. All the reliable data that were obtained by the Joint Commission are shown

きわめて高度の放射線傷害

きわめて高度の放射線傷害を有する患者の血液像はすべて日本側の資料から求めた。両市における混乱状態のため、有効な検査は少なかった。合同調査団の入手した信頼できる資料のすべてを表4および5に示した。広島におけるきわめて高度の例のうち、鑑別血球

TABLE 4 BLOOD COUNTS OF PATIENTS WITH VERY SEVERE RADIATION INJURY: HIROSHIMA DATA (JAP)\*

表4 きわめて高度の放射線傷害を有する患者の血球計算：広島資料（日本側）

Case No.†	Days After Bombing		White Blood Cells	Hemoglobin Concentration, %	Red Blood Cells, Millions‡
	Death	Count			
	6	4	250	...	.....
	6	5	400	...	.....
	7	5	1,440	...	.....
	6	6	120	...	.....
	6	6	560	...	.....
	8	6	840	...	.....
	8	6	3,400	...	.....
	8	6	2,100	...	.....
	8	6	2,000	...	.....
	8	6	150	...	.....
	9	6	920	...	.....
	10	6	300	...	.....
	...	7	25	...	.....
	9	7	50	...	.....
	9	7	560	...	.....
	...	8	740	...	.....
	...	8	37	...	.....
	...	8	490	...	.....
	...	8	80	...	.....
	9	8	100	...	.....
	...	9	200	...	.....
	...	9	550	...	.....
	10	9	200	...	.....
	9	6	400	42	4.10 B W
	9	6	150	50	4.20 B W
	11	6	400	45	4.20 B
	8	6	400	32	2.65 B
	8	6	150	43	3.28 B
	...	6	250	40	3.75 B W
	8	6	300	40	2.82 W
	8	7	400	40	4.13 B
	9	7	300	40	3.26 W

\*Source: Tables 15 and 16, Section 6, Medical Report.<sup>2</sup>

†Case numbers refer to Joint Commission records system.

‡B indicates burns and W wounds.

§This group of patients was inside a heavy concrete building, 220 yards (200 m) from zero.

TABLE 5 LEUKOCYTE COUNTS OF PATIENTS WITH VERY SEVERE RADIATION INJURY: NAGASAKI DATA (JAP)\*

表5 きわめて高度の放射線傷害を有する患者の白血球数：長崎の資料（日本側）

Case No.	Days After Bombing		White Blood Cells
	Death	Count	
.....	2	1	2,200
.....	2	1	1,670
.....	...	2	200- 530
.....	...	2	830
.....	2	2	1,300-1,600
.....	2	2	600-1,000
.....	2	2	400- 500
.....	2	2	530-1,040
.....	2	2	830
.....	2	2	300
.....	2	2	715
.....	8	8	430- 500
.....	9	9	1,700
.....	9	9	500

\*Source: Table 14, Section 6, Medical Report.<sup>2</sup>

TABLE 6 DIFFERENTIAL COUNTS ON PATIENTS WITH VERY SEVERE RADIATION INJURY (JAP)\*

表6 きわめて高度の放射線傷害を有する患者の鑑別血球計算像（日本側）

Case No.	No. Cells Counted	Per Cent of Nucleated Cells							Nucleated Red Blood Cells
		Meta-myelocytes	Stab Cells	Poly-morpho-nuclear Cells	Lymphocytes	Mono-cytes	Eosin-ophils	Plasma Cells	
.....	50†	0	20	40	28	6	0	2	0
.....	50	0	8	50	30	4	0	0	4
.....	50	0	16	60	14	10	0	0	0
.....	20	0	0	60	5	0	0	0	35
.....	13	0	15	85	0	0	0	0	0
.....	30	0	4	73	16	7	0	0	0
.....	20	0	0	90	5	5	0	0	0
.....	50	0	10	70	16	2	0	0	0
.....	100	4	26	56	8	4	2	0	0
Average	...	0.5	11.0	65.0	13.5	3.0	...	...	8.0

\*Source: Table 20, Section 6, Medical Report.<sup>2</sup>

†In general, the number of cells counted was all that could be found.

in Tables 4 and 5. Of the very severe cases from Hiroshima records were available of nine differential counts. These are reproduced in Table 6. It is apparent that there was no characteristic hemogram at this time, since the proportion of the various cell types is about normal. Other observers reported that only lymphocytes were seen in the blood films made

計算の記録が入手されたのは9例である。これは表6に示した。この時期では、各種血球の割合はほぼ正常で、特徴的な血液像は認められない。第1週に作成された血液塗抹標本にリンパ球のみを認めた報告もあるが、その種の所見を示す塗抹標本も信頼すべき記録も発見できなかった。残留血球は少数であり、好中球の



during the first week, but no films or reliable records of such films were located. The structure of the few cells that remained appeared normal except that some of the neutrophils were "giant polymorphonuclear cells."

The blood counts of these patients are of interest because of the rapidity with which leukopenia occurred in human beings exposed to amounts of radiation considerably in excess of the estimated median lethal dose.

一部が「巨大多形核」である以外は、その構造は正常であった。

これらの血球計算は推定致死線量中央値よりかなり多量の放射線を受けた者に白血球減少が急速に出現することを示した点で興味深い。

**TABLE 7 DISTRIBUTION OF LOWEST LEUKOCYTE COUNTS IN PATIENTS WITH SEVERE RADIATION INJURY, WEEKS 3 TO 5 (JAP)\***

表7 高度の放射線傷害を有する患者における最少白血球数の分布, 第3から第5週 (日本側)

White Blood Cell Count	Fatal Cases	Nonfatal Cases
0- 500 .....	14	1
501-1,000 .....	7	8
1,001-2,000 .....	4	10
Over 2,000 .....	0	4
Total .....	25	23

\*Source: Table 16, Section 6, Medical Report.<sup>2</sup>

**TABLE 8 DISTRIBUTION OF LEUKOCYTE COUNTS DURING WEEKS 2 TO 5 IN EXPOSURE GROUPS A AND B (JC): PERSONS\* WHO WERE LIVING TWENTY DAYS AFTER BOMBING†**

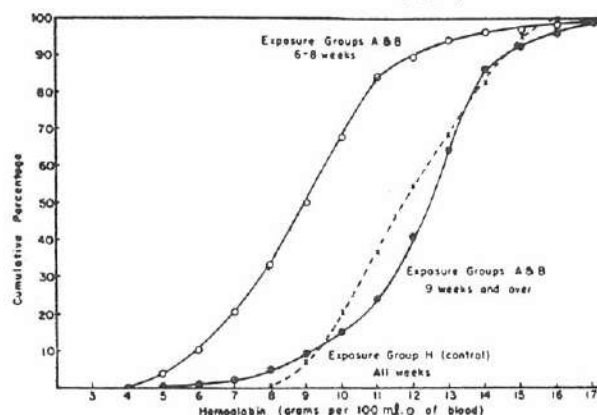
表8 被爆群AおよびBにおける第2から第5週の白血球数の分布 (合同調査団): 原爆後20日間以上の生存者

White Blood Cell Count	Hiroshima		Nagasaki	
	A	B	A	B
0- 499 .....	22	15	2	7
500- 999 .....	37	27	12	21
1,000-1,999 .....	51	41	15	28
2,000-2,999 .....	36	38	11	35
3,000-3,999 .....	23	35	11	23
4,000-4,999 .....	16	22	4	23
5,000-5,999 .....	4	12	4	21
6,000-6,999 .....	2	10	7	9
Over 7,000 .....	4	11	5	15
Mean .....	2,096	2,979	3,170	3,856
Pooled groups				
A and B .....	2,555		3,673	

\*These are single counts for different persons.

†Source: Tables 34H and 34N, Section 9, Medical Report.<sup>2</sup>

FIGURE 2 Cumulative percentage distribution of hemoglobin values.  
 図2 血色素値の累積百分率分布



### SEVERE RADIATION INJURY

A great many blood examinations were made on patients with severe radiation injury. The data have been selected on the basis of the diagnoses of the Japanese attending physicians and of the exposure group in which the subjects were placed. The distribution of leukocyte counts in these patients is shown in Tables 7 and 8.

There is no simple explanation for the discrepancy in the distribution of leukocyte counts of the persons included in the statistical study of the Joint Commission, as shown in Table 8. When groups of patients with apparently similar diagnoses are compared, there is much less difference between persons from the two cities. The typical character of the changes in white blood cell count in severe radiation injury is better demonstrated when one considers the time trend of the mean leukocyte count.

This is shown for three groups of persons in Figure 1. Curve I is the weekly pooled leukocyte counts of 1,057 persons in exposure groups A and B from Hiroshima (source: Figure 13 H and Table 33 H, Volume 9, Medical Report<sup>2</sup>). Curve II is the weekly pooled leukocyte counts of 287 persons with specific signs of radiation injury in exposure groups A and B from Hiroshima (source: Table 21, Volume 3, Section 6, Medical Report<sup>2</sup>). Curve III is the weekly average leukocyte counts of 16 patients with severe radiation injury who were studied in the Misao Clinic, Kyushu Imperial University (source:

### 高度の放射線傷害

高度の放射線傷害を有する患者の多数例の血液検査が行なわれていたので、日本側担当医の診断およびその患者が分類された被爆群に基づいて資料を選んだ。これらの患者における白血球数の分布を表7および8に示した。

表8に示したように、合同調査団の統計学的検討に含まれた人々の白血球数の分布に認められる差異は簡単には説明できない。同様の診断を受けたと考えられる人々を比較すると、両市間の差がはるかに少ない。高度の放射線傷害における白血球数変化の典型的な特徴は、平均白血球数の時間的傾向の考察によって最も明瞭に示すことができる。

三つの群に属している人々についてこれを示したのが図1である。曲線Iは、広島市の被爆群AおよびBに属する1057名における1週間ごとの合計白血球数である(出所: 合同調査団の医学的報告書,<sup>2</sup>第9巻, 表13Hおよび33H), 曲線IIは、広島市の被爆群AおよびBに属する者のうち放射線傷害の特異的な徴候を示した287名の1週間ごとの合計白血球数である(出所: 合同調査団医学的報告書,<sup>2</sup>第3巻, 第6章, 表21)。曲線IIIは、九州帝国大学操内科教室で検査を受けた高度放射線傷害者16名の1週間ごとの平均白血球数である(出所: 合同調査団医学的報告書,<sup>2</sup>第3巻, 第6

TABLE 9 TIME TREND FOR PAIRS OF LEUKOCYTE COUNTS, EXPOSURE GROUPS A AND B: HIROSHIMA (JC)\*

表9 2回の白血球計算における時間的傾向, 被爆群AおよびB: 広島 (合同調査団)

No. of Cases	First White Blood Cell Count		Repeat White Blood Cell Count	
	Week	Mean	Week	Mean
29.....	2-4	2,986	5-7	3,497
40.....	2-4	2,390	8-10	7,395
32.....	2-4	2,487	11-13	6,781
56.....	5-6	2,930	7-8	5,861
29.....	5-6	2,834	9-10	6,403
53.....	5-6	2,700	11-12	6,625

\*Source: Tables 36H and 36N, Section 9, Medical Report.<sup>2</sup>

TABLE 10 TIME TREND FOR PAIRS OF LEUKOCYTE COUNTS, EXPOSURE GROUPS A AND B AND C AND D: NAGASAKI (JC)\*

表10 2回の白血球計算における時間的傾向, 被爆群AおよびBならびにCおよびD: 長崎 (合同調査団)

Group	No. of Cases	First White Blood Cell Count		Repeat White Blood Cell Count	
		Week	Mean	Week	Mean
A and B.....	57	2-4	3,009	5-16	7,177
A and B.....	57	5-6	3,461	7-16	7,614
C and D†.....	54	2-4	3,967	5-16	6,531
C and D.....	47	5-6	4,194	7-16	7,413

\*Source: Tables 36H and 36N, Section 9, Medical Report.<sup>2</sup>

†Time trend of leukocyte count in exposure groups C and D is shown for comparison.

TABLE 11 EXPOSURE GROUPS A AND B WITH SPECIFIC SIGNS OF RADIATION INJURY, POOLED DIFFERENTIAL COUNTS BY WEEKS (JC)\*

表11 被爆群AおよびBにおいて放射線傷害の特異的徴候を有する者, 週別の合計鑑別白血球計算 (合同調査団)

Week	No.	Average White Blood Cell Count	Polymorpho-nuclear Cells		Lymphocytes		Monocytes		Eosinophils		Basophils	
			No.	%	No.	%	No.	%	No.	%	No.	%
4	11	1,000	365	36.5	575	57.5	55	5.5	10	1.0	1	0.1
5	39	2,435	1,347	55.3	883	37.3	104	4.4	30	1.2	5	0.2
6	18	3,094	1,836	59.3	1,215	39.5	107	3.5	100	3.1	14	0.4
7	22	4,113	2,448	59.5	1,152	28.0	364	8.9	122	3.0	16	0.4
8	13	5,384	3,220	59.8	1,638	31.0	276	5.2	124	2.3	20	0.3
9	10	7,320	4,692	64.1	2,012	27.1	557	7.5	236	3.2	...	...
10	17	6,576	3,922	59.6	1,940	29.7	331	5.1	292	4.5	37	0.5
11	66	7,048	4,248	60.3	2,048	31.0	343	4.9	340	4.8	25	0.4
12	91	6,908	4,031	58.4	2,080	30.1	369	5.3	390	5.7	25	0.3
†	28	7,042	3,745	53.2	2,660	38.0	350	5.0	252	3.6	35	0.5

\*Source: Table 21, Section 6, Medical Report.<sup>2</sup>

†Average of 28 normal Japanese men, September 1945.

Table 19, Volume 3, Section 6, Medical Report<sup>2</sup>). The similarity of these three time trend curves is remarkable when one considers the origins of the data.

In all the blood examinations made on patients with the severe type of radiation injury, leukopenia was most prominent in weeks 3 to 5, and the return to normal values was seen in weeks 8 to 10. The typical time trend of the white cell count is also seen when pairs of counts on the same persons are compared. This was possible with some persons from exposure groups A and B. These comparisons are shown in Tables 9 and 10.

The relationship between the tempo of the evolution of the syndrome of radiation injury and the severity has been discussed in another report.<sup>8</sup> It is important to note that the mean day of onset of epilation and of purpura (specific symptoms of radiation injury) was the twentieth and twenty-fifth

章, 表19)。資料の出所を考えると, これらの時間的傾向は驚くほど似ている。

高度の放射線傷害を有する患者について行なわれた血液検査では, いずれも第3ないし第5週にかけて白血球減少が最も顕著であり, 第8から第10週にかけて正常値へ回復した。同一対象者を2回検査した場合の白血球数を比較してみた時にもこの典型的な時間的傾向が見られた。被爆群AおよびBに属する者若干名についてこの比較が可能であった。それを表9および10に示した。

放射線傷害の症候の進行の速さとその重症度との関係は別の報告に記述した。<sup>8</sup>被爆群AおよびBに属する者では, 脱毛および紫斑(放射線傷害の特異的症候)の平均発症日が, それぞれ20日目および25日目であったことは注目すべきである(出所: 合同調査団医学的

TABLE 12 DISTRIBUTION OF RETICULOCYTE COUNTS IN PATIENTS WITH SEVERE RADIATION INJURY, WEEKS 3 TO 4 AFTER THE BOMBING (JAP)\*

表12 高度の放射線傷害を有する患者の細網赤血球数の分布, 原爆後3ないし4週(日本側)

Fatal Cases	% Reticulocytes	Nonfatal Cases
9	0-0.4	6
0	0.5-0.9	4
0	1.0-2.0	2
0	Over 2.0	1
9		13

\*Source: Table 5, Section 6, Medical Report.<sup>2</sup>

TABLE 13 MEAN RED CELL DIAMETERS OF PATIENTS WITH SEVERE RADIATION INJURY (JC)\*

表13 高度の放射線傷害を有する患者の平均赤血球直径(合同調査団)

Source	Week	Mean Diameter, Microns†	Number
Hiroshima .....	3- 4	7.02 ± 0.312	6
Nagasaki .....	4- 5	7.28 ± 0.610	10
Nagasaki .....	9-10	7.85 ± 0.428	20
Normal Japanese .....	.....	7.52 ± 0.292	23

\*All measurements were made by Major Samuel Berg, Medical Corps, Army of the United States. Source: Table 9, Section 6, Medical Reports.<sup>2</sup>

†Mean ± standard error of the mean.

TABLE 14 RED BLOOD CELLS OF PATIENTS WITH SEVERE RADIATION INJURY, WEEKS 9 TO 12 AFTER THE BOMBING (JC)\*

表14 高度の放射線傷害を有する患者における原爆9ないし12週後の赤血球 (合同調査団)

No.	Source	Mean Cell Volume, † Cubic Microns	Mean Cell Hemoglobin, † Micromicrograms	Mean Cell Hemoglobin Concentration, † %
66	Nagasaki.....	93.1 ± 1.31	31.2 ± 0.51	33.2 ± 0.45
55	Controls .....	89.1 ± 1.35	31.2 ± 0.37	33.9 ± 0.27

\*Source: Table 8, Section 6, Medical Report.<sup>2</sup>

†Mean ± standard error of the mean. The difference between the means of patients and controls is significant in the case of mean cell volume and mean cell hemoglobin.

day, respectively (source: Table 18, Section 9, Medical Report<sup>2</sup>), for persons in exposure groups A and B. It is quite evident that weeks 3 to 5 are the critical ones for casualties with severe radiation injury.

*Differential Counts.*—The most satisfactory group of differential counts available is shown in Table 11. These differential counts were made at the same time, and on the same persons, as the counts comprising curve II of Figure 1, i. e., persons from Hiroshima in exposure groups A and B who had specific signs of radiation injury. In this table both absolute numbers and percentages of each cell type are shown. The most significant feature of these data is the fact that the absolute number of lymphocytes had not returned to normal by the twelfth week, whereas the granulocytic cells reached normal levels in the eighth to ninth week.

Detailed analyses of the various cell types revealed no other significant or useful trends. The eosinophilia which was observed, particularly among citizens of Nagasaki, was apparently not related to the atomic bomb, since it appeared in control groups to an even greater extent than in exposure groups A and B.

Erythrocyte and hemoglobin variations in patients with severe radiation injury were less consistent than the changes in the leukocytes. It appeared that the lowest values occurred in weeks 6 to 8 after the bombing and that the return toward normal was evident after the ninth week. The data most useful

報告書,<sup>2</sup>第9章,表18)。高度の放射線傷害では,第3から第5週が重要な時期であることは明白である。

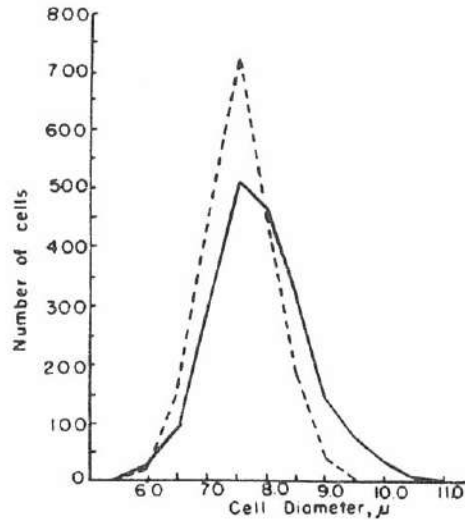
**鑑別血球計算** 入手した鑑別血球計算のうちの最も満足すべきものを表11に示した。これは、図1における曲線IIと同一時期かつ同一患者について求めたものである。すなわち、広島市の被爆群AおよびBのうち、放射線傷害の特異的徴候を呈した者の成績である。この表では、各種血球の絶対数および百分率を示した。この資料における最大の特徴は、リンパ球の絶対数が第12週に至っても正常に回復していないのに対し、顆粒球が第8ないし第9週に正常値に達していることである。

各種血球の詳細な解析を行なったが、そのほかには有意な、または、有効な傾向は認められなかった。好酸球増加は、長崎の市民に特に認められたが、これは原爆と関係がないようであった。すなわち、これは、被爆群AおよびBにおけるよりも対照群においてより著しかった。

高度の放射線傷害を有する患者にみられた赤血球数および血色素量の変動は、白血球の変化ほど一貫していない。最小の値が原爆後の第6ないし第8週に生じ、第9週から正常への回復がみられるようであった。実例として最も有効な資料を図2に示した。対照

**FIGURE 3** Price-Jones curves for patients with severe radiation injury during weeks 9 to 10 after the bombing (solid line) and for normal Japanese controls (broken line).

図3 原爆9ないし10週後の高度放射線傷害者(実線)および正常な日本人対照群(点線)におけるPrice-Jones曲線



for purposes of illustration are shown in Figure 2. It will be seen that in the control group (H) 50% of the normal subjects had values for hemoglobin concentration of less than 11.5 g. These low values are probably a reflection of the poor nutritional state of the residents of the bombed cities.

*Reticulocytes.*—A small number of reliable reticulocyte counts was performed, the results of which are shown in Table 12.

*Red Cell Size.*—Measurements of the diameter of erythrocytes were made, using blood films obtained from typical patients with severe radiation injury. The results are shown in Table 13.

The Price-Jones curves for the last two groups (Table 14) are shown in Figure 3. The difference in the mean red cell diameters between patients convalescent from severe radiation injury and normal Japanese controls from the same vicinity is significant.

*Corpuscular Constants.*—The values for mean cell volume, mean cell hemoglobin and mean cell hemoglobin concentration were determined on samples of

群(H)では、正常者の50%の血色素濃度が11.5g未満であったことがわかる。この低値は、両被爆都市における住民の栄養状態が不良であったことをおそらく反映しているであろう。

**細網赤血球** 信頼できる細網赤血球計算が少数例について実施されていたので、その結果を表12に示した。

**赤血球直径** 典型的な高度放射線傷害を有する患者の血液塗抹標本を用いて赤血球直径の測定を行なった。結果は表13に示した。

最後の2群(表14)におけるPrice-Jones曲線を図3に示した。回復期にある高度放射線傷害者と同地域の正常日本人対照群との間に平均赤血球直径に有意な差がある。

**赤血球恒数** 原爆から9ないし12週後に高度放射線傷害の回復期にある患者の一群の血液標本を用いて平均赤血球容積、平均赤血球赤色素量および平均赤血

TABLE 15 DISTRIBUTION OF THROMBOCYTE COUNTS IN PATIENTS WITH SEVERE RADIATION INJURY DURING WEEKS 3 TO 6 (JAP)\*

表15 高度の放射線傷害を有する患者における第3ないし第9週の  
 栓球数の分布 (日本側)

Fatal Cases	Thrombocytes	Nonfatal Cases
10	Less than 25,000	3
2	25,100- 50,000	8
0	50,100-100,000	5
0	100,100-150,000	5
0	150,100-200,000	1
0	More than 200,000	2
12		24

\*Source: Tables 27 and 28, Section 6, Medical Report.<sup>2</sup>

TABLE 16 RELATIONSHIP BETWEEN LEUKOCYTE COUNT AND HEMORRHAGIC TENDENCY IN PATIENTS EXAMINED IN FOURTH WEEK (JAP)\*

表16 第4週に検査した患者における白血球数と出血傾向との関係 (日本側)

White Blood Cell Count, Less Than 1,000					White Blood Cell Count, 1,000 to 2,000				
Rumpel-Leede Reaction	Bleeding Time, Min.	Clotting Time, Sec.	Clotting Time, Min.	Clotting Time, Sec.	Rumpel-Leede Reaction	Bleeding Time, Min.	Clotting Time, Sec.	Clotting Time, Min.	Clotting Time, Sec.
+	28	00	13	30	-	16	30	...	...
+	23	00	12	30	-	11	30	12	30
+	30	00	16	30	-	6	30	12	30
+	13	30	13	30	-	10	00	14	00
+	30	30	15	00	-	4	30	11	30
+	22	30	15	30	White Blood Cell Count, 2,000 to 3,000				
-	20	00	12	30	-	8	30	13	00
-	17	00	15	00	-	7	00	9	00
-	16	00	14	00	-	5	00	13	00
-	24	30	...	...					
-	19	30	20	30					
-	26	30	10	30					
-	20	00	8	30					
-	3	30	...	...					

\*Source: Table 32a, Section 6, Medical Report.<sup>2</sup>

blood from a group of patients convalescent from severe radiation injury during weeks 9 to 12 after the bombing. The results of this examination are shown in Table 14.

These studies of cell size indicate that during the recovery period after radiation injury the red cells are larger than normal. It is assumed that this is due to the occurrence of a reticulocytosis at this time.

球色素濃度を測定した。検査結果を表14に示した。

赤血球の大きさに関するこれらの検査によれば、放射線傷害の回復期における赤血球は正常よりも大であることが示唆される。これは、この時期に生じた細網赤血球増加のためと思われる。

*Thrombocytes and Clotting Studies.*—A considerable number of thrombocyte counts is available, as well as a lesser number of valid studies of the clotting mechanism. The significant data for thrombocytes are shown in Table 15.

The relationship between the defect in the clotting mechanism and the injury to the bone marrow as reflected by the leukocyte count is well shown in Table 16. The fate of these particular patients is not known, but they were selected for study during the fourth week because they obviously had severe radiation injury. All had spontaneous purpura, and 13 of the 22 had experienced epilation at that time.

**栓球および凝血検査** かなり多数例についての栓球計算が入手されており、それよりも例数は少ないが、凝血転機に関する有効な検査も行なわれていた。栓球に関して有意と思われる資料を表15に示した。

凝血転機の障害と白血球数に反映される骨髄傷害との関係は、表16において明白である。これらの患者の運命は不明であるが、明らかな高度の放射線傷害があったので、第4週に検査を行なった。全例に特発性紫斑があり、22例中13例にはその時に脱毛があった。

**TABLE 17** STUDY OF THE HEMORRHAGIC TENDENCY IN THE SEVERE TYPE OF RADIATION INJURY (JAP), AVERAGE VALUES FOR SEVEN PATIENTS\*

表17 高度の放射線傷害における出血傾向の検査（日本側），7例の平均値

Week After Bombing	Thrombocytes	Bleeding Time, †		Clotting Time, ‡		Capillary Fragility §	
		Min.	Sec.	Min.	Sec.	Infra-clavicular Region	Volar Area of Arm
4	105,000	12	45	6	30	16.0	16.5
5	81,300	8	20	6	45	17.3	16.6
6	90,800	4	00	5	30	18.8	19.6
7	82,000	2	45	5	15	22.0	22.2
8	75,000	3	00	4	30	23.5	23.5
Normal	250,000	2	00	3	00	More than 25 to 26 mmHg	
	300,000	3	00	4	00		

\*Source: Table 33, Section 6, Medical Report.<sup>2</sup>

†Bleeding time determined by Duke's method.

‡Clotting time determined by capillary tube method.

§Capillary fragility determined by vacuum method.

**FIGURE 4** Serial hemograms of patient (Case 4, Nakao) with typical fatal severe radiation injury.

図4 典型的な高度放射線傷害で死亡した例（症例4，中尾）の連続的血液像

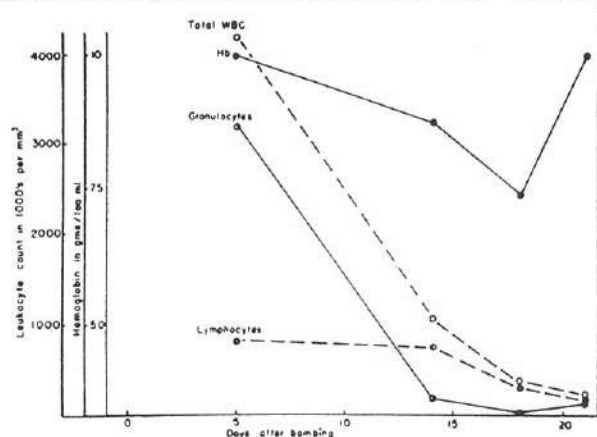
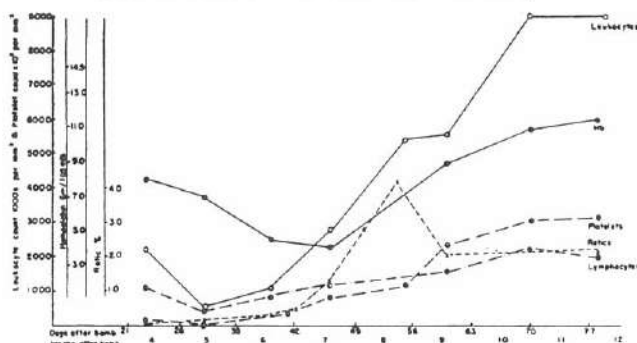




FIGURE 5 Serial hemogram of typical nonfatal case (Patient S. K., a man 23 years of age, from the Kusunoki series) of severe radiation injury.

図5 典型的な高度放射線傷害を示した生存例の連続的血液像 (患者 S.K., 23歳の男, 楠調査班の調査による)



The only reliable serial study of the hemorrhagic tendency was made on a group of patients with severe radiation injury who recovered and who were studied for 5 weeks. The results of this study are shown in Table 17. The hematological changes in patients with severe radiation injury form a characteristic pattern which is consistent with the other clinical findings. To complete this section, attention is directed to the serial blood counts of a typical fatal case, Figure 4, and to those of a typical nonfatal case, Figure 5.

#### MODERATELY SEVERE AND MILD RADIATION INJURY

The Japanese physicians did not devote much attention to patients with milder grades of radiation injury. For purposes of analysis and demonstration, it is desirable to use exposure groups C, D and E. With reference to Table 2, this includes all persons outdoors and in wooden buildings from 1,650 to 3,300 yards (1,500 to 3,000 m) from zero, persons in heavy buildings from 1,100 to 2,750 yards (1,000 to 2,500 m) from zero and persons in bomb shelters and tunnels from 0 to 2,200 yards (0 to 2,000 m) from zero.

The incidence of either epilation or purpura (i. e., specific signs of radiation injury) in these exposure groups was 13.3, 5.8 and 4.1% for Hiroshima, and 21.8, 10.4 and 3.0% for Nagasaki, in groups C, D and E, respectively.

出血傾向に関する信頼すべき連続調査としては、高度の放射線傷害から回復した患者の一群を5週間におたり検査したものがあただけである。その調査の結果を表17に示した。高度の放射線傷害における血液学的変化は、その他の臨床所見と同様な特徴的傾向を示す。この項を終るにあたって、典型的な死亡例の連続的血液計算、図4、および典型的な生存例のそれ、図5に注意していただきたい。

#### 中等度ないし軽度の放射線傷害

日本側の医師は、放射線傷害がより軽度の患者にあまり注意を払わなかった。解析および資料提示のためには、被爆群C、DおよびEを用いることが望ましい。表2をみれば、これはゼロ地点から1650~3300ヤード(1500~3000m)で屋外または木造家屋内にいた者、1100~2750ヤード(1000~2500m)で重構造物内にいた者および0~2200ヤード(0~2000m)で防空壕やトンネル内にいた者を含むことがわかる。

被爆群C、DおよびEにおける脱毛あるいは紫癍の出現率は、広島でそれぞれ13.3、5.8および4.1%、長崎で21.8、10.4および3.0%であった。

FIGURE 6 Time trend of pooled weekly leukocyte counts in exposure groups with moderately severe and mild radiation injury (source: Table 33N, Section 9, Medical Report<sup>2</sup>). Star indicates average of less than 10 counts. Base line at 7,000 cells represents normal value for Japanese.

図6 中等度および軽度の放射線傷害を有する被爆群における週別の合計白血球数の時間的傾向

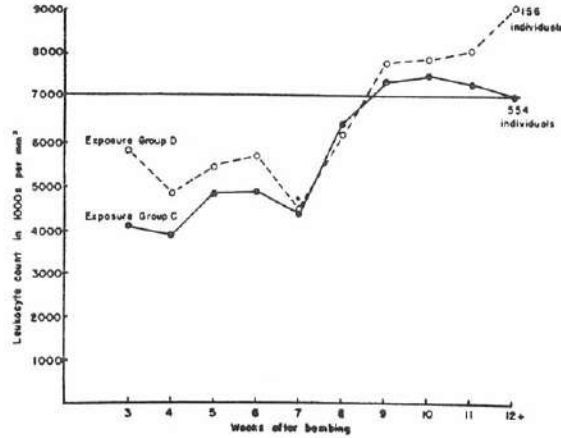


TABLE 18 DISTRIBUTION OF LEUKOCYTE COUNTS DURING WEEKS 2 TO 5, EXPOSURE GROUPS C, D AND H: PERSONS WHO WERE LIVING TWENTY DAYS AFTER THE BOMBING (JC AND JAP)\*

表18 第2から第5週における白血球数の分布、被爆群C、DおよびH：原爆後20日間以上生存した者（合同調査団および日本側）

White Blood Cell Count	Hiroshima			Nagasaki		
	C	D	H	C	D	H
0- 499 .....	3	0	0	2	2	0
500- 999 .....	3	1	0	12	1	0
1,000-1,999 .....	13	3	0	26	6	0
2,000-2,999 .....	12	6	2	30	3	0
3,000-3,999 .....	23	11	6	21	5	1
4,000-4,999 .....	24	15	20	33	4	3
5,000-5,999 .....	29	24	24	30	5	15
6,000-6,999 .....	17	18	26	16	7	22
Over 7,000 .....	32	33	34	34	15	53
Mean .....	5,010	5,870	6,366	4,447	5,408	7,961
Pooled groups C and D .....		5,370			4,630	

\*Source: Tables 34H and 34N, Section 9, Medical Report.<sup>2</sup>

*Leukocytes.*—In the case of leukocyte counts, there are insufficient data per week to justify considering exposure group E at this time. Pooled weekly mean leukocyte counts for persons in exposure groups C and D are shown in Figure 6. The distribution of the leukocyte counts obtained in weeks 2 to 5 for these groups is shown in Table 18.

**白血球** 白血球数については、被爆群Eを考察するためには週別の資料が不十分である。被爆群CおよびDに属する者の週別の合計平均白血球数を図6に示した。これらの群について第2週から第5週にかけて求められた白血球数の分布を表18に示した。

The distribution of leukocyte counts of persons in group H (i. e., persons who received no or insignificant amounts of radiation) is shown for comparison. Here again, there is no simple obvious explanation for the difference between the means in group H. The differences between the means of groups C and D and of the pooled groups C and D are not significant. The differences between these means and the means of group H are significant. The differential counts for persons in groups C and D for the period 2 to 6 weeks after the bombing are shown in Table 19.

Erythrocyte and hemoglobin variations in patients with the milder grades of radiation injury are best demonstrated in terms of the cumulative percentage

比較のため、H群に属する者（すなわち、放射線に被曝しなかったか、線量が有意でなかった者）における白血球数の分布も示した。この場合も、H群の平均値の間にみられる差の簡単で明確な説明はない、C群、D群およびCとDを合計した群の平均値の間に有意な差はない。これらの群の平均値とH群の平均値との差は有意である。原爆後の第2から第6週にかけてのCおよびD群における鑑別血球計算を表19に示した。

軽度の放射線傷害を有する患者における赤血球および血色素の変化は、血色素濃度の累積百分率分布によって最も明瞭に表わすことができる。この資料を図7

TABLE 19 POOLED MEAN DIFFERENTIAL COUNTS FOR PERSONS IN EXPOSURE GROUPS C AND D, TWO TO SIX WEEKS AFTER THE BOMBING\*

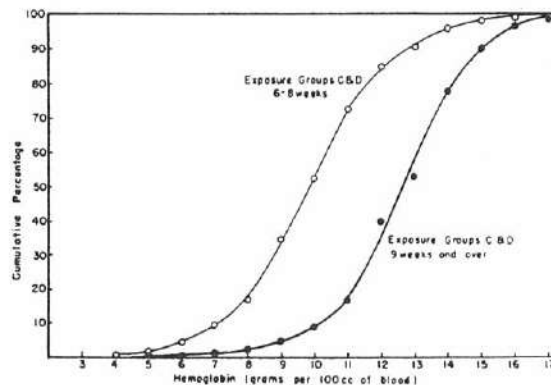
表19 原爆後の第2から第6週における被爆群CおよびDの合計平均白血球像

Cell Type	Hiroshima		Nagasaki	
	Absolute Count, Mean	%	Absolute Count, Mean	%
Neutrophils .....	3,032	60.1	2,520	57.1
Lymphocytes .....	1,669	33.1	1,647	37.3
Monocytes .....	175	3.5	114	2.6
Eosinophils .....	160	3.2	127	2.9
Basophils.....	6	0.1	8	0.1
Total .....	5,042	.....	4,416	.....
Number of cases.....	135		14	

\*Source: Tables 40H and 40N, Section 9, Medical Report.<sup>2</sup>

FIGURE 7 Cumulative percentage distribution of hemoglobin values.

図7 血色素量の累積百分率分布



distribution of hemoglobin concentration. The data are shown in Figure 7. As in the case of severe radiation injury, the values for erythrocytes and hemoglobin concentration were lowest in the 6 to 8 weeks after bombing and then returned toward normal.

*Thrombocyte Counts and Clotting Studies.*—There was not a sufficient number of thrombocyte counts recorded for patients with milder grades of radiation injury to justify presenting the data. It is reasonable to assume, however, that the thrombocytopenia in persons of exposure groups C, D and E was less severe than in the more exposed patients. A good indication of the severity of the damage to the clotting mechanism is obtained from a tabulation of symptoms of hemorrhage, purpura and other hemorrhagic manifestations. For the sake of comparison, data for the first five exposure groups are shown in Table 20. Here again, there is no simple explanation for the discrepancy in the incidence of hemorrhagic manifestations in persons similarly exposed to radiation in the two cities.

*Relationship Between Hematological Findings and Clinical Evidence of Radiation Injury.*—It was mentioned above that one of the objectives of the Joint Commission's study was to determine the symptomatology of total body radiation injury in man. It is apparent that the changes in the white blood cell count in man are of the same order of magnitude and show the same time trend as have been observed in other large mammals exposed to

に示した。高度放射線傷害の場合と同様、赤血球数および血色素濃度は、原爆後の第6から第8週にかけて最低値を示し、それから回復に向かった。

**栓球数および凝血検査** 軽度の放射線傷害を有する患者についての栓球数の記録は、例数が不十分であるので、資料を記述するに値しない。しかし、被爆群C、DおよびEに属する者の血小板減少は、より高度に被曝した患者ほど著しくなかったと考えるのが合理的であろう。凝血機能に対する傷害の程度は、出血、紫斑およびその他の出血性症状の集計でかなり判明した。比較のため、初めの五つの被爆帯における資料を表20に示した。この場合も、同程度の放射線を受けた者の出血性症状の頻度にみられる两市間の差については簡単に説明できない。

**血液学的所見と放射線傷害の臨床的所見との関係** 前述のとおり、合同調査団の行なった調査の目的の一つは、ヒトに対する全身放射線照射による傷害の症状を決定することであった。ヒトにおける白血球数の変化は、電離放射線の致死量を受けたその他の大哺乳動物に見られているものと同程度であり、同様の時間的傾向を示すことが明らかである。調査票に記録された症状の統計学的解析の結果、脱毛および紫斑の二つを

TABLE 20 INCIDENCE OF PURPURA AND OTHER MANIFESTATIONS OF A HEMORRHAGIC TENDENCY BY EXPOSURE GROUPS (JC)\*

表20 紫斑および出血傾向のその他の症状の被爆区分別頻度（合同調査団）

Exposure Group	Hiroshima		Nagasaki	
	Number	%	Number	%
A .....	550	96	248	66
B .....	485	43	610	42
C .....	227	12.5	387	24
D .....	137	8.5	93	13
E .....	52	7.0	38	6

\*Source: Tables 23H and 23N, Section 9, Medical Report.<sup>2</sup>

TABLE 21 RELATIONSHIP BETWEEN SYMPTOMS AND LEUKOCYTE COUNT  
BY EXPOSURE GROUPS IN WEEKS 2 TO 6 AFTER BOMBING\*

表21 原爆後の第2から第6週における各被爆群の症状と白血球数との関係

White Blood Cell Count.....	Hiroshima				Nagasaki			
	Exposure Groups A and B		Exposure Groups C and D		Exposure Groups A and B		Exposure Groups C and D	
	Under 3,000	Mean	Under 3,000	Mean	Under 3,000	Mean	Under 3,000	Mean
Specific symptoms.....	%	.....	%	.....	%	.....	%	.....
Epilation and purpura...	80.0	1,923	73.3	2,420	78.0	2,181	63.3	2,943
Epilation or purpura.....	63.4	2,694	29.6	4,157	60.2	3,018	66.2	2,975
Suggestive symptoms only...	38.6	3,980	8.6	5,944	31.6	4,511	25.0	5,006
No symptoms.....	10.6	4,791	6.0	6,268	23.1	5,148	14.5	5,839

\*Source: Tables 57H and 57N, Section 6, Medical Report.<sup>2</sup>

lethal doses of ionizing radiation. As a result of statistical analysis of symptoms recorded in the questionnaires used, it was possible to define two specific symptoms of radiation injury, epilation and purpura. It was also possible to define three suggestive symptoms of radiation injury, vomiting on the day of the bombing, oropharyngeal lesions and hemorrhagic manifestations (other than cutaneous purpura). In general, a person with one or both of the specific symptoms had some or all of the suggestive symptoms. It is reasonable to assume that a person with few symptoms either had received less radiation or had a greater resistance to the effects of it than had the person who experienced the complete syndrome. In any case, if the symptoms are a valid indication of the severity of the radiation injury, there should be a close correlation between them and the leukopenia that occurred. Such a relationship is clearly demonstrated in Table 21. These data are important, since they validate mutually not only the significance of the changes in the white blood cell count but also the prescribed symptomatology.

#### SUMMARY AND CONCLUSIONS

It is possible to describe the syndrome of radiation injury in man in terms of typical clinical symptoms and a typical blood picture. The time trend of the syndrome is important, and the characteristic elements in the diagnosis become apparent at various times after exposure.

放射線傷害の特異的症狀として定義することが可能であった。また、原爆当日の嘔吐、口腔咽頭部病変および（皮膚紫斑以外の）出血性症状を放射線傷害の示唆的症狀として定義することが可能であった。一般に、特異的症狀の一方または両方を有する者は、示唆的症狀の一部または全部を呈した。症状の少なかった者は、症候群を完全に呈した者に比べて、放射線照射が少なかったか、その影響に対する抵抗が大きかったと考えるのが合理的であろう。いずれにしても、これらの症状が放射線傷害の程度の有効な指標であるとすれば、それと被爆後に生じた白血球減少との相関が高いはずである。表21にはその種の関係が明白に認められる。これらの資料は、互いに白血球数変化の意義ばかりでなく、想定された症状をも裏づけるので、重要である。

#### 総括および結論

ヒトにおける放射線傷害の症候群は、典型的な臨床症状および典型的な血液像の形で記述することが可能である。この症候群における時間的傾向は重要であり、被爆後の各時期にその診断の特徴的所見が出現する。

In general, the severity of the symptoms paralleled the severity of the leukopenia. Likewise, the important symptoms became evident at about the time the lowest leukocyte count was observed.

The changes in the thrombocytes paralleled those in the leukocytes. The onset and severity of a hemorrhagic tendency followed closely the variations in the thrombocyte count. The alteration in the red blood cells was less consistent and less useful in diagnosis or prognosis than was the time trend of the leukopenia.

From the standpoint of prognosis, the Japanese physicians stated that patients with less than 500 leukocytes per cubic millimeter were least likely to recover. The data presented here neither support nor deny this clinical observation.

In general, the observation quoted at the head of this paper is borne out: "the greater the dose (of radiation), the more profound is the blood damage, the more rapidly it develops and the more slowly it is repaired."

It is apparent that knowledge of the serial variation in the leukocyte count of a victim of radiation injury is of great clinical importance. It is doubtful whether the other elements of the hemogram are of comparable significance.

In the event of an emergency, it would be perfectly justifiable to perform only leukocyte counts and determinations of hemoglobin, hematocrit and protein by the copper sulfate ( $\text{CuSO}_4$ ) method. This would be an economical procedure and would provide the type of information required to evaluate individual cases and to aid in control of therapy.

一般に、症状の程度は白血球減少の程度と平行関係にある。同様に、重要な症状は白血球数が最低値を示すころに出現した。

栓球の変化は白血球の変化に平行して現われた。出血傾向の出現および程度は、栓球数の変化と密接な関係を示した。赤血球の変化は一貫性がやや少なく、白血球減少における時間的傾向ほどには診断あるいは予後の決定に役だたない。

予後の立場からは、 $1\text{ mm}^3$ 当たりの白血球数が500以下の患者は回復の見込が最も少ないと日本側の医師は報告している。ここに記述した資料は、この臨床観察を支持も否定もしない。

一般的には、本報告の冒頭で引用した観察が確認できた。すなわち、「線量が多いほど、血液損傷は顕著で、急速に出現し、回復もおそい。」

放射線傷害を有する被爆者の白血球数における連続的な変化に関する知見は、臨床的に大きな重要性をもつことは明らかである。血液像のその他の部分がこれほどの意味をもつかは疑わしい。

緊急の場合においては、白血球計算ならびに硫酸銅( $\text{CuSO}_4$ )法に基づいて血色素量、ヘマトクリット値および蛋白の測定のみを実施することが妥当であろう。これは経済的な方法であるとともに、これによって各例の評価および治療法の管理の参考となる資料が得られるであろう。

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