TECHNICAL REPORT
27-59
業 績 報 告 書

HEMATOLOGIC STUDIES IN HIROSHIMA AND A CONTROL CITY TWO YEARS AFTER THE ATOMIC BOMBING

原爆2年後の広島および対照都市における血液学的研究

FRED M. SNELL, M. D.[1]
JAMES V. NEEL, M. D., Ph. D.[2]
KOICHI ISHIBASHI, M. D.[3] (石橋洪一)

(Originally published 1949 既発表)

1. American Cancer Society and Massachusetts Institute of Technology, Massachusetts
米国癌学会および工科大学
2. University of Michigan Medical School, Michigan
Michigan 大学医学部
3. ABCC Department of Medicine
ABCC 臨床部

ATOMIC BOMB CASUALTY COMMISSION
HIROSHIMA AND NAGASAKI, JAPAN

A Cooperative Research Agency of
U.S.A. NATIONAL ACADEMY OF SCIENCES - NATIONAL RESEARCH COUNCIL
and
JAPANESE NATIONAL INSTITUTE OF HEALTH OF THE MINISTRY OF HEALTH AND WELFARE

with funds provided by
U.S.A. ATOMIC ENERGY COMMISSION
JAPANESE NATIONAL INSTITUTE OF HEALTH
U.S.A. PUBLIC HEALTH SERVICE

原 爆 傷 害 調 査 委 員 会
広島および長崎

米国学士院－学術会議と厚生省国立予防衛生研究所
との日米共同調査研究機関

(米国原子力委員会，厚生省国立予防衛生研究所および米国公衆衛生局の研究費による)

ACKNOWLEDGMENT

Gen. C. F. Sams, Chief, Public Health and Welfare Section, General Headquarters, Supreme Command for the Allied Powers, and his staff aided the progress of this work in many ways. The laboratory staff was composed of Drs. K. Takeshima and Y. Yamasowa, Misses Kubota, Tsuchitori, Yoshinaga, Nakagawa and Uemura, Mrs. Fujimoto, and Messrs. Fujii, A. Takahashi, Y. Takahashi, Takami, Togawa, Mukuda, Itano, Yajima, Kato, Taniguchi, Nitta, Mizuki and Shiroma. Clerical assistance was given by the Statistical Division, Bureau of Medicine and Surgery, United States Navy.

Dr. J. S. Lawrence and Dr. C. W. Cotterman contributed a number of stimulating discussions. Dr. K. Takeuchi, Director, Red Cross Hospital, Hiroshima, and Dr. M. Miyake and Dr. J. Ryu, Directors, Kure Mutual Relief Hospital, Kure, were in many ways most helpful.

感 謝 の 言 葉

連合軍最高司令官総司令部公衆衛生局長C.F. Sams将官と局員の方々からは，本調査実施について多岐にわたる御助力を頂いた。検査室職員は次の諸氏である。武島，山組両医師，久保田，土取，吉永，中川，上村，藤本，藤井，高橋明，高橋寧，高味，外川，棹田，板野，矢島，加藤，谷口，新田，水木，城馬。事務的な仕事については米国海軍医務局統計課より援助を受けた。Dr. J. S. Lawrence および Dr. C. W. Cottermanには多くの点につき貴重な討論を頂いた。

広島赤十字 竹内 親病院長ならびに呉共済病院 三宅正一院長，笠 潤一郎副院長には多くの面でお世話になった。

CONTENTS
目　次

TABLES
挿 入 表

HEMATOLOGIC STUDIES IN HIROSHIMA AND A CONTROL CITY TWO YEARS AFTER THE ATOMIC BOMBING

原爆2年後の広島および対照都市における血液学的研究

FRED M. SNELL, M. D.
JAMES V. NEEL, M. D., Ph. D.
KOICHI ISHIBASHI, M. D. (石橋洪一)

INTRODUCTION

The atomic bomb explosions in Hiroshima and Nagasaki, in August 1945, subjected large numbers of persons to significant amounts of radiation. The immediate, acute effects of the exposure have been evaluated by a group of United States Army and Navy and Japanese civilian investigators, usually referred to as the Joint Commission.[1] Their observations did much to confirm and extend the already recognized picture of acute radiation sickness and the early periods of recovery in man. There exists, then, at the present time, a considerable body of knowledge pertaining to the findings during the first few months after the exposure of man to ionizing radiation.

In contrast, relatively little is known concerning the late effects of irradiation of the whole body in man, such as may develop after apparent recovery. The data which do exist deal largely with the sequelae of repeated exposure to small doses occurring in radiologists before the necessity of adequate shielding was fully recognized, or following chronic poisoning with long-lived radioactive elements. A large number of the survivors of Hiroshima and Nagasaki, on the other hand, were persons who had received in an extremely brief time varying amounts of ionizing radiation, ranging from negligible to the maximum tolerable. The need for long range, detailed, methodical studies of the cases of these persons

緒　言

1945年8月，広島および長崎に投下された原子爆弾により，多数の人々が有意量の放射線照射を受けた。照射直後の急性影響は，通称合同調査団[1]と呼ばれる米国陸海軍人および日本民間人で構成された団体によって評価された。その観察は，人間における急性放射線疾患およびその回復期初期の病像についてすでに知られていたことがらを確認し，更に新しい知見を得る上に大変に役立った。現在では，人間が電離放射線の照射を受けた後の2，3か月間の所見については相当の知識があるわけである。

これに反し，人間が全身照射を受けてから一見回復した後になって生ずる後影響については，比較的知られていない。今までは主として，適切な遮蔽の必要性が十分に認識される以前に，放射線医が微量線量の頻回照射を受けたために生じた後遺症，または半減期の長い放射性物質による慢性中毒後に生じた後遺症に関する資料があったのみである。一方，広島および長崎の被爆生存者の多数は，ごく短時間内に極めて少量から最大許容量に至る範囲の線量を受けている。現在の科学的進歩の状態から考えて，今後ますます多数の人々が有意量の放射線を受けることになろうが，これら

Reprinted by permission from Archives of Internal Medicine, 84 : 569-604, 1949

cannot be overstated in an era when increasing numbers of people will, in the very nature of current scientific developments, be exposed to significant amounts of radiation. Recognition of this fact resulted in the issuance, on Nov 26, 1946, of a presidential directive, charging the National Research Council with the responsibility of conducting appropriate studies of the surviviors of Hiroshima and Nagasaki. The background for this directive, as well as for subsequent organizational developments, has been briefly detailed elsewhere.[2]

One of the foremost of the many problems clamoring for investigation relates to the cellular elements of the blood. The studies described in the present paper were carried out in Hiroshima and Kure, Japan, from March 1947 to April 1948. They were designed to answer the question: What is the peripheral hematologic picture twenty to thirty-three months after atomic bombing in persons who received large amounts of radiation to the whole body? Such studies serve the dual purpose of attempting to evaluate the current hematologic status of these persons and of providing a base line by comparison with which subsequent developments may be appreciated.

PRESENT DAY CONDITIONS IN JAPAN

A reference to health conditions in Japan at the time of this report is essential to an understanding of some of the problems and difficulties which beset a survey study of the present type. Japan suffered rather severely during the previous decade. The maintenance of a large fighting force necessarily invoked considerable privation on the general populace. Japan had never been a country of abundance and, in fact, was existing at a near equilibrium level during the prewar days. The increased demands imposed by the war reduced the general standard of living significantly beneath the initial plane. The lowest ebb of general conditions was probably reached shortly after the cessation of hostilities. During the several years previous to this report there has been a considerable improvement in living standards, but at the time of writing many essential commodities remain in short supply. Available provisions consist, for the most part,

被爆生存者についての長期にわたる，綿密で系統的な研究が極めて重要である。この事実が認識された結果，1946年11月26日付で大統領指令が発せられ，広島および長崎の被爆者について適切な調査を行なう責任が米国学術会議に与えられた。この指令の背景ならびにその後の組織の発展については別の報告に簡単に述べてある。[2]

調査を要する問題は多いが，そのうちの重要なものの一つは血液の細胞要素の調査である。本報告の調査は1947年3月より1948年4月まで広島および呉で実施され，全身に多量の放射線を受けた人々が被爆後20か月乃至33か月にどんな末梢血液像を呈するかという問題を解明すべく企画された。この調査ではこの人々の現在の血液学的状態の評価を試みると同時に，今後の変化を調べる場合の比較検討の基礎を求めるという二重の目的をもつものである。

日本の現状

本報告に述べる如き，いろいろな問題や困難が伴うが，そのうちのあるものを理解するためには，この調査が行なわれた時の日本における保健事情を知ることが必要である。過去10年間は日本にとって相当苦しい時期であった。大規模な戦力を維持するために，必然的に一般国民に相当の窮乏が強いられた。日本はもともとあまり豊かな国ではなく，戦前においても同じ窮乏状態が続いていた。更に戦争による需要の増加のため一般の生活水準は大きく下がった。おそらく，戦争が終ってしばらくしてから，全般の状態は最低になった。この報告を作成する数年前より生活水準はかなり向上したが，報告作成当時は，必需品の多くはまだ不足していて手に入る食料は，主として炭水化物の主食品ならびに季節の野菜，および少量の魚類であった。一般の家庭が有意量の動物性脂肪および蛋白質を摂取

of the carbohydrate staple products, seasonal vegetables and a small amount of fish. Only on festive occasions does the average family enjoy significant amounts of animal fat and protein. The official government ration during the period covered by these studies was about 1,500 calories a day. Inflation had forced the cost of the necessary additional calories to fantastic levels.

Although a full appreciation of the true circumstances and conditions is difficult without firsthand observations, it may be appreciated that the general health conditions parallel the standard of living. This is well illustrated by the reported tuberculosis mortality rates for four years[3]: In 1944, there were 240.2 deaths per 100,000 persons; in 1945, 280.0; in 1946, 264.2, and in 1947, 189.0. For comparison, the mortality rate in the United States in 1945 for all forms of tuberculosis was 40.1 deaths per 100,000 persons.[4] Imamura,[5] in a recent photofluorographic survey of 144,350 persons in Osaka and its suburbs, observed 2.0 per cent with active tuberculosis and 1.5 per cent with suspected lesions. The morbidities of ascariasis and ancylostomiasis among the general population have been estimated to be from 80 to 90 per cent and from 50 to 60 per cent, respectively.[6] Dysentery and diarrhea, due to a variety of causes, are much more prevalent than in the United States.

Thus, despite the significant accomplishments of the Public Health and Welfare Section, General Headquarters, Supreme Commander for the Allied Powers,[7] and the strenuous postwar efforts of various Japanese groups, health conditions in Japan during the period covered by this study were significantly below those in the United States, a fact extremely pertinent to any consideration of the results described.

PLAN OF OBSERVATION

General Data.— An attempt was made to compare certain aspects of the hematologic status of Japanese of Hiroshima who, at the time of the atomic bombing, had been relatively heavily irradiated with the findings for an appropriate control group. The minimum interval in man between exposure to radiation and development

するのは祝祭日の時だけである。この調査が行なわれた期間中の政府の公定配給量は1日に約1500カロリーであった。インフレのため，必要カロリーの補足は驚くほど高価であった。

直接観察を行なわないと実情を十分認識することは困難であるが，一般的に健康状態は生活水準と平行することは考えられると思う。このことは4年間の結核死亡率を見ればよく分る。[3] 即ち，人口100,000人当りの死亡者数は1944年には240.2人，1945年には280.0人，1946年には264.2人，1947年には189.0人であった。これを米国の場合と比較してみると，米国では1945年における全結核の死亡率は人口100,000人当り40.1人であった。[4] 今村[5]は最近大阪およびその近郊に在住する144,350人に対しレントゲン間接撮影法による調査を行ない，活動性結核を有するもの2.0%，病変の疑があるもの1.5%を認めた。一般人口の鉤虫症および十二指腸虫症罹病率はそれぞれ80乃至90%，50乃至60%と推定されている。[6] 赤痢および諸種の原因による下痢の発生頻度は米国に比べて極めて高い。

連合国最高司令部厚生課[7]の有意な業績ならびに日本の各種団体の戦後のたゆまない努力にもかかわらず，この調査の行なわれた時期においては，日本の保健衛生状態は米国に比べて極めて低水準にあった。このことはここに述べる調査結果を検討する場合考慮に入れるべき重要な事実である。

観察計画

概　況——原爆時に比較的多量の放射線を受けた広島の日本人と適当な対照群における血液学的状態の特定な面について比較検討を試みた。人間が放射線を受けてから，白血病あるいは再生不能性貧血などの血液学的後障害の発生までの最短期間ははっきり知られて

of such possible late hematologic complications as leukemia or aplastic anemia is known only vaguely. The rapidity and degree of completeness of hematologic recovery in a group such as that irradiated in Hiroshima is unknown. Adequate follow-up studies in Hiroshima, therefore, called for frequent sampling of the irradiated population. Unfortunately, between the termination of activities of the Joint Commission[1] and the initiation of the investigations of the Atomic Bomb Casualty Commission there elapsed, for various reasons, a period of some sixteen months, during which only a few observations were made; these were largely by Japanese groups working under considerable handicap. Moreover, the early activities of the Atomic Bomb Casualty Commission were largely exploratory and not designed to support a large scale study. Hiroshima, in 1947, contained very little in the way of laboratory facilities, and the city was depleted of much of its native medical and technical talent. The plan whereby our observations were carried out represents a compromise between inadequate laboratory and technical facilities and the desirability of getting observations under way as quickly as possible.

Subjects.— The survivors of the Hiroshima bombing received varying amounts of radiation, according to their distance from the explosion and the amount of shielding protecting them. In this first survey it was felt desirable to study those persons who had received relatively large doses of radiation. The Joint Commission had established the fact that epilation of the scalp was one of the more reliable and objective signs of the absorption of large amounts of radiation.[1] It may be assumed that the majority of persons who received sufficient radiation to the scalp to cause epilation received corresponding amounts of radiation to the whole body. The epilating dose of gamma radiation of this type is estimated to be about 400 r. Consequently, epilation was utilized as the criterion for the selection of subjects. In order to control the observations on these irradiated persons, parallel studies on comparable nonirradiated persons were carried out in the city of Kure. Located 18 miles (28.97

いない。広島の被爆者のように放射線を受けた群における血液学的回復の速度およびその回復の程度は知られていない。従って広島で追討的な観察調査を十分に行なうためには，被爆者人口から自由に標本を抽出する必要があった。不幸にして，合同調査団の活動[1]が終了してから原爆傷害調査委員会の調査が開始されるまでには種々の理由により約16か月期間が経過し，その間に僅かに少数の観察が行なわれたに過ぎない。これらの観察は相当不利な条件の下で，主として日本の調査隊によって行なわれた。更に，原爆傷害調査委員会の初期の活動は大部分実験的なものであって，大規模な調査の遂行を目的としては企画されていなかった。1947年には，広島における検査設備は少なく，また地元医師および技術者の多くを失っていた。従って本調査の計画は検査設備および専門技術員の不足を充分承知の上で，できるだけ速かに調査を行う目的でなされたものである。

対　象——広島の被爆生存者は，爆発地点からの距離および遮蔽物の程度により，各々異なる放射線量を受けた。この調査は最初のものであるため，比較的多量の放射線を受けた者について調査することが望ましいと考えられた。多量の放射線を吸収したことを示す客観的徴候として，頭髪の脱毛が比較的信頼できると合同調査団は証明している。[1] 脱毛を起す程度の放射線を頭皮に受けた者の大多数は，全身にもこれに相当する量の放射線を受けたものと推測される。この種のガンマ放射線の脱毛線量は約400 r と推定されている。従って脱毛を対象選択の規準とした。被爆者の観察と比較対照するため，呉市において非被爆者の調査が実施された。呉市は広島から18マイル (28.97*km*) 離れており，その大きさは広島の約半分で，やはり港町である。人口構成も栄養状態も似ている。[3] 主要な海運基

kilometers) from Hiroshima, and about half its size, Kure is also a seaport town, with a comparable population pattern and nutritional status.[3] Being the site of a principal naval base, it had been subjected to severe incendiary and explosive bombing raids, with extensive damage, although casualties were extremely few in comparison with Hiroshima.

Precautions.— Prerequisite to a study of this type are the elimination of as many undesirable varieties as possible and the observation of sufficiently large samples to validate the results statistically. Sampling was executed in such a manner as to insure maximum comparability of the two groups, aside from the factor of radiation. For instance, it was well appreciated that a large number of the survivors of Hiroshima, pretentiously suffering from "atomic bomb disease," would desire inclusion in such an nvestigation, with the hope of receiving treatment and advice for their ailments, the symptoms of which most conveniently dated from the atomic bombing. The inclusion of such persons in a sample would obviously have created a bias in the form of extraneous pathologic factors, whic h would have been extremely difficult to duplicate in parallel controls.

In order to minimize the occurrence of unrelated hematologic complications and biologic variation, as well as for reasons of convenience, it was felt desirable to study, so far as possible, the younger age groups in schools.

To eliminate such systematic errors as might have arisen through the use of different groups of technicians in the two laboratories, all observations in the two cities were made by the same technicians, who alternated days between Kure and Hiroshima. During the last four months of the investigation, as many as possible of the originally selected subjects were reexamined and the results of the two observations averaged, thereby reducing seasonal changes and possible systematic laboratory errors. Actually, only about one half of the subjects were reexamined, the interval between the two examinations varying from three to eight months.

地の所在地であったので，猛烈な焼夷弾および爆発弾の空襲を受け多大の損害を蒙ったが，広島と比較すれば死傷者は極めて少なかった。

注意事項——この種の調査の前提条件は，その結果を統計学的に信頼できるものとするために，好ましくない多様性をできるだけ除外する事と，十分な標本を観察する事である。標本抽出は，放射線の要因を除いては，両群ができるだけ一致するように行なわれた。例えば，広島の被爆生存者のうち多数の者が病気に対する治療および指示を期待して症状があたかも原爆の時から始ったかのように「原爆症」を装い，このような調査に参加を希望することは十分に考えられた。このような者を標本に含めることは，異質の病理学的要因に関して偏りを生ずることは明らかで，対照に同様の要因を入れることは極めて困難である。

放射線とは無関係の血液学的合併症および生物学的差異の発生を最小限に止めるため，また便宜上からも，できるだけ在学中の若い年齢層を調査することが望ましいと考えられた。

両都市の検査室にそれぞれ別の技術員をおくという組織では誤差が生まれると思われたので，呉および広島の間を同じ技術員が1日毎に交代して検査を行なった。調査末期の4か月間は，最初に選んだ対象をできるだけ多く再検査した。2回の測定値の平均を求めて季節的変動および検査上の誤差を少なくしたが，実際には再検査を行なったのは対象の約半分に過ぎず，2回の検査の間隔は3か月乃至8か月であった。

Finally, to test the comparability of our technics and results with those of other investigators, a small group of 25 United States Army personnel were examined.*

GENERAL PROCEDURES

A random selection of epilated subjects, with the elimination of a maximum of undesirable bias of the aforementioned type, was insured through the adoption of a screening questionnaire. This included a variety of direct questions, relating to the subject's injuries and to his symptoms after the atomic bombing. The form was distributed to many of the schools in Hiroshima and likewise to a randomly selected portion of the remainder of the civil population. Approximately 16,000 screening questionnaires were completed. Those persons listing epilation were requested to report for examination. All were unaware of the criterion of selection.

In Kure, selection of the control sample was achieved through the principals of the various schools and through various local organizations, persons being selected to equate in sex and age to those actually examined in Hiroshima. All heads of organizations responsible for selection were fully appreciative of the possibility of undesirable bias arising from the inclusion of "volunteers." The accompanying histogram indicates comparison, by age and sex, of the epilated and control samples.

The selected subjects, on reporting to the laboratory for examination, were interviewed by a trained interpreter, who, after asking specific, direct questions, completed a detailed questionnaire. The items on the record were chosen in an attempt to bring out possible significant relations between hematologic findings and the history at the time of the bombing, with emphasis on position of the subject at the time of the explosion, signs and symptoms of radiation sickness, and associated trauma. It should not be assumed that the record in all instances represents an entirely true account, considering the fact that the

最後に，我々の検査法と結果を他の研究と比較できるかどうかを確かめるため，25人の米国軍人を検査した。*

一般調査要領

審査用質問表の使用により，前記のような好ましからぬ偏りを最大限に排除し，脱毛した対象の無作為抽出を確実にした。この質問表には対象の負傷および原爆後の症状に関するいろいろな直接的質問を記載した。この書式は広島の多くの学校に配布され，またその他の住民の中から無作為に選んだものにも配布されて，約16,000枚の質問表が完成された。脱毛があったと記入した者については受診のため来所するよう要請した。対象には選択の規準については知らされなかった。

呉においては，対照標本は各学校の校長および地元の諸団体を通じて求め，広島で実際に検査を受けた者と性および年齢構成が一致するよう選定された。選定に当った各団体の責任者はいずれも"志願者"を入れることによって好ましからぬ偏りが生ずる可能性を十分に認識していた。次の度数分布図に，脱毛のあった標本と対照の年齢・性別比較を示す。

選定された対象が診察のため来所すると，熟練した通訳が面接し，質問に対する回答を詳細な質問表に記入した。質問事項は，血液学的所見と原爆当時の病歴との間に有意な関係があればそれを明らかにしようとして選ばれたものである。特に爆発時における対象の位置，放射線疾患の徴候および症状，ならびに原爆による外傷に重点がおかれた。面接は原爆投下から18乃至30か月後に行なわれたので，記録がすべて真実であるとは言いきれない。

* The United States Army personnel were volunteers from the Chugoku Military Government Region and the Hiroshima Military Government Team, whose headquarters were in Kure.
米国軍人は呉に本部のあった中国地方軍政部と広島軍政部隊からの志願者であった。

interview was conducted eighteen to thirty months after an intense experience.

A similar questionnaire was used for the controls, but in the section devoted to the history only identifying information was recorded.

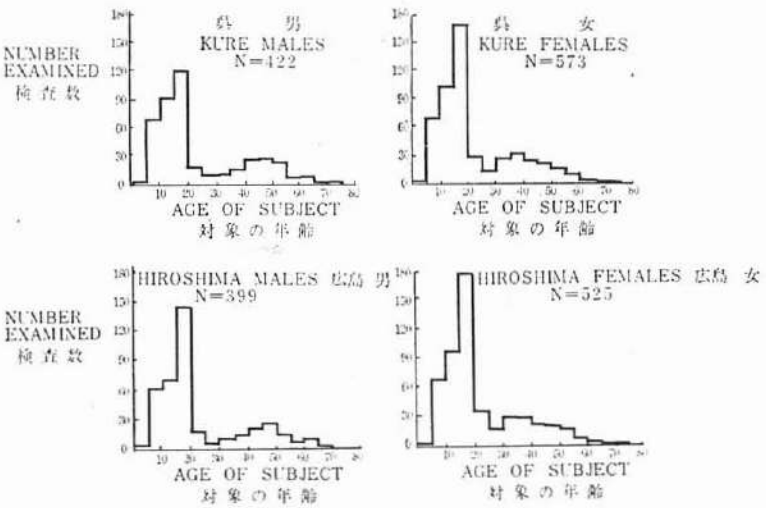
After the interview, a brief physical examination was carried out, with particular regard to general health, extent of injuries and occurrence of gross pathologic features. Persons with minor infections were common and were not eliminated from the series. Comparable examinations were made on both epilated and control groups. No physical examination was made at the time of reevaluation.

対照に対しても同様の質問表が使用されたが，病歴の欄には身許確認用の資料のみ記録された。

面接後，簡単な全身検査が実施され，その際，特に一般健康状態，負傷の程度および明らかな病的特徴の有無に注意が払われた。軽い感染症を有する者は多かったが，標本からは除外しなかった。脱毛群および対照群の双方について同様の検査を行なった。再検査の際には診察は行なわなかった。

FREQUENCY DISTRIBUTION OF THE POPULATION SAMPLES ACCORDING TO SEX AND AGE

人口標本の性別および年齢別度数分布



An attempt was made to secure the following hematologic data for each subject: erythrocyte, leukocyte and differential counts; hemoglobin concentration; hematocrit reading, and plasma protein values. In addition, reticulocyte counts were obtained for a limited number of persons. Leukocyte and differential counts were made on blood flowing freely from an incision of the ear lobe. The remaining observations were made from a 5 cc. sample of venous blood, drawn with no particular reference to meal time; all precautions were taken to avoid stasis. However, it should be noted that during the cold months, with the absence of adequate heating and, in some instances, adequate clothing, the peripheral

各被検者について赤血球数，白血球数および百分率算定，血色素濃度，ヘマトクリット測定，および血漿蛋白値等の血液学的資料を求めた。更に，少数の者については網状赤血球数も求めた。白血球数および百分率の算定は，耳朶の切創より自然に流出する血液を採取して行なった。その他の検査は，食事時間には特に注意しないで採血した静脈血5 ccについて行なわれた。血行静止を避けるためあらゆる注意が払われた。しかしながら，寒い時期には十分な暖房がなく，また時には十分な衣服がないため，多くの人の四肢の末梢循環は，手指に軽度のチアノーゼが明白に認められ，

circulation of the extremities was in many persons relatively static, as evidenced by slight cyanosis of the fingers. This factor introduced the possibility of some seasonal variation but did not invalidate the results, for the climatic condiitions were comparable in the two laboratories. The venous sample was placed in a clean, dry tube containing 5 mg. of potassium and ammonium oxalate, in the proportions recommended by Heller and Paul.[9] The various hematologic determinations were usually made within an hour, and always within four hours, of the time the specimen was secured.

HEMATOLOGIC PROCEDURES AND EVALUATION OF ERRORS

Erythrocyte and Leukocyte Counts.— The erythrocyte count was carried out in the standard manner, using Army–Navy equipment which was not certified by the United States Bureau of Standards. Dilutions of 1:200 were made with filtered Hayem's solution, samples of blood being withdrawn from the well mixed oxalated venous sample. Pipets were vigorously shaken for three to five minutes just prior to filling the chamber. Counting was carried out in 5 0.004 cu. mm. volumes. Duplicate dilutions and counts were made in all instances. When the original pair differed by more than 400,000 cells per cubic millimeter, one or more additional dilutions and counts were made. The average of all counts was taken as the final value. (The practice of utilizing only that pair of a series of repeated counts on the blood of an individual subject which differs no more than a set amount is statistically an unsound procedure. The establishment of a range limit, by which a pair of counts may acceptably differ, should be considered only as a means to aid in the detection of technical errors.)

Leucocyte counts were also carried out in the customary manner. Capillary blood was routinely employed; dilutions of 1:20 were made with filtered Turk's solution.[10] Pipets were vigorously shaken for three to five minutes just prior to filling the counting chamber. Counting was carried out in 4 0.1 cu. mm. volumes. Duplicate

比較的に静止の状態にあったことに留意する必要がある。この要因のために若干の季節的変動の可能性が考えられたが，両市の検査室の気候上の状態は似ていたので検査結果を無効にはしなかった。静脈血をHellerおよびPaulの勧めている割合でカリウムおよび蓚酸アンモニア溶液5 mgを入れた清浄な乾燥した試験管に移した。[9] 各種の血液学的測定は通常採血後1時間以内，遅くても4時間以内に行なわれた。

血液学的検査要領および誤差の評価

赤血球および白血球数の算定——赤血球数の計算は米国陸海軍の器具を用い，標準検査法によって行なわれた。但し，器具は米国基準局の検定を受けていないものである。静脈血と蓚酸とをよく混合して，その中から血液標本をとり沪過したHayem液で1：200の割合で希釈を行なった。計算室に血液を入れる直前にピペットを3乃至5分間強く振った。算定は0.004㎣について5副行なった。すべての場合に希釈液を2つ作り2回算定をした。2つの間に1㎣につき400,000以上の差を認めたときは，更に希釈液を作り，再計算を1回またはそれ以上行なった。すべての計算値の平均値を最終値とした。（1人の被検者について血球数算定を2回行ない，差が一定の値以下である場合のみを利用することは統計学的には妥当ではない。2つの血球計算値の差に一定の範囲を設けることは検査上の誤差を発見するための手段としてのみ考慮されるべきである。）

白血球数算定も通例の方法で行なった。毛細管血液を使用し，沪過したTurk液[10]で1：20の希釈を行なった。計算室に血液を入れる直前にピペットを3乃至5分間強く振った。算定は0.1㎣について4副行なった。すべての場合に，希釈液を2つ作り，算定を2回

dilutions and counts were made in all cases. When the difference btween the pair of counts was greater than 20 per cent of the mean, additional dilutions and counts were made if the subject was still available; otherwise, the original pipets were reshaken and the leukocytes recounted. In every case, the final value accepted was the average of all counts.

The problem of error involved in the estimation of numbers of erythrocytes and leukocytes has been examined by several investigators.[11] The work of Berkson and his collaborators[11e-g] was most extensive. They carried out repeated dilutions and counts on a series of blood samples, utilizing standard pipets and a photographic-mechanical method of enumerating blood cells in a standard chamber.

In these circumstances, the standard deviation for the determinations on any one sample was ±390,000 cells when the mean was approximately 5,000,000 cells per cubic millimeter, resulting in a coefficient of variation of (0.390/5.00)×100, or 7.8 per cent. When each item in the frequency distribution of counts was an average of duplicate dilutions and counts, the standard deviation was reduced to $\frac{1}{\sqrt{2}}\times 0.390$, or ±276,000 cells, and the coefficient of variation for the paired count means was 5.5 per cent. Approximately 95 per cent of the averages of all duplicate counts on a single blood sample might be expected to fall within ±552,000 cells (twice the standard deviation), or ±11.0 per cent of the mean, at a mean of 5,000,000 cells.

Similarly, in regard to enumeration of leukocytes by the standard procedure, the coefficient of variation of a distribution of repeated dilutions and counts on a single sample of blood containing about 7,000 leukocytes per cubic millimeter was 10.7 per cent. The use of the averages of duplicated dilutions and counts reduced this to $\frac{1}{\sqrt{2}}\times 10.7$ per cent, or 7.6 per cent; approximately 95 per cent of paired count means might then be expected to fall within ±15.2 per cent of the mean, if the mean were approximately 7,000 leukocytes per cubic millimeter.

行なった。2回の算定値の差が平均値の20%より大であった時は，できれば今一度採血して更に希釈液を作り算定を行なった。それができない場合は，初め採血した血液を入れたピペットをもう1度振り，白血球数の再算定を行なった。いずれの場合も最終値としてはすべての算定値の平均値を使った。

赤血球および白血球数の計算における誤差の問題については数人の研究者[11]によって調査されている。Berksonとその協力者ら[11e-g]の調査が最も大規模なものであった。彼らは標準ピペットを使用して一連の血液標本について幾つかの希釈液を作り，標準計算室内の血液細胞を数える方法として写真法を用いて何回も算定を行なった。

この場合，平均血球数が1㎣当り，5,000,000であるとき，1つの標本の測定の標準偏差は±390,000で変動係数は(0.390/5.00)×100，即ち，7.8%となる。計算値の度数分布のそれぞれの点が2つの希釈液を作って算定した平均値であれば標準偏差は$\frac{1}{\sqrt{2}}\times$0.390即ち±276,000になり，2つの計算値の平均に対する変動係数は5.5%である。平均血球数が5,000,000である場合，1つの血液標本について行なわれたすべての重複算定の平均値のうち約95%が平均血球数の±552,000(標準偏差の2倍)以内，即ち，平均血球数の±11.0%以内になると期待される。

同様に，標準検査法による白血球数の計算についても，1㎣当り白血球数が約7,000ある1つの血液標本につき何回も希釈液を作って算定すると，その分布の変動係数は10.7%であった。重複希釈および算定の平均値を用いるとこれは$\frac{1}{\sqrt{2}}\times 10.7\%$即ち，7.6%になる。そこで平均白血球数を1㎣当り約7,000とすれば，2回の算定値のうち約95%は，平均白血球数の±15.2%以内になると考えられる。

The errors in these two hematologic procedures are considerably greater than is generally appreciated.

Determination of Hemoglobin and Plasma Protein Content.— These determinations were made by the copper sulfate method for measuring specific gravity, as described by Phillips and others.[12] One hundred cubic centimeter portions of copper sulfate solutions, graded at intervals of 0.001 gm. per cubic centimeter, were prepared according to instructions with appropriate dilutions of a stock solution, prepared either from commercially weighed samples of copper sulfate or by the saturation technic. Each set so prepared was calibrated by direct measurement of the specific gravity of representative samples, either with a calibrated hydrometer or by comparing the weight of a filled pyknometer with that of one filled with water at the same temperature. During the last six months of the survey, the solutions were prepared in 200 cc. portions and divided into two sets, one for the Kure laboratory and the other for the Hiroshima laboratory. Venous blood was used for all determinations and correction applied for the anticoagulant. Each set was used for determinations on the blood of not more than 100 persons. The bulk of the data represent single determinations, but occasionally an average of two determinations made by different independent technicians was employed. The revised nomogram was utilized to compute the hemoglobin concentration and the protein values.

The usefulness and relative accuracy of the determination of specific gravity of whole blood and plasma, in estimating the hemoglobin concentration and plasma protein content of blood, which is not grossly abnormal, have been well established,[12] although two investigators[13] have failed to demonstrate satisfactory correlation between the specific gravity of the plasma or serum and its protein content. The propriety of using this method in determinations on grossly abnormal blood is still open to question.

In an attempt to evaluate at least a portion of the error of this method in our laboratories, duplicate estimates of hemoglobin content were made by two independent technicians in 191 cases.

これら2つの血液学的検査方法における誤差は一般に認められているよりは相当大きい。

血色素量および血漿蛋白量の測定——これらの測定はPhillipsら[12]の報告している比重より測定する硫酸銅法で行なった。秤量した硫酸銅の市販品を使用してまたは飽和法によって原液を作り，処理要領に従って原液を適当に希釈して，それぞれ1 *cc*当り0.001 *g* の間隔で硫酸銅溶液系列を100*cc* ずつ作った。このように調製した基準液の代表的な標本についてその比重を調べた。これは目盛のついた比重計によって，または比重瓶にこの標本を入れたものと同一温度の水を入れたものの目方を比較することによって直接測定して調べた。調査の後半6か月間は，溶液を200*cc* ずつ調製し，それを2組に分け，1組は呉検査室，1組は広島検査室で使用した。すべての測定に静脈血を用い，凝血阻止剤に対する修正を加えた。基準液は100名の血液の測定を行なうと新たに調製した。資料の大部分は1回の測定であるが，時々2人の技術員が別々に行なった2つの測定の平均値を使用した。血色素濃度および蛋白量を計算するため修正計算図表を使用した。

明らかな異常のない血液についての血色素濃度および血漿蛋白量の計算に当って，全血および血漿の比重測定が有用で比較的正確であることはよく知られているところであるが，[12] 血漿あるいは血清の比重と蛋白量との間に十分な相関を立証することができなかったと言う者もある。[13] 明らかに異常のある血液の測定にこの方法を用いることの妥当性についてはなお疑問の余地がある。

我々の検査室において少なくともこの方法による誤差の一部でも評価しようとして，191例について血色素量測定を2人の技術員が別々に行なう重複測定を行

Statistical analysis of the differences revealed no significant systematic error on the part of either technician; that is, regarding the mathematical sign of the differences, the mean difference was -0.01 ± 0.016 gm. per cubic centimeter.* The standard deviation of the distribution of the differences was ± 0.22 gm. per cubic centimeter. Taking twice the standard deviation as indicating the significant limits of variability, 95 per cent of the absolute differences between duplicate estimations were within 0.44 gm. per hundred cubic centimeters. Utilizing the fact that the standard deviation of differences is equal to $\sqrt{2}$ times the standard deviation about the mean, one can estimate from the variation of differences between two determinations of hemoglobin content, the variation about a mean value for hemoglobin content. Thus, the standard deviation about the mean equals $\frac{\pm 0.22}{\sqrt{2}}$, or ± 0.156 gm., and 95 per cent of the values might be expected to fall within twice the standard deviation (± 0.31 gm.) or, at an assumed mean of 13 gm. per hundred cubic centimeters, within ± 2.4 per cent of the mean. The last value, then, is an estimate at a fiducial limit of 0.95 of the error in determination of hemoglobin concentration by the method of observed differences in specific gravity.

Similar treatment of the differences in 191 duplicate estimations of plasma protein contents gave a mean difference of $+0.003 \pm 0.015$ gm. per hundred cubic centimeters when the mathematical sign of the differences was taken into consideration. The standard deviation was ± 0.20 gm.; again, if twice the standard deviation were taken as indicating the significant limits of variability, 95 per cent of the differences might be expected to fall within 0.40 gm. per hundred cubic centimeters. Again, the 95 per cent expected variation about a mean plasma protein value was $\frac{\pm 0.40}{\sqrt{2}} = \pm 0.28$ gm., or within ± 3.7 per cent of a mean of 7.5 gm. per hundred cubic centimeters. When one again assumes a fiducial limit of 0.95, ± 3.7 per cent is an estimate of the error in

なった。その差の統計学的解析の結果，いずれの技術員にも有意な規則的に起る誤差を認めなかった。すなわち平均差は1 ccにつき-0.01 ± 0.016 gであった。* 差の分布の標準偏差は1 ccにつき± 0.22 gであった。標準偏差の2倍が有意な変動の限界を示すものとすれば，重複計算の差の絶対値のうち95%は100 ccにつき0.44 g以内である。差の標準偏差が平均値の標準偏差の$\sqrt{2}$倍に一致する事実を利用すれば，血色素量を2回測定した場合の差の変動から血色素量の平均値の変動を計算することができる。従って，平均値の標準偏差は$\frac{\pm 0.22}{\sqrt{2}}$即ち，$\pm 0.156$ gになり，検査数値のうち95%は標準偏差の2倍(± 0.31 g)以内，即ち100 cc当りの平均値を13 gと推定すれば，平均の± 2.4%以内となると期待される。つまり，この最後の値は比重の差による血色素濃度の測定法の0.95の基準水準における誤差の概算である。

191例につき血漿蛋白量を2回測定し，その差を同様な方法で調べると差の数学的符号を考慮した場合，平均差は100 ccにつき$+0.003 \pm 0.015$ gとなり，標準偏差は± 0.20 gであつた。ここでも標準差の2倍を有意な変動の限界を示すものとすれば，差のうち95%は100 ccにつき0.40 g以内になると期待される。また平均血漿蛋白値の95%予想変動は$\frac{\pm 0.40}{\sqrt{2}} = \pm 0.28$ g，即ち100 ccにつき平均7.5 g，± 3.7%以内となる。更にまた0.95の基準水準では，比重の差による血漿蛋白量測定法における誤差の概算は± 3.7%である。

* All errors given in this paper are standard errors.
この報告書の誤差はすべて標準誤差である。

determination of plasma protein content by the method of observed differences in specific gravity.

Hematocrit Reading.— All hematocrit readings were made with Wintrobe tubes,[15] utilizing oxalated venous blood. The tubes were centrifuged routinely for one hour at 3,300 revolutions per minute in a centrifuge with a radius of 15 cm. from the midpoint of the hematocrit tube, or at 4,000 revolutions per minute in a centrifuge with a radius of 10 cm. from the midpoint of the tube. This resulted in equal centrifugal force in the two centrifuges.[16] The buffy coat layer was not included in the reading. In an attempt to evaluate the personal error involved in reading the hematocrit, duplicate readings were made by two independent technicians in 192 cases. Statistical analysis of the results, taking the mathematical sign of the differences into consideration, revealed that there was a slight systematic variation between the work of the two technicians. The mean difference was −0.082 ±0.017 cc. per hundred cubic centimeters, a systemic error of only 0.18 per cent at a mean of 45.0 cc. per hundred cubic centimeters. The standard deviation of the frequency distribution of the differences was ±0.24 per cent, and 95 per cent of the absolute differences might be expected to be within 0.48 per cent. The 95 per cent level of variability about a mean is given by the calculation $2 \times \frac{0.24}{\sqrt{2}}$, or ±0.34 per cent, this variability being due to the error involved in the reading of a hematocrit. Therefore, at a mean of 45 per cent and a fiducial limit of 0.95, this error is estimated at 0.76 per cent. Moreover, the error has been shown to be systematic; on the average, one technician read slightly, but significantly, higher than the other.

In the attempt to evaluate the error in the hematocrit readings due to differences in tubes and to the personal error introduced by a single observer, fifty-two determinations were made on the same blood, utilizing fifty-two different tubes, all of which were read by the same person. The mean hematocrit reading in this experiment was 47.84 per cent, with a standard deviation of ±0.27 per cent. This indicates that 95 per cent of observations might be expected to fall within ±0.54

ヘマトクリット測定——ヘマトクリット測定にはいずれの場合も蓚酸ナトリウムを加えた静脈血を用い，wintrobe 管[15] を使用した。ヘマトクリット管の中心までの半径が 15*cm* である遠心分離機で 1 分間 3,300回転あるいは試験管の中心までの半径が10*cm* の遠心分離機で 1 分間 4,000 回転で 1 時間遠心した。この方法では 2 つの遠心分離の遠心力は等しい。[16] 淡黄色の 被覆層は測定しなかった。ヘマトクリット測定における検査員による誤差を算定するため 192 例について重複測定を 2 人の技術員により別々に行った。数学的符号による差を考慮に入れて統計学的解析を行なった結果，2 人の技術員の間には規則的な変動が少々あることを認めた。平均差は100*cc* につき −0.082±0.017*cc* で，平均値が 100*cc* につき 45.0*cc* の場合，定誤差はわずか 0.18% であった。差の度数分布の標準偏差は±0.24% であり，差の絶対値のうち95%は0.48%以内となると思われる。平均値の変動の95%水準は，$2 \times \frac{0.24}{\sqrt{2}}$ 即ち±0.34%で，この変動はヘマトクリット値の読みの誤差によるものである。従って平均値45%および0.95の基準水準では，この誤差は0.76%と推定される。なお，その誤差は規則的なものであることが認められ，平均して一方の技術員の測定は他の技術員よりわずかではあるが可成り高い。

試験管の相違と観察者によって起る個人差が，ヘマトクリット測定にいかなる誤差を生ずるかを評価する試みとして，同一血液標本について52本の異った試験管を用いて，同一検査員が52回の測定を行なった。この実験における 平均ヘマトクリット測定値は 47.84% で，標準偏差は±0.27% であった。これによれば所見の95%が ±0.54% (標準偏差の 2 倍)，即ち 平均値の

per cent (twice the standard deviation), or ±1.13 per cent of the mean.

The variance due to the error involved in reading a hematocrit has been estimated at $\overline{0.17}^2$, or 0.0289, per cent. The variance due to this source of error plus the error introduced by the use of different tubes has been estimated at $\overline{0.27}^2$, or 0.0729 per cent. The difference between these two variances, or 0.0440 per cent, is a rough estimate of the variance introduced by differences in hematocrit tubes. The latter source of error, therefore, appears to outweigh the personal error.

Determination of Cell Constants.— The cell constants, mean cell volume, mean cell hemoglobin and mean cell hemoglobin concentration, were routinely calculated in the usual manner.[17] A preliminary discussion of the error involved in the determination of these ratios and of the variability of normal values seems indicated at this point.

The normal mean cell volume for healthy adults is commonly stated to be 87 cubic microns and the normal range from 82 to 92 cubic microns.[18] The mean has been confirmed, but the basis on which the normally accepted range rests is probably less secure. Pearson,[19] in 1897, reported an equation for the standard deviation of a ratio of two variables where the coefficient of variation of the numerator and denominator and the degree of correlation between them are known:

$$\text{S. D.}_{\frac{y}{x}} = \frac{\bar{y}}{\bar{x}}\sqrt{v^2_x + v^2_y - 2\,r_{xy}\,v_x\,v_x}$$

in which S. D.$_{\frac{y}{x}}$ is the standard deviation of the ratio $\frac{y}{x}$, $\bar{x}$ is the mean of the first variable, x, $\bar{y}$ is the mean of the second variable, y, v_x and v_y are the coefficients of variation of the two variables, x and y, expressed as simple proportions rather than as percentages, and r_{xy} isthe coefficient of correlation of x and y.

One may assume, for the moment, that one is dealing with a single sample of blood and that repeated erythrocyte counts and hematocrit determinations have been made. In this instance r is zero, since separate subsamples are used for the

±1.13%以内となることが予想される。

ヘマトクリット値の読みの誤りによる分散は $\overline{0.17}^2$ 即ち，0.0289%と推定された。このために生ずる誤差に，異った試験管の使用がもたらす誤差を加えた時の分散は$\overline{0.27}^2$，即ち0.0729%と推定された。これら2つの分散の差，即ち0.0440%はヘマトクリット管が異ることによって生ずる分散の概算である。従って後にあげた誤差の原因が検査員による差より大であるようである。

血球定数の測定——血球定数，すなわち平均血球容量，平均血球血色素量および平均血球血色素濃度を通常の方法[17]で計算した。ここでこれらの比率の測定における誤差および正常値の変動について予め検討する必要があると思われる。

健康成人の正常平均血球容量は87μ^3，正常範囲は82乃至92μ^3であると一般にいわれている。[18] この平均値は確認されているが正常範囲の根拠はそれ程確実であるとは思われない。Pearson[19]は1897年に，分子および分母の変動係数ならびにその間の相関の度合がわかっている場合，2つの変数の比率の標準偏差を求める方程式を報告している。すなわち，

この式において S. D.$_{\frac{y}{x}}$ は比率$\frac{y}{x}$の標準偏差，$\bar{x}$は第1変数xの平均値，$\bar{y}$は第2変数yの平均値，v_xおよびv_yは，2つの変数xとyの変動係数の百分率ではなく簡単な割合として示したものでr_{xy}はxとyの相関係数である。

1つの血液標本について繰り返えし赤血球数の算定およびヘマトクリット測定を行なう場合，測定には別々の副標本を用いるので，rは零である。処理方法のための誤差による変動係数はすでに述べた通りで，こ

determinations. The coefficients of variation due to error inherent in the procedures have been estimated in the foregoing paragraphs. Applying these data to the preceding equation, the expected variation in the mean cell volume can be calculated. Assuming a single estimate of the erythrocyte count ($v_x=0.078$), a single hematocrit determination ($v_y=0.0057$), and single values for the mean ($\bar{x}=5{,}000{,}000$ cells per cubic millimeter and $y=43.5$ per cent) the computation is:

れらの資料をこの方程式にあてはめると平均血球容量の予想分散を計上することが出来る。赤血球数の単一算定（$v_x=0.078$），ヘマトクリットの単一測定（$v_y=0.0057$），および平均値に対する単一数値（$\bar{x}=1\,mm^3$につき5,000,000，$y=43.5\%$）の場合，計算は次の通りである。

$$\text{S. D.}_{\frac{y}{x}} = \frac{43.5}{5.00} \times 10\sqrt{(0.078)^2+(0.0057)^2}$$

$$= 87\sqrt{61.16\times10^{-4}}$$

$$= \pm87\,(7.82\times10^{-2})$$

$$= \pm6.8 \text{ cubic microns.}*$$

This value signifies that in a single sample of blood, with means as just assumed, 95 per cent of the determined values for mean cell volume may be expected to fall within a range of twice the standard deviation, or 73.4 to 100.6 cubic microns. The utilization of the average of duplicate erythrocyte counts and hematocrit determinations in the calculation of the values for mean cell volume would reduce the variation to $\frac{\text{S. D.}_{\frac{y}{x}}}{\sqrt{2}}$, or ±4.8 cubic microns and thereby reduce the range for 95 per cent of the values to 77.4 to 96.6 cubic microns. The utilization of the average of additional determinations in a similar manner would reduce the error further, in the proportion of $\frac{1}{\sqrt{n}}$, in which n is the number of determinations averaged.

この値の意味するところは，今推定したような平均値を有する1つの血液標本においては，平均血球容量の測定値のうち95%は標準偏差の2倍の範囲内，即ち73.4ないし100.6μ^3以内となると予想されることである。平均血球容量を計算するに当り，赤血球数およびヘマトクリット値を2回測定してその平均値を用いると，分散は$\frac{\text{S. D.}_{\frac{y}{x}}}{\sqrt{2}}$即ち，±4.8$\mu^3$に下がり，従って数値の95%が含まれる範囲は77.4ないし96.6μ^3になる。更に同様に追加測定を行ない，その平均値を用いると，$\frac{1}{\sqrt{n}}$の割合で更に誤差が少なくなり，この場合，nは平均された測定値の数である。

One may now consider a population of normal men, for whom the mean erythrocyte count is 5,500,000 cells per cubic millimeter, the mean hematocrit reading is 47.8 per cent and the respective standard deviations, based on duplicate determinations, are ±380,000 cells and ±3.0 per cent. (These standard deviations are only an estimate and serve here simply as an illustrative assumption. The literature shows considerable variation from investigator to investigator.[20] Similarly, the variability of hemoglobin concentration in a sample of

ここで正常男性人口を検討することとし，その平均赤血球数を1 mm³につき5,500,000，平均ヘマトクリット値を47.8%および2回の測定に基くそれぞれの標準偏差を±380,000，±3.0%とする。（これらの標準偏差は概算に過ぎず，ここでは単に一例として示した。文献によると，研究によって相当の相違がある。[20] 同様に，健康男性の標本における血色素濃度の平均値が100ccにつき約16gであれば分散は±0.90gと推定さ

*The constant 10 is introduced in order that the result may be expressed in cubic microns.
結果をμ^3で表わすために定数10を用いた。

healthy men may be estimated as ±0.90 gm., at a mean of approximately 16 gm. per hundred cubic centimeters. This standard deviation for the erythrocyte count of a population is only slightly greater than Berkson's standard deviation for repeated duplicate determinations on the same sample. The discrepancy between theory and "observation" may well be a result of the sampling bias introduced by the probably not infrequent statistical malpractice of repeating, because of too rigid criteria of acceptability, those counts which look "off" and then accepting only those which appear more "reasonable," discarding the "off" counts as errors in technic, when actually they may well be chance variations.) These values would have corresponding coefficients of variation of 6.91 and 6.28 per cent. One may assume that the correlation coefficient between these two determinations is 0.60. (The correlation coefficient, as calculated from data appearing in the literature,[21] likewise shows considerable variation, ranging from 0.10 to 0.75. The value quoted previously is a working estimate. In the present study, the correlation coefficients for 143 male control subjects aged 15 to 30 were 0.529 for erythrocyte count and hematocrit reading 0.569 for hemoglobin concentration and erythrocyte count, and 0.782 for hematocrit reading and hemoglobin concentration. On substitution of the aforementioned assumed values in the equation, the standard deviation of the mean cell volume is estimated to be ±5.2 cubic microns. The mean plus or minus twice this value indicates an estimate of the range within which 95 per cent of the values of mean cell volume for the assumed population might be expected to fall. The range would be 76.6 to 97.4 cubic microns. In this instance, the utilization of additional erythrocyte counts and hematocrit readings, to calculate the mean cell volume for each person, would not reduce the variation by $\frac{1}{\sqrt{n}}$, but by somewhat less, for in following such a procedure one can only approach the true biologic variation.

In a similar manner, assuming approximate coefficients of variation of the hematologic determinations, as mentioned previously one can calculate the expected ranges of the other cell constants,

れる。ある人口における赤血球数に対するこの標準偏差は，同一血液標本に対して繰り返し重複測定を行なったBerkson の標準偏差よりわずかに大であるに過ぎない。理論的な数値と「観察値」との不一致は採用規準があまりにも厳格であるため「誤り」と思われる算定について再検査を繰り返して，より「合理的」と思われる数値を採用し，「誤り」と思われるものは，それが実際は偶然の変動かも知れないのに技術上の誤差として棄てるという，統計上しばしばあると思われる悪い慣行による標本抽出の偏りの結果であると思われる)。これらの値はそれぞれ6.91%および6.28%の変動係数を有する。これら2つの測定値間の相関係数は0.60であると推定できる。（文献[21]に載っている資料に基いて計算した相関係数も0.10から0.75の範囲で相当の相違を示している。先に見積もられた値は作業上の推定値である。本調査においては，15才から30才までの対照男性143名に対する相関係数は赤血球数とヘマトクリット測定値に対しては0.529，血色素濃度と赤血球数に対しては0.569，ヘマトクリット測定値と血色素濃度に対しては0.782であった。方程式に前述の推定数値を代入すると，平均血液容量の標準偏差は ±5.2μ^3 と推定される。平均値にこの値の2倍を加えるか或は引いたものが，その人口における平均血球容量値の95%が該当すると思われる範囲である。この範囲は76.6から97.4μ^3となる。この場合，各人の平均血球容量の計算に更に赤血球数算定およびヘマトクリット測定を加えて利用すると変動は$\frac{1}{\sqrt{n}}$少なくなるのではなく，それよりは幾分減少の程度が少ない。このような要領に従ってのみ真の生物学的変動値を得ることができるようになるからである。

同様に前述のごとく，血液学的測定値の大体の変動係数を推定すると，他の血球定数，平均血球血色素量および平均血球血色濃度の予想範囲を計算することが

mean cell hemoglobin and mean cell hemoglobin concentration. For determinations on a single blood sample, then, the means and standard deviations are 29.0±2.3 micromicrograms for mean cell hemoglobin and 34±0.45 per cent for mean cell hemoglobin concentration, utilizing single hematologic determinations in computation of the ratios. The standard deviations would be reduced by $\frac{1}{\sqrt{2}}$ if the average of duplicate determinations were employed in the computation.

One may assume that in the case of a population sample, the correlation coefficient between erythrocyte count and hemoglobin concentration and between hemoglobin concentration and hematocrit reading is 0.60, and that standard deviations for the population are as previously mentioned (erythrocyte count, ±380,000 cells; hemoglobin concentration, ±0.90 gm., and hematocrit reading, ±3.0 per cent), thus giving, at their respective means, coefficients of variation of 6.91 per cent, 5.62 per cent and 6.28 per cent. In a normal population, then, the ranges of variability of 95 per cent of values about the means of the mean cell hemoglobin and mean cell hemoglobin concentration become 29.0±3.4 micromicrograms and 34±3.6 per cent, respectively.

By utilizing the averages of repeated determinations for each person, one can only approach the true biologic variation.

Differential Count.— Blood films were prepared from free-flowing capillary blood by the cover slip technic. The prepared films were routinely stained with Wright's stain. The differential counts were made only by physicians. Two hundred or more consecutive cells were differentiated. All films were checked by one of us (J. V. N. or F. M. S.), and in cases of apparent discrepancies, additional cells were differentiated and averaged with the previous differential count.

The question of the error involved in the differential count, expressed as a percentage, received adequate treatment by Goldner and Mann.[22] They stated the belief that the greatest error was the statistical error of sampling and that the variability could, in spite of skewness of distribution in case of means on either side of 50.0 per cent,

できる。そこで，1つの血液標本の測定において比率の計算に単一の血液学的測定を使用すると平均値および標準偏差は平均血球血色素量については29.0±2.3 $\mu\mu g$，平均血球血色濃度については34±0.45%である。計算に2回の測定の平均値を使用すると，標準偏差は$\frac{1}{\sqrt{2}}$だけ少なくなる。

人口標本の場合，赤血球数と血色素濃度との間および血色素濃度とヘマトクリット測定値との間の相関係数は0.60で，その人口に対する標準偏差は前述の通りである（赤血球数 ±380,000，血色素濃度 ±0.90 g，ヘマトクリット測定値 ±3.0%）と推定できるので，夫々の平均値では，変動係数は6.91%，5.62%および6.28%となる。従って正常人口においては，平均血球血色素量および平均血球血色素濃度の平均値の95%の変動性の範囲が，夫々29.0±3.4 $\mu\mu g$ と34±3.6%となる。

各人に対し繰り返し測定し，この平均を利用することによってのみ，真の生物学的変動値は得られるのである。

血液像算定——載せガラス法により自然に流出する毛細血管血液の血液塗沫標本をつくり，Wright 染色を施した。百分率算定はすべて医師が行ない，200個またはそれ以上の白血球を鑑別した。すべての塗沫標本は著者の1人（J. V. N. または F. M. S.）が点検し，明らかな相違を認めた場合は，更に白血球の鑑別を行ない，その結果と前の百分率算定の結果との平均を求めた。

白血球百分率算定における誤差の問題は，Goldner および Mann[22] によって十分に検討されている。彼らは最大の誤差は，標本抽出の統計上の誤差で50.0%前後の平均値の場合，分布の歪度にもかかわらず，その変動性は百分率の標準偏差を求める式によってかなり

be estimated with reasonable accuracy by the formula for the standard deviation of a percentage. The formula is S. D.$=\sqrt{\frac{pq}{n}}$, where n is the number of cells counted, p is the estimate of the mean percentage of the cell in question and q is 100—p. Thus, at a mean neutrophil count of 60 per cent, based on the differentiation of 200 cells, S. D.$=\sqrt{\frac{60\times40}{200}}=\pm3.46$ per cent, and 95 per cent of successive differential counts on 200 cells of this blood might be expected to fall within ±6.9 per cent of the mean of 60 per cent. Ponder and others[19c] stated that a considerable portion of the error in differential counts depended on the technics of preparation.

Reticulocyte Count.— Reticulocytes were stained vitally by the method described by Osgood and Wilhelm.[23] Smears were then prepared in the usual manner and counterstained with Wright's stain. The number of reticulocytes per 3,000 erythrocytes was counted in each case and the percentage computed.

The variation involved in the estimates of reticulocytes on a percentage basis (not in absolute number, since this would likewise involve the error of estimation in the erythrocyte count) may probably be assumed to follow the gaussian curve of error in a manner similar to that of the error in the differential counts. If such is the case, limits of variability for 95 per cent of values may be estimated at $2\sqrt{\frac{1\times99}{3,000}}$, or ±0.36 per cent, at a mean of 1 per cent and with the count based on a total of 3,000 cells.

Laboratory Checks.— Further to insure the reliability of our hematologic procedures, from time to time during the course of the study a 10 cc. sample of venous blood was drawn from a subject, unknown to the staff of technicians. The sample was divided into two of the usual 5 cc. portions and treated in the laboratory as the blood of 2 individual subjects. Analysis of the differences in fifteen such tests indicated variations within the limits of error of the technics.

正確に推定することができると信じている。この式は S. D.$=\sqrt{\frac{Pq}{n}}$ で，この場合，n は血球の算定数，p は当該血球の推定平均百分率，q は 100 − p である。このようにして白血球 200 個の鑑別に基いて平均好中球数が60%の場合，S. D.$=\sqrt{\frac{60\times40}{200}}=\pm3.46\%$ であり，この血液標本について更に繰り返し白血球 200 個の算定を行なえば，数値の 95%は平均値60%の ±6.9% 以内となると予想される。Ponder ら[19c] は百分率算定における誤差は標本作成技術の影響を相当受けると述べている。

網状赤血球算定——網状赤血球は，Osgood および Wilhelm[23] の述べている方法で生体染色し，その後通常の方法で塗沫標本を作り，Wright 染色で対比染色した。いずれの場合にも赤血球 3,000 個あたりの網状赤血球数を算定し，その百分率を計算した。

網状赤血球百分率（絶対数の場合は赤血球数推定の誤差もからんでくるので絶対数では用いない）の推定における変動は，白血球百分率算定における誤差と同様に，誤差は正規曲線を示すであろう。もしそうだとすると，値の95%の変動性の範囲は平均値 1 %とし，算定を赤血球 3,000 個に基づいて行なったとすれば，$2\sqrt{\frac{1\times99}{3,000}}$ 即ち，±0.36% と推定できる。

検査の検定——更に血液学的検査法の信頼性を保証するため，調査の途中において，技術者が知らない間に時々 1 人の対象から静脈血液標本10cc を採血し，それを所要の 5 cc に分け，それぞれ異った 2 人の対象の血液として試験室で取り扱った。このような試験を15回行ないその差を解析したところ，技術上の誤差の範囲内の変動を認めた。

TABLE 1. MEAN HEMATOLOGIC VALUES AND STANDARD DEVIATIONS IN UNITED STATES ARMY PERSONNEL

表 1　米国陸軍軍人の平均血液学的数値および標準偏差

Observation* 観察項目	Number of Subjects 対象者数	Mean and Standard Error 平均値及び標準誤差	Standard Deviation 標準偏差
Erythrocyte count 赤血球数	25	5,674,000±114,000	±570,000
Hemoglobin concentration 血色素濃度	25	15.97±0.19	±0.93
Hematocrit reading ヘマトクリット測定値	25	47.94±0.50	±2.50
Mean cell volume 平均血球容量	25	89.9±1.4	±7.0
Mean cell hemoglobin 平均血球	25	29.5±0.4	±2.0
Mean cell hemoglobin concentration 平均血色素濃度	25	33.4±0.3	±1.4
Leukocyte count 白血球数	24	8,084±481	±2,359
Neutrophils 好中球	18	60.6±1.8	±7.7
Lymphocytes リンパ球	18	30.3±1.5	±6.5
Monocytes 単球	18	6.0±0.6	±2.6
Eosinophils 好酸球	18	2.8±0.4	±1.9
Plasma protein value 血漿蛋白値	25	7.66±0.08	±0.38

*In this and subsequent tables, erythrocyte count is expressed in cells per cubic millimeter; hemoglobin concentration, in grams per hundred cubic centimeters; hematocrit reading, in per cent; mean cell volume, in cubic microns; mean cell hemoglobin, in micromicrograms; mean cell hemoglobin concentration, in per cent; leukocyte count, in cells per cubic millimeter; differential count values, in per cent, and plasma protein values, in grams per hundred cubic centimeters.

この表および以後の表において，赤血球数は1 mm^3中の細胞数で，血色素濃度は100 cm^3についてのグラム数で，ヘマトクリット測定値は百分率で，平均血球容量はμ^3で，平均血球は$\mu\mu g$で，平均血色濃度は百分率で，白血球数はmm^3中の細胞数では百分率で，血漿蛋白値は100cm^3についてのグラム数で表わされている。

CONTROL STUDIES ON AMERICANS

The mean values and respective standard deviations for the various hematologic procedures performed on 25 United States Army volunteers are presented in Table 1. The subjects formed a group of healthy young men who had a rather heterogeneous racial background. For instance, the series included second generation Japanese and Chinese. Hamre and others[20K-m] found no significant racial differences in the cellular elements of the blood in persons in the Hawaiian islands, having studied the problem rather extensively in a variety of age groups.

It may be noted in Table 1 that the mean values for the various hematologic determinations agree with the usually accepted means.[13a] The variabilities about the means, however, are somewhat higher than the usual standards. This question of acceptable

米国人について行なった対照調査

自発的に申し出た米国陸軍軍人25名について行なった各種血液学的測定の平均値およびそれぞれの標準偏差を示すと表1の通りである。この群は人種的背景をかなり異にする健康な青年より構成されていた。例えば日本系および中国系米人も含まれていた。Hamreら[20K-m]はハワイ諸島においてこの問題を色々の年齢群につき相当大規模に調査したが，血液の細胞要素に有意な人種差は認めなかった。

表1に示すごとく，各血液学的測定の平均値は一般に認められている平均値と一致している[13a]が，変動の程度は通常の標準より幾分高目である。変動の許容範囲の問題はすでに検討したが，この報告書の終りの

variability has been discussed and will be returned to again near the end of this report.

STATISTICAL PROCEDURES

Although every effort was made to establish two subpopulations within the cities of Kure and Hiroshima comparable in all respects except exposure to anatomic bombing, there existed within each of these two populations considerable hematologic variability, introduced by such well recognized factors as age and sex. Comparison of the two populations in terms of the means and the standard error of the difference is a relatively crude statistical procedure, since in these circumstances the standard error of the means, on which the evaluation of the significance of any observed difference rests, receives a substantial contribution of variation from the aforementioned factors, which are of no particular interest in the present study. In order to refine the comparison of the two groups, each epilated person was paired at random with a control subject of the same sex and of similar age. The differences between the corresponding hematologic values of these pairs were then treated statistically. Once pairs had been established, the same pairs were retained for all subsequent analysis. Since only those persons who had been seen twice were included in this paired series, the total number of pairs which could be established was far less than the number of observations, so that this procedure, while inherently more sensitive, entailed sacrificing a considerable number of observations. However, the procedure did avoid, in part, the necessity of establishing multiple regression equations for adequate comparison of the two groups. It was felt that the survey was not sufficiently complete, in many respects, to justify treatment of the data by the more elaborate analysis of covariance.

PRESENTATION OF DATA

Over-All Blood Picture.— Table 2 presents the mean, standard deviation, and standard error of the mean for all the hematologic determinations carried out in Hiroshima and Kure, as well as a summary of the gross differences between subjects in the two cities. These differences are expressed in

方で再びとりあげることにする。

統計学的処理

呉市および広島市に，被爆の事実を除いてすべての点で一致した2つの人口集団を設けようとあらゆる努力を払ったが，これら2つの人口集団には各々年齢および性などよく認識されている要因による血液学的変動性が相当ある。差の平均値および標準誤差によって2つの人口集団の比較を行なうことは比較的粗雑な統計学的処理である。なぜならばこれらの事情のもとにおいては，観察される差の有意性の評価の基礎となる平均値の標準誤差は，本調査においては特に問題ではない前述の要因変動が相当あるからである。この2群の比較を精密にするため，脱毛対象者と同性および同年齢の対照者とを任意に組み合せてその血液学的数値の差を統計学的に処理した。この組み合せはその後のすべての解析にも用いられた。2回診察を受けた者のみを組み合せたので，組み合せの総数は観察数よりはるかに少なかった。従ってこの処理方法は本来感度の強いものではあるが，相当数の観察を犠牲にしなければならないという不利を伴う。しかしながらこの処理では，2群を十分に比較するための多重の回帰方程式を設けることを一部避けられた。資料の解析を更に複雑な共分散処理によって行なうためには本調査は多くの点で不十分であると考えられた。

資　料

血液像の概要——広島および呉で行なったすべての血液学的測定の平均値，標準偏差および平均値の標準誤差ならびに2市の対象間の明らかな差異の概要を示すと表2の通りである。差異は2通りに表わしてある。即ち，1つは2市で行なった各種測定の平均値の

two ways, first as the differences between the means of the various determinations carried out in the two cities, and secondly as the mean differences between the series of the aforementioned paired individual subjects. In both methods, the t statistic was used to evaluate the significance of any observed difference. With samples of this size, any value of t in excess of 2.0 indicates a difference significant at the 95 per cent probability level, whereas a value in excess of 2.6 denotes a difference significant at the 99 per cent probability level. Differences greater than twice their errors, corresponding to a t value in excess of 2.0, are printed in bold face type in all tables. Differences are listed with an arithmetical sign, + indicating a higher value for controls, and − indicating a higher value for epilated persons.

Because most of the hematocrit determinations were made during the latter part of the study, there were not sufficient duplicate observations on the same persons to warrant an analysis by differences of the established pairs, a fact which resulted in the omission also of the analysis of mean cell volume and mean cell hemoglobin concentration by this method. The small number of reticulocyte counts likewise did not justify an analysis of the differences of established pairs. These ommissions are also evident in subsequent tables.

A number of interesting facts emerge from a study of Table 2:

1. Determinations of erythrocyte count and hemoglobin concentration, by both types of analysis, were slightly lower in Hiroshima than in Kure. Hematocrit values were also lower in Hiroshima. These differences are of statistical significance. There is, on the other hand, no significant difference with respect to differences in mean cell volume, mean cell hemoglobin or mean cell hemoglobin concentration. The differences between the two series, epilated subjects and control subjects, thus appear to be quantitative rather than qualitative. However, a discussion of standard deviations appears later in this report.

2. Leukocyte levels were practically identical in the two cities and were probably on the high

間の差異であり，他は前述の組み合せた対象者の間の差異である。いずれの方法においても，観察した差異の有意性の評価に t 検定を行なった。この規模の標本では，2.0 を超える t の値は確率 95% で有意の差を示し，2.6を超える値は確率99%で有意の差を示す。2.0 を超える t の値に相当する誤差の 2 倍より大である差異はすべての表に肉太活字で印刷してある。差異には算術符号を附し，＋は対照の値の方が高いことを示し，－は脱毛対象者の値の方が高いことを示す。

ヘマトクリット測定の大部分は調査の後半に行なわれたので，組み合せた対象者について差異を十分解析できるほどの重複観察は行なわれなかった。このためこの方法で平均血球容量および平均血球血色素濃度の解析を行なわないことになった。また網状赤血球算定の数も少ないので，同様に組み合せた対象間の差異の解析を行なわなかった。以後の表にはこれらは省略されている。

表2を検討するといくつかの興味ある事実が認められる。

1. 赤血球数および血色素濃度の測定では，この2種の解析法とも，広島の値は呉の値よりやや低かった。ヘマトクリット値も広島が低かった。これらの差は統計学的に有意である。一方，平均血球容量，平均血球血色素量または平均血球血色素濃度には有意の差はない。従って，脱毛対象と対照の間の差異は質的よりは量的なもののようであるが，標準偏差については後程この報告で検討することにする。

2. 白血球数は両市とも殆んど同一であり，米国の

SUBJECTS IN HIROSHIMA AND THOSE IN KURE

表 2　広島および呉における対象者の血液学的差異の総合的比較

Observation 観察項目	Subjects in Kure 呉の対象者			Subjects in Hiroshima 広島の対象者			+ Difference ± Error of Difference 差異±差の誤差	++ Value for t tの値	+++ Value for F Test F試験の値	No. of Pairs 組合せを行なったものの数	Mean Difference and Standard Error 平均差及び標準誤差	Value for t tの値
	No. of Observations 観察の数	Mean and Standard Error 平均値及び標準誤差	Standard Deviation 標準偏差	No. of Observations 観察の数	Mean and Standard Error 平均値及び標準誤差	Standard Deviation 標準偏差						
Erythrocyte count 赤血球数	709	4,604,000 ±17,000	±442,000	629	4,521,000 ±20,000	±501,000	+83,000 ±26,000	3.2	1.29	437	+65,000 ±27,000	2.4
Hemoglobin concentration 血色素濃度	912	13.14±0.041	±1.25	872	12.84±0.046	±1.34	+0.30 ±0.061	4.9	1.15	447	+0.26 ±0.075	3.5
Hematocrit reading ヘマトクリット測定値	802	41.46±0.13	±3.60	757	40.98±0.14	±3.73	+0.48 ±0.19	2.5	1.08	…	……	…
Mean cell volume 平均血球容量	629	87.85±0.28	±6.90	546	88.34±0.30	±7.26	−0.49 ±0.41	1.2	1.11	…	……	…
Mean cell hemoglobin 平均血球血色素	708	28.74±0.088	±2.34	627	28.55±0.14	±2.59	+0.19 ±0.16	1.2	1.23	433	+0.21 ±0.13	1.6
Mean cell hemoglobin concentration 平均血球血色素濃度	665	32.15±0.053	±1.37	757	32.20±0.052	±1.43	−0.05 ±0.074	0.7	1.09	…	……	…
Plasma protein value 血漿蛋白値	912	7.59±0.017	±0.500	872	7.65±0.019	±0.549	−0.06 ±0.025	2.4	1.21	443	−0.021 ±0.028	0.8
Leukocyte count 白血球数	707	9,903±101	±2,693	645	9,847±122	±3,100	+56 ±160	0.4	1.32	455	+ 20 ±170	0.1
Neutrophils 好中球	707	54.96±0.35	±9.35	637	54.96±0.39	±9.94	0.00 ±0.53	0.0	1.13	432	−0.59 ±0.64	0.9
Lymphocytes リンパ球	707	29.40±0.28	±7.54	637	28.01±0.31	±7.89	+1.39 ±0.42	3.5	1.10	432	+2.02 ±0.48	4.2
Monocytes 単球	707	6.36±0.085	±2.26	637	6.33±0.093	±2.35	+0.03 ±0.13	0.2	1.08	432	+0.02 ±0.14	0.1
Eosinophils 好酸球	707	8.93±0.26	±7.02	637	10.76±0.32	±7.97	−1.83 ±0.41	4.5	1.29	432	−0.99 ±0.47	2.1
Reticulocyte count* 網状赤血球数	133	0.89±0.03	±0.38	120	0.96±0.04	±0.49	−0.07 ±0.05	1.4	1.72	…	……	…

* In this and subsequent tables, reticulocyte count is expressed in per cent of erythrocytes.
この表および以後の表において，網状赤血球数は赤血球数に対する百分率として表わされている。又差がその誤差の2倍より大なるものは肉太の活字で示してある。

\+ In this and subsequent tables, differences carrying a plus sign indicate a higher value for control subjects and those carrying a minus sign, a higher value for epilated subjects.
この表および以後の表において，正の記号の付してある差は対照の方が高いことを示し，負の記号の付してあるものは脱毛を量した対象者の方が高いことを示す。

++Values for t in excess of 2.0 indicate differences significant at the probability level of 95 per cent; values in excess of 2.6 differences significant at the 99 per cent probability level.
2.0を超えるtの値は，確率95%で有意の差を示し，2.6を超える値は確率99%で有意の差を示す。

+++Values for F in excess of 1.16 indicate differences significant at the probability level of 95 per cent; values in excess of 1.24 differences significant at the 99 per cent probability level.
In this and subsequent tables, differences greater than twice their errors are indicated with bold face type.
Fの値が1.16以上のものは確率95%で，有意の差を示し，1.24以上のものは確率99%で有意の差を示す。
この表および以後の表において，その誤差の2倍より大なるものは肉太の活字で示してある。

TABLE 3. RELATION BETWEEN AGE AND SEX AND EPILATED SUBJECTS: MEAN VALUES

表 3　脱毛対象ならびにその対照の年齢および性と

Subjects in Hiroshima 広島の対象者						Mean Difference ±Standard Error 平均差±標準誤差	
Male 男			Female 女				
Number 数	Mean and Standard Error 平均値と標準誤差	Standard Deviation 標準偏差	Number 数	Mean and Standard Error 平均値と標準誤差	Standard Deviation 標準偏差	Male Subjects 男性対象	Female Subjects 女性対象
85	4,676,000±38,000	±346,000	···	·····	·····	+38,000±54,000	·····
79	4,682,000±39,000	±346,000	···	·····	·····	−36,000±50,000	·····
94	4,898,000±46,000	±447,000	72	4,464,000±41,000	±346,000	−16,000±59,000	+169,000±66,000
46	4,813,000±72,000	±490,000	106	4,223,000±43,000	±447,000	−9,000±89,000	+163,000±64,000
74	4,408,000±61,000	±529,000	73	4,081,000±48,000	±410,000	+154,000±78,000	+107,000±64,000
127	12.34±0.077	±0.87	···	·····	·····	+0.31±0.12	·····
150	12.55±0.082	±1.00	···	·····	·····	+0.31±0.10	·····
140	13.73±0.112	±1.32	155	12.78±0.084	±1.05	+0.46±0.15	+0.18±0.12
47	14.47±0.193	±1.32	107	12.21±0.118	±1.22	−0.02±0.23	+0.38±0.17
73	13.39±0.165	±1.41	73	12.03±0.155	±1.32	+0.55±0.22	+0.23±0.20
120	38.63±0.23	±2.53	···	·····	·····	+0.48±0.32	·····
143	39.35±0.25	±3.00	···	·····	·····	+0.58±0.29	·····
135	43.28±0.30	±3.46	122	40.78±0.24	±2.65	+0.77±0.44	+0.15±0.33
36	46.00±0.51	±3.04	85	40.24±0.38	±3.46	+0.14±0.67	+0.43±0.55
57	43.90±0.56	±4.20	59	39.86±0.44	±3.39	+1.18±0.71	+0.02±0.62
81	83.40±0.56	±5.00	···	·····	·····	−0.17±0.78	·····
77	84.40±0.60	±5.29	···	·····	·····	+0.66±0.81	·····
90	84.18±0.60	±5.66	62	88.13±0.72	±5.66	+3.97±0.88	−1.25±1.05
36	91.33±0.94	±5.66	84	90.57±0.82	±7.48	−0.33±1.29	−1.49±1.55
57	94.72±0.96	±7.21	59	92.39±1.01	±7.75	−1.50±1.26	−2.26±1.26
85	26.76±0.24	±2.24	···	·····	·····	+0.09±0.30	·····
79	27.17±0.23	±2.00	···	·····	·····	+0.51±0.29	·····
94	28.23±0.23	±2.24	71	28.65±0.25	±2.12	+1.02±0.30	−0.41±0.33
46	29.96±0.34	±2.33	106	28.97±0.24	±2.52	+0.21±0.43	−0.22±0.35
73	30.36±0.31	±2.65	73	29.38±0.30	±2.54	+0.31±0.38	−0.02±0.39
120	32.11±0.12	±1.26	···	·····	·····	+0.17±0.18	·····
143	32.09±0.13	±1.50	···	·····	·····	+0.15±0.16	·····
135	32.43±0.13	±1.55	122	31.94±0.12	±1.32	+0.06±0.19	−0.00±0.18
36	33.33±0.17	±1.04	85	32.00±0.15	±1.41	−0.78±0.30	−0.24±0.23
57	32.11±0.22	±1.66	59	32.08±0.16	±1.22	−0.12±0.29	−0.21±0.23
87	12,305±386	±3,606	···	·····	·····	+270±500	·····
79	11,791±363	±3,226	···	·····	·····	−1,820±420	·····
95	10,394±303	±2,956	84	9,338±267	±2,449	−460±400	+320±370
47	9,053±342	±2,347	105	8,481±218	±2,236	−110±440	+940±350
73	8,555±274	±2,338	75	8,233±258	±2,236	+720±360	+270±350
87	49.53±1.07	±10.00	···	·····	·····	−0.73±1.35	·····
79	51.19±1.01	± 9.02	···	·····	·····	−0.83±1.28	·····
95	52.64±1.09	±10.61	84	58.13±1.13	±10.31	+2.14±1.35	+3.06±1.43
45	56.58±1.30	± 8.75	103	57.34±0.85	± 8.66	+0.25±1.78	−0.21±1.27
71	57.76±1.03	± 8.66	73	57.76±0.97	± 8.29	−0.65±1.47	−1.28±1.32
87	32.14±0.89	±8.29	···	·····	·····	+0.75±1.13	·····
79	30.11±0.89	±7.91	···	·····	·····	+3.10±1.16	·····
95	27.46±0.81	±7.91	84	26.46±0.75	±6.91	+0.68±0.98	−0.50±1.04
45	27.08±1.12	±7.48	103	26.15±0.74	±7.46	−0.49±1.46	+0.94±1.00
71	26.64±0.77	±6.51	73	28.10±0.93	±7.91	+1.95±1.18	+2.23±1.23
87	6.06±0.23	±2.10	···	·····	·····	+0.51±0.31	·····
79	6.42±0.27	±2.37	···	·····	·····	−0.22±0.32	·····
95	6.30±0.22	±2.17	84	5.70±0.23	±2.06	+0.34±0.32	−0.00±0.32
45	6.63±0.34	±2.29	103	6.14±0.22	±2.25	−0.34±0.42	+0.16±0.33
71	7.20±0.33	±2.75	73	6.54±0.31	±2.65	−0.32±0.46	−0.37±0.39
87	12.08±0.89	± 8.29	···	·····	·····	−0.50±1.19	·····
79	12.14±0.83	± 7.39	···	·····	·····	−2.07±1.07	·····
95	13.93±1.09	±10.61	84	9.79±0.83	±7.64	−3.44±1.34	−2.28±1.02
45	9.34±1.11	± 7.42	103	10.21±0.73	±7.37	+1.14±1.61	−0.61±1.05
71	8.72±0.66	± 5.55	73	8.34±0.70	±6.04	−1.66±0.80	−1.43±0.89
127	7.52±0.05	±0.57	···	·····	·····	−0.06±0.06	·····
150	7.64±0.04	±0.53	···	·····	·····	−0.15±0.06	·····
140	7.85±0.04	±0.49	155	7.78±0.04	±0.53	−0.21±0.06	−0.09±0.06
47	7.63±0.09	±0.59	107	7.61±0.05	±0.54	−0.13±0.12	+0.17±0.07
73	7.37±0.06	±0.53	73	7.63±0.06	±0.50	+0.20±0.08	+0.07±0.08
11	0.92±0.17	±0.56	···	·····	·····	−0.08±0.22	·····
17	0.90±0.10	±0.43	···	·····	·····	−0.05±0.13	·····
20	0.84±0.12	±0.54	16	1.38±0.17	±0.68	−0.11±0.13	−0.28±0.18
10	1.06±0.13	±0.42	18	0.95±0.09	±0.37	+0.05±0.16	−0.02±0.14
14	0.79±0.07	±0.25	14	0.89±0.10	±0.36	−0.04±0.11	−0.17±0.12

*in thls and the subsequent table, data for subjeets nnder 14 are not differentiated
この表および以後の表において，14才以下の対象の資料は性により区別しない。

HEMATOLOGIC FINDINGS IN CONTROL AND AND DIFFERENCES BETWEEN MEANS

血液学的所見との関係：平均値および平均値間の差

Observation 観察項目	* Age, Years 年齢	Subjects in Kure 呉の対象者					
		Male 男			Female 女		
		Number 数	Mean and Standard Error 平均値と標準誤差	Standard Deviation 標準偏差	Number 数	Mean and Standard Error 平均値と標準誤差	Standard Deviation 標準偏差
Erythrocyte count ..... 赤血球数	0－9	99	4,714,000±38,000	±0.378	...	.....	.....
	10–14	111	4,646,000±32,000	±0.340	...	.....	.....
	15–19	101	4,882,000±37,000	±0.368	84	4,633,000±52,000	±368,000
	20–39	52	4,804,000±53,000	±0.383	95	4,386,000±48,000	±466,000
	40＋	90	4,562,000±48,000	±0.457	77	4,188,000±42,000	±372,000
Hemoglobin concentration..... 血色素濃度	0－9	136	12.65±0.080	±0.93	...	.....	.....
	10–14	187	12.86±0.063	±0.86	...	.....	.....
	15–19	118	14.19±0.105	±1.14	157	12.96±0.080	±1.00
	20–39	51	14.45±0.122	±0.87	96	12.59±0.126	±1.24
	40＋	90	13.94±0.140	±1.33	77	12.26±0.132	±1.16
Hematocrit reading..... ヘマトクリット測定値	0－9	119	39.11±0.22	±2.41	...	.....	.....
	10–14	171	39.93±0.15	±2.00	...	.....	.....
	15–19	116	41.05±0.32	±3.40	137	40.93±0.23	±2.74
	20–39	44	46.14±0.45	±2.96	77	40.67±0.40	±3.55
	40＋	74	45.08±0.43	±3.69	64	39.88±0.43	±3.47
Mean cell volume ..... 平均血球容量	0－9	95	83.23±0.55	±5.35	...	.....	.....
	10–14	109	85.06±0.55	±5.76	...	.....	.....
	15–19	99	88.15±0.64	±6.34	67	86.88±0.76	±6.19
	20–39	44	91.00±0.89	±5.88	77	89.08±0.80	±7.06
	40＋	74	93.22±0.82	±7.09	64	90.13±0.75	±6.04
Mean cell hemoglobin..... 平均血球血色素量	0－9	99	26.85±0.18	±1.76	...	.....	.....
	10–14	111	27.68±0.18	±1.91	...	.....	.....
	15–19	101	29.25±0.19	±1.89	84	28.24±0.22	±1.97
	20–39	51	30.17±0.27	±1.94	95	28.75±0.25	±2.40
	40＋	90	30.67±0.22	±2.12	77	29.36±0.25	±2.20
Mean cell hemoglobin concentration 平均血球血色素濃度	0－9	105	32.28±0.13	±1.35	...	.....	.....
	10–14	130	32.24±0.09	±1.07	...	.....	.....
	15–19	99	32.49±0.14	±1.35	73	31.94±0.14	±1.22
	20–39	43	32.55±0.25	±1.62	77	31.76±0.17	±1.48
	40＋	75	31.99±0.19	±1.64	64	31.87±0.17	±1.37
Leukocyte count ..... 白血球数	0－9	100	12,570±312	±3,124	...	.....	.....
	10–14	112	9,973±206	±2,177	...	.....	.....
	15–19	101	9,926±245	±2,467	84	9,655±262	±2,402
	20–39	52	8,942±277	±1,995	95	9,415±267	±2,607
	40＋	88	9,284±240	±2,251	75	8,500±228	±1,972
Neutrophils..... 好中球	0－9	100	48.80±0.82	±8.19	...	.....	.....
	10–14	112	50.36±0.79	±8.35	...	.....	.....
	15–19	101	54.78±0.79	±7.96	84	61.19±0.87	±7.98
	20–39	52	56.83±1.22	±8.78	95	57.13±0.94	±9.21
	40＋	88	57.11±1.05	±9.97	75	56.48±0.90	±7.83
Lymphocytes..... リンパ球	0－9	100	32.89±0.70	±6.98	...	.....	.....
	10–14	112	33.21±0.75	±7.89	...	.....	.....
	15–19	101	28.14±0.56	±5.67	84	25.96±0.72	±6.60
	20–39	52	26.59±0.94	±6.79	95	27.09±0.67	±6.66
	40＋	88	28.89±0.90	±8.53	75	30.33±0.81	±7.02
Monocytes..... 単球	0－9	100	6.57±0.21	±2.08	...	.....	.....
	10–14	112	6.20±0.18	±1.89	...	.....	.....
	15–19	101	6.64±0.23	±2.36	84	5.70±0.22	±2.03
	20–39	52	6.29±0.25	±1.79	95	6.30±0.24	±2.37
	40＋	88	6.88±0.32	±3.02	75	6.17±0.23	±2.03
Eosinophils..... 好酸球	0－9	100	11.58±0.79	±7.89	...	.....	.....
	10–14	112	10.07±0.67	±7.09	...	.....	.....
	15–19	101	10.49±0.78	±7.91	84	7.51±0.60	±5.51
	20–39	52	10.48±1.16	±8.37	95	9.60±0.76	±7.52
	40＋	88	7.06±0.45	±4.24	75	6.91±0.55	±4.83
Plasma protein value..... 血漿蛋白値	0－9	136	7.46±0.04	±0.48	...	.....	.....
	10–14	187	7.49±0.04	±0.50	...	.....	.....
	15–19	118	7.64±0.04	±0.46	157	7.69±0.04	±0.48
	20–39	51	7.5 ±0.08	±0.57	96	7.78±0.05	±0.48
	40＋	90	7.57±0.05	±0.48	77	7.70±0.06	±0.53
Reticulocyte count ..... 網状赤血球数	0－9	7	0.84±0.14	±0.37	...	.....	.....
	10–14	11	0.85±0.09	±0.31	...	.....	.....
	15–19	25	0.73±0.06	±0.28	28	1.10±0.05	±0.29
	20–39	15	1.11±0.10	±0.40	14	0.92±0.11	±0.41
	40＋	16	0.75±0.08	±0.32	17	0.72±0.07	±0.28

aeeordlng to sex.

side by American standards. However, there appeared to be slight differences in the percentage values for some of the various types of leukocytes. By comparison with Kure, the number of lymphocytes showed an absolute depression of 1.39 per cent in Hiroshima, and the number of eosinophils was elevated by 1.83 per cent. These differences, although small, are statistically significant.

3. Plasma protein values were slightly higher in Hiroshima than in Kure, but the significance of the difference is problematic. In both cities, plasma protein values were slightly elevated by American standards.

4. For every hematologic characteristic studied, the standard deviation was larger in Hiroshima than in Kure. Taken singly, these differences are not striking. However, because of the large numbers involved, they are, in several cases, statistically significant, as indicated by the F test, on which data are included in Table 2.[24] With the number of degrees of freedom involved here, a value of F in excess of 1.16 indicates a difference significant at the 95 per cent probability level and one in excess of 1.24 exceeds a 99 per cent probability level. Six of the thirteen values exceed the 95 per cent level and four of these, the 99 per cent level. Moreover, the facts that the differences are, in all instances, in the same direction and that the value for F, in all instances, exceeds 1.08 are of themselves of great significance. It may be concluded that the Hiroshima population studied was hematologically more variable than that studied in Kure.

There were, then, a number of slight, yet statistically significant, differences between the peripheral hematologic pictures in the two cities. The appreciation of the meaning of these differences can perhaps be furthered through additional analysis of the data with respect to these questions:

1. Is there evidence that any particular age or sex group contributed disproportionately to the observed differences?

2. Is there evidence that the traumatic injuries and flash burns which were so frequent and severe in Hiroshima played a role in the hematologic difference?

標準からすれば高い方ではないかと思われた。しかしある種の白血球の百分率にやや差異があるようであった。呉と比較するとリンパ球数は広島において1.39%の絶対的な低下を示し，好酸球数は1.83%上昇していた。これらの差異は小さいが，統計学的には有意である。

3. 血漿蛋白値は呉より広島がやや高かったが，その差が有意であるかどうかは問題である。両市とも血漿蛋白値は米国の標準からすればやや上昇していた。

4. 血液学的検査の数値について，いずれも標準偏差は広島の方が呉より大であった。個々に観察するとこれらの差は顕著ではないが，数が多いので表2[24]に示す通りF検定で統計学的に有意なものが数例ある。この場合の自由度ではFの値が1.16を超えると確率95%で有意の差を示し，1.24を超える値は確率99%の水準を超える。13の値のうち，6は95%の水準を超え，そのうち4は99%の水準を超える。なお，差異がいずれの場合も同一の方向を示し，Fの値がいずれの場合も1.08を超える事実は，それ自体大きな意義がある。広島の調査人口は呉の調査人口と比べて血液学的変動が大きいと結論できる。

末梢血液像には2都市間に軽微ではあるが統計学的に有意な差があった。次の点に関し資料を更に解析すれば，これらの差異の意味を更に認識できるであろう。

1. 特定の年齢群，または性別によって，観察された差異が特に影響された形跡があるかどうか。

2. 広島に多い強度の外傷性傷害および原爆火傷がこの血液学的差異に役割を演じた形跡があるかどうか。

3. Is there evidence that the amount of radiation over and beyond the minimal epilating dose, as estimated by distance from the hypocenter of the explosion, extent of epilation or degree of severity of radiation sickness, influenced the final picture?

3. 爆心地からの距離，脱毛の程度あるいは放射線疾患の重症度から見て最低脱毛線量を超える放射線量を受けたと思われる者に，放射線のために最終血液像に影響があった形跡があるかどうか。

TABLE 4. RELATION BETWEEN AGE AND SEX AND HEMATOLOGIC FINDINGS: COMPARISON OF MEAN DIFFERENCES OF ESTABLISHED PAIRS, GROUPED ACCORDING TO AGE AND SEX

表　4　年齢および性と血液学的所見との関係：組み合せた対象の年齢・性別平均差の比較

Observation 観察項目	Age, Years 年齢	Male Subjects 男性		Female Subjects 女性	
		Number 数	Mean Difference and Standard Error 平均差および標準誤差	Number 数	Mean Difference and Standard Error 平均差および標準誤差
Erythrocyte count 赤血球数	0–9	55	+3,000±59,000	…	.....
	10–14	55	+3,000±69,000	…	.....
	15–19	91	−45,000±66,000	42	+110,000±84,000
	20–39	31	−131,000±92,000	66	+114,000±81,000
	40+	49	+232,000±92,000	48	+210,000±70,000
Hemoglobin concentration 血色素濃度	0–9	56	+0.29±0.167	…	.....
	10–14	55	+0.22±0.164	…	.....
	15–19	94	+0.24±0.160	42	+0.24±0.182
	20–39	32	−0.25±0.280	68	+0.28±0.221
	40+	51	+0.69±0.289	49	+0.27±0.250
Mean cell hemoglobin 平均血球血色素量	0–9	55	+0.46±0.312	…	.....
	10–14	55	+0.50±0.357	…	.....
	15–19	94	+0.71±0.254	40	−0.30±0.396
	20–39	31	−0.05±0.454	65	+0.04±0.371
	40+	49	−0.13±0.446	47	−0.59±0.458
Leukocyte count 白血球数	0–9	71	+218±566	…	.....
	10–14	61	−1,484±499	…	.....
	15–19	87	−604±379	39	−64±533
	20–39	29	−155±596	68	+1,427±399
	40+	52	+320±374	51	+500±396
Neutrophils 好中球	0–9	60	−1.87±1.77	…	.....
	10–14	55	−1.27±1.81	…	.....
	15–19	79	−1.29±1.43	37	+4.59±2.18
	20–39	30	+0.40±2.15	69	+0.14±1.59
	40+	52	−0.85±1.93	51	−2.00±1.77
Lymphocytes リンパ球	0–9	60	+2.33±1.44	…	.....
	10–14	55	+1.55±1.46	…	.....
	15–19	79	+1.76±1.07	37	+1.65±1.53
	20–39	30	+0.07±1.68	69	+1.12±1.15
	40+	52	+2.88±1.47	51	+3.90±1.49
Monocytes 単球	0–9	60	+0.88±0.35	…	.....
	10–14	55	−0.06±0.40	…	.....
	15–19	79	+0.07±0.31	37	−0.61±0.42
	20–39	30	−0.43±0.54	69	+0.38±0.42
	40+	52	−0.75±0.42	51	−0.15±0.42
Eosinophils 好酸球	0–9	60	−1.40±1.60	…	.....
	10–14	55	−0.53±1.15	…	.....
	15–19	79	−0.34±1.23	37	−3.86±1.70
	20–39	30	+1.33±1.49	69	−0.88±1.09
	40+	52	−0.81±1.15	51	−2.41±1.18
Plasma protein value 血漿蛋白値	0–9	56	−0.09±0.07	…	.....
	10–14	56	−0.18±0.08	…	.....
	15–19	94	−0.16±0.06	42	+0.07±0.10
	20–39	32	−0.05±0.09	67	+0.18±0.07
	40+	49	+0.18±0.09	49	−0.01±0.08

Relation Between Age and Sex and Response to Atomic Bombing.— A breakdown of the results of hematologic observations on the control and epilated groups, with respect to age and sex, is given in Tables 3 and 4. Data are not distinguished with respect to sex at ages below 14. Although the control figures on normal Japanese subjects bring out the number of facts of general hematologic interest, these findings will not be discussed at

年齢および性と原爆に対する反応との関係—年齢・性別に，対照および脱毛群に対する血液学的観察の結果の内訳を見ると，表3および4の通りである。14才以下の資料は性により区別されていない。正常日本人の対照数字によって，一般に血液学的に興味ある事実がいくつか明らかになったが，これらの所見は別の論

TABLE 5. RELATION BETWEEN EXTENT OF ASSOCIATED TRAUMATIC INJURY AND BURNS AND HEMATOLOGIC FINDINGS FOR EPILATED PERSONS: COMPARISON OF MEAN VALUES ACCORDING TO EXTENT OF INJURY

表 5　脱毛者の外傷性傷害および火傷の程度と血液学的所見との関係：平均値の傷害の程度別比較

Observation 観察項目	Subjects in Group 1* 1群の対象		Subjects in Group 2 2群の対象		Subjects in Group 3 3群の対象	
	No. 数	Mean and Standard Error 平均値および標準誤差	No. 数	Mean and Standard Error 平均値および標準誤差	No. 数	Mean and Standard Error 平均値および標準誤差
Erythrocyte count ..... 赤血球数	197	4,524,000±36,000	294	4,512,000±29,000	89	4,574,000±50,000
Hemoglobin concentration..... 血色素濃度	302	12.80±0.079	411	12.78±0.065	105	12.96±0.137
Hematocrit reading..... ヘマトクリット測定値	268	40.66±0.232	353	41.08±0.199	93	41.41±0.384
Mean cell volume..... 平均血球容量	174	87.48±0.528	254	88.69±0.472	76	88.42±0.733
Mean cell hemoglobin..... 平均血球血色素	196	28.44±0.175	294	28.51±0.157	89	28.28±0.252
Mean cell hemoglobin concentration 平均血球血色素濃度	268	32.33±0.091	352	32.15±0.074	93	32.07±0.164
Leukocyte count ..... 白血球数	199	10,394±228	296	9,689±179	88	9,477±319
Neutrophils..... 好中球	196	53.80±0.736	294	54.70±0.601	86	55.29±1.009
Lymphocytes..... リンパ球	196	28.16±0.572	294	28.12±0.461	86	27.53±0.824
Monocytes..... 単球	196	6.35±0.163	294	6.42±0.146	86	6.41±0.217
Eosinophils..... 好酸球	196	11.51±0.519	294	10.94±0.484	86	10.18±0.894
Plasma protein value..... 血漿蛋白値	302	7.67±0.032	411	7.63±0.027	105	7.64±0.050
Reticulocyte count ..... 網状赤血球数	37	0.934±0.069	58	0.922±0.065	17	0.874±0.070

*In this and the subsequent table, group 1 indicates those persons with no injuries, or with minor burns and glass cuts; group 2, those with moderately severe first, second or third degree burns involving up to approximately 10 per cent of the body area, or with comparable other traumatic injury, and group 3, those with burns involving more than 10 per cent of the body area, or with other types of severe traumatic injury.

この表および以後の表において，1群は傷害のないものまたは火傷，ガラスの切傷等の軽度のもの，2群は体表面の約10%に亘って1，2，または3度の火傷が中等度にあったもの，あるいはこれに匹敵するその他の外傷性傷害のあったもの，3群は体表面の10%以上に亘って火傷またはその他の強度の外傷性傷害のあったものを示す。

this time but will be considered in another paper.[25] It is apparent from the tables that there was no clear and consistent tendency for any particular age or sex group to contribute disproportionately to the observed differences in erythrocyte count, hemoglobin content and hematocrit value. Rather, the over-all difference for these determinations seems to be due to contributions from most of the groups studied. Thus, in Table 4, for instance, six of the eight differences in erythrocyte count and seven of the eight differences in hemoglobin content agree in sign with that for the group as a whole. There were, however, a few apparently disproportionate responses of particular sex and age groups, which, taken at their face value, are statistically significant. It should be borne in mind that on the basis of chance alone values in 5 per cent of *t* tests may be expected to exceed the value of 2.0. This variation also occurred in determination of the cell constants, even though there was no significant over-all tendency. The fact that the two different analytic approaches failed in many instances to yield confirming results lessens the weight to be given to these findings.

The total leukocyte count and the percentage of neutrophils and monocytes, which showed no significant gross differences in Table 2, likewise showed no clearly consistent tendencies on the breakdown, although there were several minor differences which may, in the light of future research, prove significant. The decrease in percentage of lymphocytes and the increase in percentage of esinophils recorded in Hiroshima apparently occurred in groups of all ages and both sexes. Differences in plasma protein values, although statistically significant in many of the groups, fell into no simple pattern. Reticulocyte counts, likewise, showed no significant pattern.

Relation Between Traumatic Injuries and Flash Burns and Hematologic Observations.— As noted previously, many epilated subjects received, in addition to the radiation, flash burns, glass cuts and injuries from other flying debris. The possibility that the observed differences between subjects in Kure and those in Hiroshima were actually due to these associated injuries rather than

文[25]において考察することにする。特定の年齢群または性別によって，赤血球数，血色素量およびヘマトクリット値に観察された差異に影響を与えた明確な一貫した傾向はなかったことは表により明らかである。むしろ，これらの測定の全体の差には，各調査群の大部分が寄与しているようである。例えば表4に示すごとく，赤血球数の8つの差のうち6および血色素量の8つの差のうち7は，符号が群全体の符号と一致する。しかし，ある性別年齢群には，額面通りに受取れば，統計学的に有意な不均衡と思われる反応が2，3あった。*t* 検定の5%が偶然2.0の値を超えると予想されることに留意する必要がある。全体としては有な意傾向はなかったけれども，この変動は血球定数の測定にも起った。2つの異なった解析方法で裏付となる結果が得られなかったことが多いのでこれらの所見の意義は小さくなる。

表2のごとく，有意な差異を明らかに示さなかった白血球総数および好中球と単球の百分率をそれぞれの分類に分けて見た場合も同様に，明確な，一貫した傾向を示さなかったが，将来の研究により有意と認められるかも知れない若干の軽度の差異はあった。広島で記録されたリンパ球百分率の減少と好酸球百分率の増加は，全年齢および男女ともに起ったと思われる。血漿蛋白値における差異は多くの群において統計学的に有意であるが，簡単な型にははまらなかった。網状赤血球数も同様に有意な型は示さなかった。

外傷性傷害および原爆火傷と血液学的所見との関係

前記のごとく，多くの脱毛対象は放射線に加え，原爆火傷，ガラスによる切傷，およびその他の飛散物による傷害を受けたので，広島と呉の対象間に認められた差異が，実際には放射線照射の要因よりはこれら傷害に起因するかもしれない可能性について探究せねば

to the factor of irradiation had to be explored. Accordingly, Hiroshima subjects were classified into three groups, Group 1 consisting of those persons with no injuries or with minor burns and glass cuts, Group 2 consisting of those with moderately severe first, second or third degree burns involving up to approximately 10 per cent of the body area, or with roughly comparable other traumatic injury, and Group 3 consisting of those who received either burns of varying severity involving more than 10 per cent of the body area or other types of severe traumatic injury. The records of relatively few persons, who could not be readily classified from the available data, were not incorporated into the analysis. The mean values in these three groups, and the mean differences between the established pairs, are shown in Tables 5 and 6.

The significance of the various trends shown here has been investigated by an analysis of the variance between and within groups. There was a tendency for the erythrocyte count to be higher for those subjects who received the severest injuries. This tendency is evident in both Table 5 and Table 6 but is statistically significant only in Table 6. Moreover, inspection of Tables 5 and 6 reveals that values for hemoglobin concentration and hematocrit reading tend to vary in the same manner as do those for erythrocyte count, although the trend is not statistically significant by this analysis. One faces, then, the paradox that those persons most severely burned or otherwise injured at the time of the bombing later showed a tendency to an increased number of erythrocytes, with correspondingly higher values for hemoglobin concentration and hematocrit reading. This point will be discussed further later in this report. The explanation of the over-all differences between subjects in Kure and those in Hiroshima does not lie here.

In Table 5 there is indicated a tendency to a lower leukocyte count for those receiving the severest injury, but this tendency, although statistically significant in Table 5, is not borne out in Table 6; therefore, its validity may be questioned.

ならなかった。従って，広島の対象を3群に分類し，傷害のないものまたは火傷，ガラスの切傷等の軽度のものを1群，体表面の約10%に亘って1，2または3度の火傷が中等度にあるもの，あるいはこれにおよそ匹敵する他の外傷性傷害のあるものを2群，体表面の10%以上に亘って種々の程度の火傷またはその他の強度の外傷性傷害のあるものを3群とした。入手した資料の中で容易に分類できないものは比較的少数であったが，それらの記録は解析には含めなかった。これら3群の平均値および組み合せた対象間の平均差を示すと，表5，6の通りである。

ここに示す色々な傾向の有意性は，各群間および各群内の分散の解析を行なって調査した。赤血球数は最も強度の傷害を受けた対象により高い値を示す傾向があった。この傾向は表5および表6のいずれにも認められるが，表6においてのみ統計学的に有意である。なお，表5および表6を調べてみると，血色素濃度ならびにヘマトクリット測定値の変動の傾向は赤血球数の場合と同じであるが，この解析では統計学的に有意ではない。原爆時に最も強度の火傷を受けまたは他の傷害を蒙ったものが，後日赤血球数増加とそれに相応する血色素濃度およびヘマトクリット測定値の上昇の傾向を示したという逆説に直面することになる。この点は後程この報告において更に検討することにする。これによって広島および長崎の対象間の総体的差異は説明できない。

表5には，最も強度の傷害を受けたものほど低い白血球数を示す傾向が認められるが，この傾向は，表5では統計学的に有意であるが，表6には認められないのでその妥当性が疑われる。

Relation Between Amount of Radiation and Hematologic Observations.— Although all the subjects in Hiroshima included in this study allegedly experienced scalp epilation, which is probably the most reliable single criterion of the absorption of large amounts of whole body radiation, there undoubtedly existed, within the group, considerable variation in the actual dose received, which may have varied from the minimal epilating dose with this type of irradiation (about 300 r) up to the maximum tolerated by a few persons (say 700 r). Moreover, it is likely that a few persons included in the study did not experience true radiation epilation. One hundred and ninety-three of 924 persons, or 20.9 per cent of those reporting epilation, were more than 2 kilometers from the hypocenter at the time of the explosion, whereas the Joint Commission found that only 8.3 per cent of the cases of epilation which they studied in the weeks immediately following the bombing were in persons who had been beyond the 2 kilometer zone.[1]

放射線量と血液学的所見との関係——本調査の広島の対象は全員，全身の大量放射線量吸収の最も信頼できる規準と思われる頭髪の脱毛を経験したと言っているが，この群の内では実際に受けた線量は種々で，この種の放射線の最少脱毛線量（約300 r）から少数のもののみがたえることのできる程度の線量（例えば700 r）までの範囲であったに違いない。調査対象のうち真の放射線による脱毛を経験していたものも恐らく少数あるであろう。脱毛を報告した924名のうち193名，即ち20.9%は原爆時に爆心地より2 *km*以上離れていたが，原爆直後の合同調査団の調査では，脱毛例のうち2 *km*の範囲外にあったものはわずか8.3% であった。[1]

TABLE 6. RELATION BETWEEN EXTENT OF ASSOCIATED TRAUMATIC INJURY AND BURNS AND HEMATOLOGIC FINDINGS FOR EPILATED PERSONS: COMPARISON OF MEAN DIFFERENCES BETWEEN ESTABLISHED PAIRS ACCORDING TO EXTENT OF INJURY OF EPILATED SUBJECTS

表 6　脱毛者の外傷性傷害および火傷の程度と血液学的所見との関係：組み合せた対象間の平均差の傷害程度別比較

Observation 観察項目	Subjects in Group 1 1群の対象		Subjects in Group 2 2群の対象		Subjects in Group 3 3群の対象	
	No. 数	Mean Difference and Standard Error 平均差および標準誤差	No. 数	Mean Difference and Standard Error 平均差および標準誤差	No. 数	Mean Difference and Standard Error 平均差および標準誤差
Erythrocyte count ..... 赤血球数	135	+154,000±51,000	214	+26,000±39,000	65	−47,000±65,000
Hemoglobin concentration..... 血色素濃度	139	+0.46±0.138	216	+0.22±0.107	66	+0.23±0.180
Mean cell hemoglobin..... 平均血球血色素	135	+0.12±0.239	212	+0.22±0.192	63	+0.72±.306
Leukocyte count ..... 白血球数	143	+10±333	221	−20±237	66	−54±422
Neutrophils..... 好中球	133	+0.80±1.133	210	−1.52±0.924	66	−1.46±1.663
Lymphocytes ..... リンパ球	133	+1.93±0.862	210	+1.82±0.716	66	+2.00±1.322
Monocytes..... 単球	133	−0.17±0.256	210	+0.12±0.220	66	+0.36±0.341
Eosinophils..... 好酸球	133	−2.20±0.863	210	−0.44±0.659	66	−0.61±1.181
Plasma protein value..... 血漿蛋白値	139	−0.07±0.05	214	+0.22±0.038	66	+0.17±0.088

TABLE 7. RELATION BETWEEN DISTANCE FROM HYPOCENTER AND HEMATOLOGIC FINDINGS: COMPARISON OF MEAN VALUES ACCORDING TO DISTANCE

表 7　爆心地からの距離と血液学的所見との関係：平均値の距離別比較

Observation 観察項目	Distance from Hypocenter 爆心地からの距離					
	0－1 km		1－2 km		＞2 km	
	No. 数	Mean and Standard Error 平均値および標準誤差	No. 数	Mean and Standard Error 平均値および標準誤差	No. 数	Mean and Standard Error 平均値および標準誤差
Erythrocyte count ..... 赤血球数	135	4,429,000±47,000	378	4,530,000±25,000	116	4,610,000±44,000
Hemoglobin concentration..... 血色素濃度	169	12.89±0.113	518	12.85±0.058	186	12.77±0.096
Hematocrit reading..... ヘマトクリット測定値	138	41.38±0.318	440	41.07±0.178	169	40.80±0.298
Mean cell volume..... 平均血球容量	108	89.46±0.745	328	88.46±0.382	108	86.69±0.618
Mean cell hemoglobin..... 平均血球血色素	135	28.96±0.265	377	28.57±0.122	121	27.97±0.225
Mean cell hemoglobin concentration 平均血球血色素濃度	138	32.44±0.132	440	32.19±0.063	168	32.05±0.119
Leukocyte count ..... 白血球数	135	9,966±277	393	9,706±156	116	10,552±299
Neutrophils..... 好中球	133	53.82±0.840	390	55.52±0.490	115	54.03±0.961
Lymphocytes..... リンパ球	133	26.55±0.603	390	28.30±0.389	115	29.01±0.844
Monocytes ..... 単球	133	6.42±0.213	390	6.30±0.119	115	6.41±0.228
Eosinophils..... 好酸球	133	13.07±0.782	390	10.02±0.360	115	9.97±0.689
Plasma protein value..... 血漿蛋白値	169	7.66±0.051	518	7.63±0.023	186	7.71±0.039
Reticulocyte count ..... 網状赤血球数	27	0.857±0.097	64	0.975±0.058	29	0.981±0.109

However, the two studies are not entirely comparable. In order to analyze the possibility that those subjects who received the most radiation contributed disproportionately to the observed differences in the two series, the data have been broken down in three different ways. In Tables 7 and 8, the data are presented in terms of the subject's distance from the hypocenter of the explosion, with individual subjects classified as to whether they were within 1 kilometer, between 1 and 2 kilometers, or beyond 2 kilometers at the time of the explosion. No attempt has been made in this analysis to evaluate further the shielding factor. In Tables 9 and 10, the data are presented in terms of the extent of scalp epilation reported by the subject; three grades of epilation were established, corresponding to loss of under one

しかし，この2つの調査は直接比較できるものではない。放射線を最も多く受けた対象が，この2群間に認める差異に特に寄与した可能性の解析を行なうため資料を原爆時の爆心地からの距離別に3つに分類した。即ち，1 km以内，1～2 kmおよび2 km以遠のものとし，表7および表8に示した。この解析において遮蔽要因の評価は試みなかった。資料を対象の言った頭髪脱毛の程度によって示すと，表9および10の通りである。脱毛に3つの程度を設け，⅓脱毛したもの，⅓ないし⅔脱毛したもの，および⅔以上脱毛したものに分けた。最後に表11，12のごとく資料は悪心，食欲不振，倦怠感，嘔吐，歯齦炎，下痢，咽頭炎，点状出血

TABLE 8. RELATION BETWEEN DISTANCE FROM HYPOCENTER AND HEMATOLOGIC FINDINGS: COMPARISON OF MEAN DIFFERENCE BETWEEN ESTABLISHED PAIRS ACCORDING TO DISTANCE

表 8　爆心地からの距離と血液学的所見との関係：組み合せた対象間の平均差の比較

Observation 観察項目	Distance from Hypocenter 爆心地からの距離					
	0－1 km		1－2 km		＞2 km	
	No. 数	Mean Difference and Standard Error 平均差および標準誤差	No. 数	Mean Difference and Standard Error 平均差および標準誤差	No. 数	Mean Difference and Standard Error 平均差および標準誤差
Erythrocyte count ..... 赤血球数	93	+212,000±65,000	256	+17,000±33,000	88	−3,000±65,000
Hemoglobin concentration..... 血色素濃度	92	+0.64±0.154	264	+0.92±0.100	90	+0.48±0.146
Mean cell hemoglobin..... 平均血球血色素	92	−0.20±0.305	250	+0.44±0.152	88	+0.97±0.299
Leukocyte count ..... 白血球数	91	−489±417	277	+323±214	88	−852±357
Neutrophils..... 好中球	83	−0.02±1.427	266	−0.59±0.834	84	−1.05±1.32
Lymphocytes..... リンパ球	83	+3.05±1.070	266	+1.23±0.640	84	+1.86±0.990
Monocytes..... 単球	83	+0.09±0.314	266	−0.00±0.180	84	+0.20±0.349
Eosinophils..... 好酸球	83	−2.11±1.178	266	−0.48±0.573	84	−1.00±0.988
Plasma protein value..... 血漿蛋白値	92	−0.10±0.063	264	+0.04±0.036	90	−0.12±0.057

third of the hair, loss of between one third and two thirds, and loss of over two thirds. Finally, in Tables 11 and 12, the data have been analyzed according to the reported symptomatologic severity of the radiation sickness, as judged by the occurrence of nausea, anorexia, malaise, vomiting, gingivitis, diarrhea, pharyngitis, petechiae and purpura. Grade 1 includes those persons with nausea and/or anorexia; grade 2, those with vomiting and/or malaise, with or without the symptoms of grade 1; grade 3, those with gingivitis and/or diarrhea, with or without the symptoms of grades 1 or 2, and grade 4, those with pharingitis, petechiae and/or purpura, with or without the signs and symptoms of grades 1, 2 or 3. In all three analyses (Tables 7 through 12) available data for a few individual subjects, not readily classifiable, have been ommitted. This is admittedly a rough classification at the best, but it probably is as satisfactory as possible under the circumstances. A statistical analysis revealed, as might have been expected, a high degree of positive association between these criteria for estimating the relative

および紫斑病の有無により放射線疾患の症候学的重症度を判定して解析を行なった。1度は悪心または食欲不振のいずれかまたは両方をもつもの、3度は1，2度の症状の有無を問わず歯齦炎または下痢のいずれかまたは両方をもつもの，4度は1，2，3度の徴候または症状の有無を問わず咽頭炎，点状出血または紫斑病のいずれかまたは全部をもつものである。3つの解析（表7～12）とも少数の対象について，資料は容易に分類できなかったがこれは省略した。これは粗雑な分類であることは認めるが，事情の許す範囲内では最良のものであると思われる。統計学的解析では，予想通りこれら相対的放射線量の算定規準間に高度の関連性を認めた。

amount of radiation.

From a study of Tables 7 through 12, three observations of some possible significance emerge:

1. The erythrocyte count showed a uniform tendency, as indicated in all these tables, to be lower in the groups presumably receiving the most radiation, whether judged by nearness to the hypocenter, by amount of epilation or by severity of radiation sickness. There were no unequivocal or clearcut parallel variations in the hemoglobin concentration or hematocrit reading, although minor variations were present.

2. By all three of the same standards, the depression of the lymphocyte count noted in Table 2

表7～12を検討すると，若干有意性があると目される次の3つの所見が認められる。

1. これらの表がいずれも示すごとく，爆心地からの距離，脱毛の程度または放射線疾患の重症度から見て，放射線を最も多く受けたと思われる群に赤血球数が低い傾向を示した。血色素濃度またはヘマトクリット測定値にはわずかの変動はあったが，明白なはっきりした平行関係を示す相違はなかった。

2. 上記の3つの基準から見て，表2に示す通り最

TABLE 9. RELATION BETWEEN EXTENT OF EPILATION AND HEMATOLOGIC FINDINGS: COMPARISON OF MEAN VALUES

表 9　脱毛程度と血液学的所見との関係：平均値の比較

Observation 観察項目	Subjects with Grade 1 Epilation* 1度脱毛の対象		Subjects with Grade 2 Epilation 2度脱毛の対象		Subjects with Grade 3 Epilation 3度脱毛の対象	
	No. 数	Mean and Standard Error 平均値および標準誤差	No. 数	Mean and Standard Error 平均値および標準誤差	No. 数	Mean and Standard Error 平均値および標準誤差
Erythrocyte count ..... 赤血球数	296	4,542,000±28,000	116	4,607,000±45,000	200	4,464,000±37,000
Hemoglobin concentration..... 血色素濃度	432	12.77±0.064	159	13.06±0.105	266	12.79±0.092
Hematocrit reading..... ヘマトクリット測定値	383	40.87±0.191	135	41.43±0.310	223	40.94±0.268
Mean cell volume..... 平均血球容量	265	88.14±0.443	102	88.24±0.714	164	88.34±0.605
Mean cell hemoglobin..... 平均血球血色素	295	23.43±0.142	120	28.63±0.224	200	28.56±0.200
Mean cell hemoglobin concentration 平均血球血色素濃度	382	32.07±0.072	135	32.32±0.122	223	32.35±0.106
Leukocyte count ..... 白血球数	300	10,046±202	120	9,836±242	202	9,550±211
Neutrophils..... 好中球	300	54.52±0.60	120	55.98±0.822	200	54.61±0.73
Lymphocytes..... リンパ球	300	28.80±0.46	120	7.31±0.69	200	27.16±0.53
Monocytes..... 単球	300	6.42±0.14	120	5.98±0.20	200	6.53±0.17
Eosinophils..... 好酸球	300	10.24±0.41	120	10.79±0.76	200	11.69±0.64
Plasma protein value..... 血漿蛋白値	432	7.64±0.025	159	7.68±0.042	266	7.66±0.037
Reticulocyte count ..... 網状赤血球数	54	0.968±0.066	29	0.902±0.081	35	0.930±0.068

*In this and the subsequent table, grade 1 epilation indicates loss of under one third of the hair; grade 2, loss of between one third and two thirds, and grade 3, loss of over two thirds.
この表および以後の表において，1度脱毛は毛髪⅓の喪失，2度脱毛は⅓～⅔の喪失，3度脱毛は⅔以上の喪失を示すものとする。

TABLE 10. RELATION BETWEEN EXTENT OF EPILATION AND HEMATOLOGIC FINDINGS: COMPARISON OF MEAN DIFFERENCE BETWEEN ESTABLISHED PAIRS

表 10　脱毛程度と血液学的所見との関係：組み合せた対象間の平均差の比較

Observation 観察項目	Subjects with Grade 1 Epilation 1度脱毛の対象		Subjects with Grade 2 Epilation 2度脱毛の対象		Subjects with Grade 3 Epilation 3度脱毛の対象	
	No. 数	Mean Difference and Standard Error 平均差および標準誤差	No. 数	Mean Difference and Standard Error 平均差および標準誤差	No. 数	Mean Difference and Standard Error 平均差および標準誤差
Erythrocyte count ..... 赤血球数	205	+37,000±42,000	83	+25,000±64,000	142	+107,000±50,000
Hemoglobin concentration..... 血色素濃度	209	+0.22±0.110	86	+0.10±0.166	143	+0.44±0.135
Mean cell hemoglobin..... 平均血球血色素	204	+0.19±0.189	82	+0.26±0.290	141	+0.15±0.242
Leukocyte count ..... 白血球数	221	+120±256	87	−548±375	140	+21±304
Neutrophils..... 好中球	203	−0.29±0.974	87	−2.18±1.373	134	+0.15±1.072
Lymphocytes..... リンパ球	203	+0.95±0.714	87	+2.66±1.175	134	+2.56±0.823
Monocytes..... 単球	203	+0.19±0.214	87	+0.52±0.281	134	−0.55±0.255
Eosinophils..... 好酸球	203	−0.85±0.652	87	−0.79±1.155	134	−1.40±0.876
Plasma protein value..... 血漿蛋白値	209	−0.04±0.038	86	−0.05±0.070	143	+0.02±0.051

appeared to be best defined for those who were most severely irradiated.

3. The elevation of the eosinophil count in irradiated persons, also brought out in Table 2, likewise appeared best defined for the more heavily irradiated subjects (tables 7 Through 10), although the data are not in complete agreement (Tables 11 and 12). Whether this was a true effect of irradiation or merely reflected an increased incidence of parasitic infection in the heavily irradiated persons, due to lowered resistance and/or poorer food conditions, with increased infection at the time of the bombing, will be discussed further later in this report.

In the preceding section, it was noted that those subjects who had received the severest burns and trauma nevertheless appeared to show the highest erythrocyte counts. The results reported in this section would seem to indicate that those who received the greatest amount of radiation had at the time of writing the lowest erythrocyte counts. One plausible hypothesis that would bring these

も強度の放射線を受けたものにリンパ球数の減少が，最も明確のようである。

3. 資料は完全に一致していない（表11，12）が表2に示した通り被爆者の好酸球数の増加は強度の放射線を受けた対象に最も明確のようである（表7～10）。これが真に被爆の影響か，或は強度の放射線を受けた者における原爆時の感染症の増加のほかに，抵抗力の低下および悪い食糧事情による寄生虫症感染の発生率増加を反映したものかは後程この報告で更に検討することにする。

前節において，最も強度の火傷および外傷を受けた対象が最も多い赤血球数を示す傾向を認めたが，この節で報告された結果は，最も多量の放射線を受けたものが，本書作成時において，最も少ない赤血球数を有していることを示しているようである。この2つの傾向を一つの型にはめる仮説は，強度の放射線および強

TABLE 11. RELATION BETWEEN SEVERITY OF RADIATION SICKNESS AND HEMATOLOGIC FINDINGS: COMPARISON OF MEAN VALUES

表 11　放射線病の重症度と血液学的所見との関係：平均値の比較

Observation 観察項目	Subjects with Grade 1 Radiation Sickness* 1度放射線病の対象		Subjects with Grade 2 Radiation Sickness 2度放射線病の対象		Subjects with Grade 3 Radiation Sickness 3度放射線病の対象		Subjects with Grade 4 Radiation Sickness 4度放射線病の対象	
	No. 数	Mean and Standard Error 平均値および標準誤差	No. 数	Mean and Standard Error 平均値および標準誤差	No. 数	Mean and Standard Error 平均値および標準誤差	No. 数	Mean and Standard Error 平均値および標準誤差
Erythrocyte count 赤血球数	43	4,556,000±61,000	87	4,578,000±48,000	201	4,592,000±33,000	290	4,460,000±31,000
Hemoglobin concentration 血色素濃度	97	12.42±0.110	137	12.87±0.098	260	12.90±0.079	358	12.90±0.077
Hematocrit reading ヘマトクリット測定値	90	39.06±0.350	127	40.96±0.307	209	41.20±0.268	313	41.44±0.219
Mean cell volume 平均血球容量	39	86.59±1.06	86	87.91±0.65	175	87.11±0.52	246	89.70±0.49
Mean cell hemoglobin 平均血球血色素	43	27.76±0.338	94	28.32±0.262	200	28.11±0.174	291	29.03±0.157
Mean cell hemoglobin concentration 平均血球血色素濃度	86	31.72±0.152	127	32.08±0.109	209	31.62±0.093	313	32.36±0.101
Leukocyte count 白血球数	45	10,811±516	98	10,102±317	210	9,795±229	288	9,656±170
Neutrophils 好中球	43	53.75±1.69	97	54.11±1.02	208	54.82±0.65	278	55.56±0.62
Lymphocytes リンパ球	43	28.40±1.15	97	28.90±0.74	208	28.56±0.54	278	27.04±0.47
Monocytes 単球	43	6.13±0.28	97	6.44±0.26	208	6.25±0.17	278	6.42±0.14
Eosinophils 好酸球	43	11.99±1.19	97	9.91±0.80	208	9.29±0.44	278	10.17±0.47
Plasma protein value 血漿蛋白値	97	7.54±0.059	146	7.69±0.04	260	7.65±0.034	358	7.67±0.029
Reticulocyte count 網状赤血球数	8	1.175±0.122	21	1.236±0.113	32	0.844±0.088	55	0.879±0.055

*In this and the subsequent table, grade 1 sickness indicates nausea and/or anorexia; grade 2, vomiting and/or malaise, with or without the symptoms of grade 1; grade 3, gingivitis and/or diarrhea, with or without the symptoms of grades 1 or 2, and grade 4, pharyngitis, petechiae and/or purpura, with or without the symptoms of grade 1, 2 or 3.

この表および以後の表において，1度の疾病は悪心または食欲不振，2度は1度の症状の有無を問わず嘔吐または倦怠感，3度は1，2度の症状の有無を問わず歯齦炎または下痢，4度は1，2，3度の症状の有無を問わず咽頭炎，点状出血，または紫斑病を示すものとする。

TABLE 12. RELATION BETWEEN SEVERITY OF RADIATION SICKNESS AND HEMATOLOGIC FINDINGS: COMPARISON OF MEAN DIFFERENCES BETWEEN ESTABLISHED PAIRS

表 12　放射線病の重症度と血液学的所見との関係：組み合せた対象間の平均差の比較

Observation 観察項目	Subjects with Grade 1 Radiation Sickness 1度放射線病の対象		Subjects with Grade 2 Radiation Sickness 2度放射線病の対象		Subjects with Grade 3 Radiation Sickness 3度放射線病の対象		Subjects with Grade 4 Radiation Sickness 4度放射線病の対象	
	No. 数	Mean Difference and Standard Error 平均差および標準誤差	No. 数	Mean Difference and Standard Error 平均差および標準誤差	No. 数	Mean Difference and Standard Error 平均差および標準誤差	No. 数	Mean Difference and Standard Error 平均差および標準誤差
Erythrocyte count 赤血球数	25	+25,000±110,000	68	+25,000±62,000	128	−11,000±46,000	218	+110,000±43,000
Hemoglobin concentration 血色素濃度	26	+0.36±0.242	68	+0.01±0.154	132	+0.22±0.135	221	+0.38±0.113
Mean cell hemoglobin 平均血球血色素	25	+0.46±0.601	65	−0.22±0.340	127	+0.65±0.235	217	−0.04±0.183
Leukocyte count 白血球数	34	+30±718	72	−218±461	129	+120±324	221	−106±230
Neutrophils 好中球	31	−1.74±2.439	72	+1.28±1.608	120	−0.35±1.128	210	−1.14±0.920
Lymphocytes リンパ球	31	+3.26±1.909	72	−0.79±1.182	120	+1.47±0.879	210	+2.81±0.703
Monocytes 単球	31	+0.60±0.476	72	−0.21±0.299	120	−0.06±0.283	210	+0.07±0.216
Eosinophils 好酸球	31	−1.97±1.606	72	+0.03±1.331	120	−0.95±0.829	210	−1.31±0.669
Plasma protein value 血漿蛋白値	26	−0.02±0.112	68	−0.10±0.076	132	+0.08±0.050	221	−0.05±0.039

two tendencies into a single pattern is that of those persons who were heavily irradiated and also received severe burns or other injuries many died. This would explain, among the epilated survivors who composed this series, a relative deficiency of those persons with both severe injuries and severe irradiation and a relative excess of those severely burned but not heavily irradiated, and/or those severely irradiated but without extensive burns or other injuries. It is felt that the present data are inadequate to serve as a basis for a rigorous test of this hypothesis.

COMMENT

It may safely be assumed that the majority of persons in this series reporting epilation in consequence of the atomic bombing exhibited within two months after the event a major depression in the number of formed elements of the peripheral blood.[1] The studies herein reported reveal that two years after the bombing the peripheral blood manifested almost complete recovery from this insult to the hemopoietic system. However, there did appear to be a number of slight residua at the time of the study, of no apparent clinical significance but of definite statistical validity. In this section we shall attempt an evaluation of the meaning of these findings. First, however, as basic to any adequate discussion, the question of comparability of the control and the epilated populations on all scores except the irradiation factor must be considered.

The atomic bombing at Hiroshima produced sudden, widespread chaos. Casualties mounted to the tens of thousands, and in spite of valiant attempts, adequate care of the survivors was almost completely lacking. There was complete interruption of all normal economy for a period of many weeks, and relief supplies failed to meet the demand in many instances. On the other hand, although Kure, the site of control observations, was subjected to bombings over a period of several months, the casualties were relatively few in number. Although there undoubtedly occurred disorganization of the normal economy, the degree and duration were minor in comparison with Hiroshima. Thus, the people were not subjected to the extreme privations encountered in Hiroshima.

度の火傷，その他の傷害をあわせ受けた者の多くは死亡したということである。これによって，この群を構成する脱毛生存者のうちに強度の傷害と強度の放射線をあわせ受けた者が，比較的少ないこと，および強度の火傷は受けたが強度の放射線を受けなかった者，または強度の放射線は受けたが強度の火傷やその他の傷害を受けなかった者が比較的多いことの説明がつくと思われる。現在の資料は，この仮説を厳密に調べる基礎としては不十分であると思われる。

考　察

被爆した結果脱毛した調査群の大部分の者は，被爆後2か月以内に末梢血液の有形成分に大きな減少があったと推定しても差支えないであろう。[1] ここに報告する調査では，原爆2年後には造血系障害が殆んど完全に回復したことを末梢血液検査によって認めた。しかし調査時に臨床的意義はあるが，統計学的には有意な軽度の障害が若干残っているようであった。本節において我々はこれらの所見の意味の評価を試みようと思う。しかし，十分な検討を行なうための基礎として，先ず被爆の要因を除いたあらゆる点で脱毛人口と対照人口が一致しているかどうかの問題を考慮せねばならない。

広島における原爆投下によって突然，広範囲にわたる混乱を生じた。死傷者は何万人にも及び献身的な努力にも拘らず，生存者に十分な医療は殆んどゆきわたらなかった。すべての経済機能は長い間全く中断され救援物資は不十分であった。一方対照観察を行なった呉では，数か月間爆撃を受けたが，死傷者は比較的少数であった。経済的混乱は確かに起ったが，広島に比べてその度合期間は軽微で，従って，呉市民は広島におけるような極度の窮乏は強いられなかった。以後の検討において常に念頭に置かなければならない問題はこの2群に認めた血液学的数値の差は実際に電離放射

In the ensuing discussion, one question must constantly be kept in mind: Are the differences in the hematologic values observed in the two groups actually a residual effect of ionizing irradiation, or are they related to the associated unhygienic and innutritious aftermath? Also, it must be recognized that the surviving irradiated group were, within themselves, a selected group of the total population irradiated.

Erythrocyte Count.— It was indicated in Table 2 that the irradiated population of Hiroshima had a mean erythrocyte count slightly below that of the nonirradiated population of Kure, the difference amounting to 65,000 to 83,000 cells per cubic centimeter, or approximately 1.6 per cent of the Kure mean. There was a correspondingly slight reduction in hemoglobin concentration (the difference was 0.26 to 0.30 gm. per hundred cubic centimeters, or about 2.1 per cent of the Kure mean) and in hematocrit reading (0.48 per cent; about 1.2 per cent of the Kure mean). Since there were no significant differences relating to the cell constants, these differences were attributed to variations in the numbers of comparable cells rather than to qualitative effects on the erythrocytes. The important reservation relating to the spread of the distribution in Hiroshima will be discussed later in the paper.

The effect of ionizing irradiation on erythropoiesis has received considerable attention. The information in the literature on the results of long-continued irradiation and that on effects of repeated small doses of radiation is not strictly applicable in the interpretation of the data of this study. The literature on the erythrocytic response to acute exposures deals almost exclusively with the early picture[26] and indicates that there generally occurs a depression of erythropoiesis, with a resultant anemia within a few weeks, the severity of which is roughly related to the dose. The recovery from the anemia is relatively slow in comparison to the leukocytic recovery.[27] Stearner and others[26k] administered 600 r of whole body radiation to rats and then followed the peripheral hematologic picture for a total of one hundred and sixty days. The lowest values for hemoglobin concentration and

線の残存影響であるか，または原爆の結果生じた非衛生的な状態および栄養不良の状態と関係があるか，である。また，この被爆生存者の調査群自体が総被爆者人口のうちのごく限られた群であることを認識しておかねばならない。

赤血球数——広島の被爆者の平均赤血球数は呉の非被爆者のそれと比べてわずかに低く，表2で示す通りその差は1 cc あたり 65,000～83,000 血球，即ち呉の平均値の約1.6% 少ない。これに相応した軽微な減少が血色素濃度（差は100cc あたり 0.26 g～0.30 g，即ち呉の平均値の約2.1%）およびヘマトリット測定値（0.48%，呉の平均値の約1.2%）に認められた。血球定数について有意差はなかったので，これらの差異は赤血球に対する質的影響よりは，その数の変動に起因すると思われた。広島における数値の分布範囲に関する重要な条件については後程本論文において検討することにする。

赤血球生成に対する電離放射線の影響は相当の注目を引いている。長期間の継続的照射の結果および反復的な微量照射による影響に関する文献の資料は厳密には本調査の資料の解釈には適用できない。急性照射に対する赤血球反応について文献の殆んどは初期の血液像をとりあげ，[26] 一般に2，3時間以内に赤血球生成能力の低下が起り，その結果貧血が現われるが，その程度は放射線量と関係がある。貧血の回復は白血球の回復に比べると比較的遅い。[27] Stearnerら[26k] はラッテに600 r の線量を全身照射し，その後160日間末梢血液像の観察を続けた。血色素濃度および赤血球数が最低になったのは18日目で，その後は急激な回復があった。しかし，平均して160 日までに完全な回復があったと

erythrocyte count were observed on the eighteenth day and were followed with a sharp recovery period. However, on the average, recovery did not appear to be complete at any time within the one hundred and sixty day period, although with the statistical measures employed, the differences between irradiated and control animals were not significant beyond the ninety-fourth day. The work of Jacobson and others[26n-o] on the rabbit, although less conclusive statistically, tends to confirm the results of the work on the rat. Henshaw and others[28] observed relatively rapid recovery of the hematologic constituents in mice following single whole body exposures either to neutrons in doses up to 90 n or to gamma rays in doses up to 700 r; the only significant late hematologic finding noted was the development of lymphomas.

は思われなかった。しかし，統計学的処置では照射動物とその対照の差は94日以後は有意でなかった。兎を使用したJacobsonらの実験[26n-o]は，統計的には前述の調査ほど決定的ではないが，ラッテについて行なった実験の結果を裏付ける傾向がある。Henshawら[28]はねずみに90 nまでの中性子量または700 rまでのガンマ線量を1回全身照射し，その後血液成分の比較的早い回復があることを観察した。唯一の有意な後発所見はリンパ腫の発生である。

On the other hand, the Japanese diet had for at least the five years previous to the study been deficient in many respects, a factor which did not favor adequate blood formation.[25] From recent surveys, the composition of the average Japanese diet during that period can be estimated to have consisted of 60 gm. of protein 12 gm. of fat and 400 gm. of carbohydrate; however, only about one tenth of the protein intake was of animal origin.[7] It has been stated that meat eaters average a higher number of red cells than vegetarians.[29] Whipple and Robscheit-Robbins[30] have extensively investigated the effects of various nutrients on blood regeneration. Evidence indicates then that diet is an extremely important consideration, and that in a population which originally had an inadequate base line standard, the further innutritious circumstances created by the atomic bombing could conceivably have resulted in such hematologic differences as are indicated here. Even the fact that erythrocyte values appeared to be most depressed in those persons who received the greatest amount of radiation may only indicate that these persons suffered the greatest material loss and so, economically, fared particularly badly, with consequent poor nutrition. The factors of irradiation and innutritious conditions perhaps were, in effect, additive.

一方日本人の食餌は本調査前の少なくとも5年間は多くの点で不十分で，このため造血は十分ではなかった。[25] 最近の調査によると当時の日本人の通常の食餌内容は，蛋白60 g，脂肪12 gおよび炭水化物400 gであったと推定されるが，蛋白摂取量の約10分の1のみが動物性であったのみに過ぎない。[7] 平均して肉食者は菜食者より赤血球数が多いといわれている。[29] WhippleおよびRobscheit-Robbins[30]は各栄養素の血液再生に及ぼす影響について大規模な調査を行なっている。過去の成績の示すところでは，食餌は考慮すべき極めて重要な事柄であり，元々栄養が不十分であった人口において，原爆のために生じた栄養事情の悪化がここに記載したような血液学的差異をもたらしたとも考えられる。最も多量の放射線を受けた人々の赤血球数に最大の減少が認められた事実は，これらの人々が最大の物質的損害を蒙ったので，経済的にも特に悪く，その結果栄養が乏しかったことを示しているにすぎないかも知れない。要するに，被爆と栄養欠乏状態の要因はおそらく相加わったのであろう。

Leukocyte Count.— There was found to be no significant difference between mean leukocyte counts for the irradiated and nonirradiated groups, but there was a slight depression of relative lymphocyte count, amounting to 1.39 to 2.02 per cent, and a slight elevation of relative eosinophil count, amounting to 0.99 to 1.83 per cent. The general increase in mean leukocyte count, in both epilated and control series, was probable an expression of the frequent infections observed, which were minor but which did not eliminate persons, from the series.

The extreme sensitivity of the lymphocyte to acute ionizing irradiation has been appreciated for many decades,[21] but recovery has been said to be adequate within a relatively short time.[26f] It has been recently reported however, that in the rabbit, the lymphocyte count was depressed for a period of ninety days after acute exposure to 800 r.[26j] Other investigators have reported that in the case of rats exposed to large single doses of whole body radiation, a possible discernible effect was observable in the lymphopoietic tissue as long as thirty-five days later, even though recovery, as indicated by the state of the peripheral blood, was essentially complete at thirty days.[26k]

Our data do suggest that there possibly existed greater residual depression of the lymphocyte count in those persons who received the heavier doses of radiation, but likewise they may indicate that it was these groups which showed the greatest increase in percentage of eosinophils. Eosinophilia is of recognized occurrence during the recovery phase in acute exposure to ionizing irradiation in as much as 10 to 20 per cent of cases.[26a,f] However, for the most part, eosinophilia is related to chronic or repeated exposure.[32] The duration of eosinophilia following acute exposure has received little attention. The high incidence of parasitic infection undoubtedly accounts for the rather high values observed in the controls,[33] but whether the relatively higher values in the Hiroshima subjects were an expression of increased parasitic disease cannot be stated without further study. The unhygienic conditions so prevalent in Hiroshima for several months after the bombing certainly would have

白血球数——被爆者群と非被爆者群の平均白血球数に有意差は認められなかったが，相対的リンパ球数に1.39%乃至2.02%の軽度の減少があり，相対的好酸球数に0.99乃至1.83%の軽度の増加があった。脱毛群および対照群において平均白血球数が全般的に増加していることは，調査群から除外の理由とならない程度の軽症の感染症を有する者が多数あったかも知れない。

リンパ球が急性電離放射線照射に対して極めて敏感であることは数10年前から認められている[21]が，比較的短期間内に十分回復するといわれている。[26f] しかし最近の報告では，兎に800 r の急性照射を行なったところ，リンパ球減少は90日間持続したと発表されている。[26j] 他の調査ではラッテに大量の放射線を1回全身照射した場合，末梢血液は30日後に実質的に全快したが，リンパ生成組織には35日後まで影響が認められたと報告している。[26k]

我々の資料は，線量が多いもの程残存リンパ球減少も大きい可能性を暗示するが，同様にまた好酸球百分率に最も大きな増加を示したのもこの人々であったことを示すかも知れない。電離放射線の急性照射例のうち10乃至20%までが回復期に好酸球増多を起すと認められている。[26a,f] しかし好酸球増多は殆んどの場合放射線の慢性または反復照射と関係がある。[32] 急性照射後の好酸球増加の持続期間は殆んど注目を受けていない。対照に好酸球がやや多いことは寄生虫症の発生率が高いためであることは確かであるが，[33] 広島の対象の比較的高い値が寄生虫症の増加のためであるかどうかは更に調査をしないと言えない。原爆後数か月間の広島における非衛生的な状態は確かに寄生虫感染と罹病率の上昇に好都合であったにちがいない。これが因果関係であったとすれば，平均白血球数が同じなのを

favored transmission and increased morbidity. If this was the causal relation, the depression of the lymphocyte count was perhaps only a compensatory depression, in view of the similar mean leukocyte counts. An increased incidence of parasitic infection in Hiroshima may, of course, be a partial explanation of the difference in erythrocyte counts.

Plasma Protein Values.— The plasma protein values in Hiroshima were slightly elevated over those in Kure. Whether this was on a basis of nutrition or of irradiation cannot be decided at the present time. To the extent that plasma protein levels could be taken as a criterion for gross malnutrition,[23b] there was no evidence of the possible greater impairment of nutrition in Hiroshima discussed previously. The high levels of plasma protein observed in both cities are noteworthy. Similar high levels were observed by the Joint Commission, using the copper sulfate method, in 1945.[1] The determination of plasma protein values by the copper sulfate gravity method depended on certain constants, derived from a study of American subjects. The necessary studies to determine whether the extrapolation to Japanese subjects was a valid procedure have not been carried out at the time of writing. It is possible that the character of the Japanese diet was reflected in the constituents of the blood to the point where a given value for specific gravity did not have the same significance for the two groups.[25]

Variation.— Perhaps one of the more significant statistical findings to emerge from this study is the greater variability of individual hematologic values in the irradiated group in comparison with those of the control group. In the case of determinations concerned with the erythroid elements, this greater variability seems to be due chiefly to the fact that counts for a certain fraction of the population, for reasons not entirely evident, had failed to return to normal levels, with a resultant increased spread in the distribution of individual determinations. That considerable qualitative and quantitative variability of hematologic recovery after irradiation exists within various animal species is a well recognized fact.[22] For leukocyte determinations in which the mean total counts are similar, the explanation is more obscure.

みれば，リンパ球数の減少はおそらく代償的減少であったに過ぎないであろう。広島における寄生虫症発生率の増加は，いうまでもなく赤血球数の差の一原因であるかも知れない。

血漿蛋白値——広島の血漿蛋白値は呉のそれよりやや高値であった。この原因が栄養にあったかまたは被爆にあったかは現在決定できない。血漿蛋白量を栄養不良の大まかな規準として用いるならば[23b] 広島に前述の栄養障害が比較的大である証拠はなかった。両市に認められた血漿蛋白の高い値は注目に値する。合同調査団も1945年に硫酸銅法を用いて検査した結果，同様に高い値を認めている。硫酸銅比重法による血漿蛋白値測定は，米国人を対象とした調査から得た定数を使用して行なわれた。日本人対象にこれを当てはめることが妥当な処理であるかどうかを確定するに必要な調査は，本書作成時にはまだ行なわれていない。日本人の食餌上の特色が血液の構成に反映して同一比重値でも両者において同意義をもたない可能性がある。[25]

変動性——この調査の統計学的にかなり有意な所見の1つは，対象群に比較して，被爆群における個々の血液学的数値の変動性が高かったことである。赤血球系細胞に関する測定の場合，変動性が比較的多いのは主として人口の一部の算定数が，理由は明確ではないが正常値に戻らず，その結果個々の測定値の分布範囲が増したためと思われる。放射線照射後血液の回復に相当の質的および量的変動性があることはよく認められている事実である。[22] 平均白血球総数は両者ではほぼ同じであるが白血球測定の変動に対する説明は更に不明確である。

The fact that the standard deviations recorded for the control population are considerably greater than those commonly accepted may lead some to question the validity of conclusions concerning relative variability. Throughout this investigation, we have been particularly conscious of procedural errors. We have attempted to evaluate the limitations of the various hematogogic methods by as precise an estimation as possible of the errors involved in the determination of each value. These attempts have indicated that there was a substantial error due to inherent deficiencies of the methods, and also to personal interpretations of the "end point." The reflection of these errors in the values for cell constants has been pointed out in some detail. On the basis of certain statistical considerations, the expected ranges of the constants for 95 per cent of values have been found to be considerably larger than those generally accepted as describing the range of normal values. For instance, Wintrobe[14] stated that 98 per cent of normal determinations of mean cell volume would fall within ±8.0 cubic microns of the mean, 87.0 cubic microns. Ninety-eight per cent of the frequencies represent ±2.7 standard deviations; therefore, 1 standard deviation is $\frac{\pm 8.0}{2.7}$, or approximately ±3.0 cubic microns. We have indicated, on the basis of calculations utilizing certain estimates of the variability of the hematocrit reading and the erythrocyte count and their correlation coefficient, that the standard deviation of the mean cell volume should approximate at least ±5.2 cubic microns. The range for 98 per cent of values would then be 2.7× (±5.2), or ±14.0 cubic microns. But even if one accepts the fact that the values customarily accepted as representing the range of the constants are too narrow, it must be admitted that in the control samples of both Japanese and American subjects, the observed variation in the mean cell volume was significantly greater than the calculated expectation. At least three factors which may have contributed to the greater variability of this and other determinations can be recognized: (1) In calculating the statistical expectation, extremely conservative estimates of population variability were utilized; (2) this study

対照人口に見られた標準偏差が普通認められる標準偏差より相当大であるので，相対的変動性に関する結論の妥当性を疑う者もあるかも知れない。本調査中，我々は特に検査上の誤差に注意してきた。我々は各値の測定に伴う誤差をできる限り正確に見積って色々な血液学的検査方法の限界を判定しようとした。これにより，本法に固有な種々の欠陥ならびに「終結点」に関する個人の解釈に起因する相当の誤差があることを認めた。これらの誤差が血球定数の値に及ぼす影響については，ある程度詳細に指摘した。統計学的考慮に基づいて，測定値のうち95%に対する定数の予想範囲は，一般に正常値の範囲とされている範囲より相当大であることが認められた。例えば，Wintrobe[14]は，平均血球容量の正常値の98%は平均値である87.0μ^3の±8.0μ^3以内であると述べている。98%とは標準偏差の±3.0μ^3である。我々はヘマトクリット測定値および赤血球数の推定変異性と相関係数を利用した計算に基いて平均血球容量の標準偏差は少なくとも±5.2μ^3に近い筈であることを示した。すると，測定値のうち98%が占める範囲は2.7×（±5.2）即ち±14.0μ^3となる。しかし，たとえ一般に定数の範囲を示すとされる値が過小であるとしても，日本人および米国人の対照標本において認められた平均血球容量の変動は計算による期待値より有意に大きかったことは認めねばならない。この測定値およびその他の測定値の比較的高い変異性に寄与したと思われる要因は少なくとも次の3つが認められる。

(1) 統計学的期待値の計算に当って，人口変異性は極めて控え目に見積られた。

(2) 血球定数の正常範囲を行なうために企画された米国人に対する調査と比べて本調査の対照人口はもっと異質のものであった。

(3) 検査を受けていない器具が用いられた。このほかに検査員による誤差も考えねばならない。これらの

involved a decidedly more heterogeneous control population than was the case in the studies of Americans, designed to determine the normal range of the blood constants, and (3) noncertified equipment was used. The further possibility of technicians' errors must be recognized. But whereas all these factors may have contributed to a greater real and apparent variability in the "normal" population used in this study than in other normal populations, they cannot be utilized to explain the differences between Kure and Hiroshima, since the two laboratories were operated under comparable conditions, with the same staff.

SUMMARY

An attempt has been made to answer the following question: What was the peripheral hematologic picture twenty to thirty-three months after the atomic bombing of Hiroshima, in persons who received relatively large amounts of whole body radiation?

The criterion adopted for the selection of relatively heavily irradiated subjects was the occurrence of scalp epilation. Epilated subjects were selected at random, through the use of a questionnaire. The majority were school children.

A control population comparable in age, sex, nutritional status and occupation was studied in the city of Kure, which is located some 18 miles (28.97 kilometers) from Hiroshima.

In Hiroshima, 924 subjects were examined; in Kure, 935.

Each person selected for study completed a brief history and was given a brief physical examination; as many of the following blood values as circumstances permitted were then determined: erythrocyte and leukocyte counts, differential blood count, hemoglobin concentration, hematocrit reading, plasma protein level and, for a smaller number of persons, reticulocyte count.

A detailed evaluation of the errors involved in the standard blood studies is presented, as a basis for an appreciation of the significance of these findings.

要因のために本調査における正常人口の変動性がその他の正常人口に比べてより大であり，はっきりしているのであるかも知れないが，呉および広島では同一の状況のもとに同じ職員によって検査が行なわれたので，それらの要因によって両市間の差異の説明は出来ない。

総　括

広島の原爆で全身に比較的多量の放射線を受けた者において，被爆20乃至33か月後の末梢血液像の調査を試みた。

比較的強度の放射線を受けた対象者を選ぶための規準として，頭髪脱毛の有無を用いた。脱毛を経験した対象は質問表を用いて任意に選定されたが，その大部分は学校の生徒であった。

広島から18マイル（28.97km）離れている呉市において，年齢，性，栄養状態および職業の類似した対象人口を調査した。

広島の調査対象は924名，呉は935名であった。

調査のため選定されたものについて簡単な問診を行ない，簡単な全身検査を行なった。その後，次の血液数値の測定のうち事情の許す限り多くの測定を行なった。すなわち，赤血球および白血球数，白血球百分比計算，血色素濃度，ヘマトクリット測定値，および血漿蛋白量の定量を行なった。なお，少数については網状赤血球数の測定を行なった。

これらの所見の有意性を認識するための根拠として，標準血液検査に伴う誤差について詳細な評価を行なった。

Results are compared not only in terms of the mean values for the two populations but also in terms of the mean differences between randomly established pairs of similar control and epilated individual subjects.

The irradiated subjects of this study appeared for the most part to have made a complete recovery from the depression of the peripheral blood values which may be assumed to have followed the bombing. However, various significant differences between the two populations were observed:

1. Erythrocyte count, hemoglobin concentration and hematocrit reading were slightly, but significantly, depressed for the subjects in Hiroshima.

2. Although the total leukocyte count was the same in the two cities, in Hiroshima there were a slight relative depression of lymphocytes and a slight elevation of eosinophils.

3. Plasma protein values were possibly slightly higher in Hiroshima.

4. There was significantly greater variability in the observations made in Hiroshima than in those made in Kure.

These differences cannot be attributed to a differential response on the part of any particular age or sex group.

Epilated persons who experienced associated flash burns or trauma showed mean erythrocyte values which were higher, if anything, than the values for those who did not suffer such associated injury, from which it is inferred that the greater frequency of these injuries in Hiroshima than in Kure does not account for the hematologic differences between the groups.

Those individual subjects who, by any of a number of criteria, absorbed greater amounts of radiation tended to show the most pronounced depression in erythrocyte and lymphocyte counts and the greatest elevation in eosinophil counts.

It is felt that in view of the great medical and civil disruption in Hiroshima after the bombing, caution must be exercised in attributing the slight recorded differences to the atomic bombing, although it seems possible that irradiation was, to some extent, responsible.

両人口の平均値を比較しただけでなく，脱毛対象者と対照とを任意に組み合せて，その間の平均差の比較をした。

被爆対象者の大部分では，原爆後に起ったと推定される末梢血液値の低下が完全に回復したようであったが，両人口間には各種の有意差を認めた。

1. 広島の対象者については，赤血球数，血色素濃度およびヘマトクリット測定値について軽度ではあるが有意な減少が認められた。

2. 両市の白血球総数は同じであったが，広島の場合，相対的にリンパ球の軽度の減少と好酸球の軽度の増加を認めた。

3. 血漿蛋白値は広島の方がやや高いようであった。

4. 異に比べて広島では所見の変動性に有意な増加があった。

これらの差異は特定の年齢または性によって選択的に反応があったためではない。

原爆火傷または外傷を経験した脱毛者の平均赤血球数値は，傷害を受けなかった者の値に比べて高かった。これから推して考えると，広島でこのような傷害の頻度が高かったことが両市間の血液学的差異の理由とはならない。

採用した規準によって比較的多量の放射線を吸収したと認められる対象者が，赤血球およびリンパ球数に最も著しい減少と好酸球に最大の増加を示す傾向があった。

原爆後広島に医療面および市民の生活面に大きな破綻が生じたので，記録された軽度の差異の原因はある程度被爆のためであり得ると思われるが，原爆のためであると結論するには注意を払わねばならない。

REFERENCES
參 考 文 献

1. Report of the Joint Commission, to be published
2. National Research Council, Committee on Atomic Casualties, Genetic Conference: Genetic effects of the atomic bombs in Hiroshima and Nagasaki, Science 106: 331, 1947
3. PHELPS LV, Chief, Division of Vital Statistics, Public Health and Welfare Section, General Headquarters, Supreme Commander for the Allied Powers: Personal communication to the authors
4. Natality and Mortality Data for the United States tabulated by Place of Residence, in Vital Statistics of the United States, 1943, United States Department of Commerce and Labor, Bureau of the Census, 1945, pt 2
5. IMAMURA A: The epidemiology and prevention of tuberculosis in Japan. Eleventh Meeting of the Japanese Medical Association, 1947
6. DUFF FL: Personal communication to the authors
7. A review covering a résume of the problems, accomplishments, and future programs of the Public Health and Welfare Section among the Japanese population in furthering the objectives of the Supreme Commander, for the period August 1945–August 1947, General Headquarters, Supreme Commander for the Allied Powers, Public Health and Welfare Section, 1947
8. HOWE FA, Public Health and Welfare Section, General Headquarters, Supreme Commander for the Allied Powers: Personal communication to the authors
9. HELLER VG, PAUL H: Changes in cell volume produced by varying concentrations of different anticoagulants. J Lab Clin Med 19: 777, 1934
10. STITT ER, CLOUGH PW, CLOUGH MC: Practical Bacteriology, Haematology and Animal Parasitology. 9th Ed Philadelphia, P. Blakiston's Son, 1938, p 299
11. a. "STUDENT": On the error of counting with a haemacytometer. Biometrika 5: 351, 1907
    b. WINTROBE MM: The size and hemoglobin content of the erythrocyte: Methods of determination and clinical application. J Lab Clin Med 17: 899, 1932
    c. PONDER E, SASLOW G, SCHWEIZER M: On variations in the white-cell count of man. Quart J Exper Physiol 21: 21, 1931
    d. BRYAN WR, CHASTAIN LL, GARREY WE: Errors of routine analysis in the counting of leukocytes. Amer J Physiol 113: 416, 1935
    e. MAGATH TB, BERKSON J, HURN M: The error of determination of the erythrocyte count. Amer J Clin Path 6: 568, 1936
    f. BERKSON J, MAGATH TB, HURN M: Error of estimate of blood cell count as made with hemocytometer. Amer J Physiol 128: 309, 1940
    g. BERKSON J: Blood cell count. In Medical Physics, by GLASSER O. Chicago, The Year Book Publishers, 1944, p 110
12. PHILLIPS RA, VAN SLYKE DD, et al: Copper Sulfate Method for Measuring Specific Gravity of whole Blood and Plasma. New York, Josiah Macy, Jr Foundation, 1945
13. a. PHILLIPS and others.[12] BARBOUR HG, HAMILTON WF: The falling drop method for determining specific gravity. J Biol Chem 69: 625, 1926
    b. MOORE NS, VAN SLYKE DD: The relationships between plasma specific gravity, plasma protein content, and edema in nephritis. J Clin Invest 8: 337, 1930
    c. WEECH AA, SNELLING CE, GOETTSCH E: The relationship between plasma protein content, plasma specific gravity, and edema in dogs maintained on a protein inadequate diet and in dogs rendered edematous by plasmapheresis. J Clin Invest 12: 193, 1933

d. NUGENT RL, TOWLE LW: The Specific gravity of synthetic solutions of serum albumin and serum globulin. J Biol Chem 104: 395, 1934

e. WEECH AA, REEVES EB, GOETTSCH E: The relationship between specific gravity and protein content in plasma, serum, and transudate from dogs. J Biol Chem 113: 167, 1936

f. KAGAN BM: A simple method for the estimation of total protein content of plasma and serum: 2. The estimation of total protein content of human plasma and serum by the use of the falling drop method. J Clin Invest 17: 373, 1938

g. ASHWORTH CT, ADAMS G: Blood Specific gravity studies. J Lab Clin Med 26: 1934, 1941

h. KOGAN BM: Studies on the clinical significance of the serum proteins: 1. The protein content of normal human venous and capillary serum and factors affecting the accuracy of its determination. J Lab Clin Med 27: 1457, 1942

i. ATCHLEY J, BACON R, et al: A clinical evaluation of the copper sulfate method for measuring specific gravities of whole blood and plasma. J Lab Clin Med 30: 830, 1945

j. HYNES M, LEHMANN H: The accuracy of haemoglobin determination by the copper sulfate-blood gravity method in Indian soldiers. J Physiol 104: 305, 1946

k. MEYER FL, ABBOTT WF, et al: Comparison of plasma protein concentration, hemoglobin and hematocrit values determined by chemical methods and calculated from specific gravity. Arch Biochem 12: 359, 1947

14. a. ZOZAYA J: A physiochemical study of blood sera. J Biol Chem 110: 599, 1935

b. LOONEY JM: The relation between specific gravity of blood serum and its protein concentration. J Lab Clin Med 27: 1463, 1942

15. WINTROBE MM: Clinical Hematology. 25th Ed Philadelphia, Lea & Febiger, 1946

16. International Centrifuge Catalogue, 1944

17. WINTROBE MM: (a)[19b], (b)[16], (c) Direct calculation of the volume and hemoglobin content of the erythrocyte. Amer J Clin Path 1: 147, 1931

18. WINTROBE MM: (a)[14], (b)[17c], (c) Blood of normal men and women. Bull Johns Hopkins Hosp 53: 118, 1933. Anemia. Arch Intern Med 54: 256, 1934

19. PEARSON: On a form of spurious correlation which may arise when indices are used in the measurement of organs. Proc Roy Soc London 60: 489, 1897

20. a. ASHWORTH and ADAMS[13g]

b. WINTROBE[18c]

c. WINTROBE MM, MILLER MW: Normal blood determinations in the South. Arch Intern Med 43: 96, 1929

d. WINTROBE MM: Blood of normal young women residing in a subtropical climate. Arch Intern Med 45: 287, 1930

e. FOSTER PC, JOHNSON JR: Oxygen capacity and hemoglobin content of normal blood of men. Proc Soc Exper Biol Med 28: 929, 1931

f. WALTERS OS: Normal erythrocyte, hemoglobin and packed cell volume standards in young men. J Lab Clin Med 19: 851, 1934

g. LINNEBERG LL, SCHARTUM-HANSEN H: Hemoglobin content of blood and number and volume of red blood corpuscles in healthy men and women. Norsk mag f laegevidensk 96: 832, 1935

h. PRICE-JONES C, VAUGHN JM, GODDARD HM: Hematological standards of healthy persons. J Path Bact 40: 503, 1935

i. OSGOOD EE: Normal hematological standards. Arch Intern Med 56: 849, 1935

j. BELK P, CURTIS E, WILSON M: Erythrocyte counts, hemoglobin and erythrocyte volume in

normal young men and women residing in the Eastern United States. Amer J Clin Path 6: 487, 1936

k. HAMRE CJ, WONG KKL: Hematologic values for normal children three, four and five years of age living in Hawaii. Amer J Dis Child 60: 22, 1940

l. HAMRE CJ, WONG K: A survey of hemoglobin and blood cell levels of pre-school children. Special Publication 34, Hawaii Academy of Science, 1940

m. HAMRE CJ, AU MH: Hematologic values for normal healthy men sixteen to twenty-five years of age. J Lab Clin Med 27:1231, 1942

n. HEATH CW: The hemoglobin of healthy college under-graduates and comparisons with various medical, social, physiologic and other factors. Blood 3: 566, 1948

o. VALENTINE WN, NEEL JV: A statistical study of the variables in subjects with thalassemia minor. Amer J Med Sci, to be published

p. PRICE-JONES C: The concentration of hemoglobin in normal human blood. J Path Bact 34: 779, 1931

q. MYERS VC, EDDY HM: The hemoglobin content of human blood. J Lab Clin Med 24: 502, 1939

21. WINTROBE and MILLER.[20c] FOSTER and JOHNSON.[20e] WALTERS.[20f] LINNEBERG and SCHARTUMHANSEN.[20g] BELK, CURTIS and WILSON.[20j]

22. GOLDNER FM, MANN WM: The statistical error of the differential white count. Guy's Hosp Rep 88: 54, 1938

23. OSGOOD EE, WILHELM MM: Reticulocytes. J Lab Clin Med 19: 1129, 1934

24. SNEDECOR GW: Statistical Methods applied to Experiments in Agriculture and Biology. 4th Ed Ames, Iowa, Iowa State College Press, 1946

25. SNELL FM: Observations on the hematological values of the Japanese, to be published

26. a. MINOR GR, SPURLING RG: The effect on the blood of irradiation, especially short wave length roentgen-ray therapy. Amer J Med Sci 168: 215, 1924

b. SHOUSE SS, WARREN SL, WHIPPLE GH: Aplasia of marrow and fatal intoxication in dogs produced by roentgen radiation of all bones. J Exper Med 53: 421, 1931

c. LAWRENCE JH, LAWRENCE EO: Biological action of neutron rays. Proc Nat Acad Sci 22: 124, 1936

d. LAWRENCE JH, TENNANT R: Comparative effects of neutrons and x-rays on the whole body. J Exper Med 66: 667, 1937

e. AEBERSOLD PC, LAWRENCE JH: The physiological effects of neutron rays. Amer Rev Physiol 4: 25, 1942

f. WARREN S, DUNLAP CE: Effects of radiation on normal tissue: 3. Effects of radiation on the blood and the hemopoietic tissues, including the spleen, the thymus and the lymph nodes. Arch Path 34: 562, 1942

g. BECK JSP, MEISSNER WA: Radiation effects of the atomic bomb among the natives of Nagasaki, Kyushu. Amer J Clin Path 16: 586, 1946

h. CRAVER BN: Radioactive emanations: Their nature, mechanism of action, biological effects, and tolerance limits. J Indust Hyg Toxicol 29: 196, 1947

i. CANTRIL ST, JACOBSON L, NICKSON JJ: The effects of irradiation on the blood and blood forming tissues. USAEC MDDC-991

j. BLOOM W, JACOBSON LO: Some hematologic effects of irradiation. Blood 3:586, 1948

k. STEARNER SP, SIMMONS EL, JACOBSON LO: The effects of total body x-irradiation on the peripheral blood and blood forming tissues of the rat. USAEC MDDC-1319

l. SUTER GM: Responses of hematopoietic system to x-rays. USAEC MDDC-824

m. HOWLAND JW, WARREN SL: The effects of irradiation from the atomic bomb on the Japanese. USAEC MDDC-1301

n. JACOBSON LO, MARKS EK: Comparative action of cyclotron fast neutrons and x-ray: 2. Hematological effects produced in the rabbit by fast neutrons. USAEC MDDC-1372

o. JACOBSON LO, MARKS EK, et al: Effects of x-rays on rabbits: 2. The hematological effects of total body x-irradiation in the rabbit. USAEC MDDC-1174

27. WARREN and DUNLAP.[26f] CANTRIL, JACOBSON and NICKSON.[26i] BLOOM and JACOBSON.[26j] STEARNER, SIMMONS and JACOBSON.[26k] SUTER.[26l] JACOBSON and MARKS.[26n]
28. HENSHAW PS, SNIDER RS, et al: Comparative late effects of single doses of fission neutrons and of gamma rays. USAEC MDDC-1254
29. WINTROBE MM: The erythrocyte in man. Medicine 10: 195, 1930
30. WHIPPLE GH, ROBSCHEIT-ROBBINS GS: Blood regeneration in severe anemia: Standard basal ration bread and experimental methods. Amer J Physiol 72: 395, 1925; Favorable influence of liver, heart and skeletal muscle in diet. Amer J Physiol 72: 408, 1925; Iron reaction favorable: arsenic and germanium dioxide almost inert. Amer J Physiol 72: 419, 1925; Green vegetable feeding. Amer J Physiol 72: 431, 1925; Influence of striated and smooth muscle feeding. Amer J Physiol 79: 260, 1927; Influence of kidney, chicken and fish livers, and whole fish. Amer J Physiol 79: 271, 1927; Influence of dairy products on hemoglobin production. Amer J Physiol 79: 280, 1927; WHIPPLE GH: Hemoglobin regeneration as influeeced by diet and other factors. JAMA 104: 791, 1935; Protein production and exchange in the body including hemoglobin, plasma protein and cell protein. Amer J Med Sci 196: 609, 1938
31. MINOT and SPURLING.[26a] HEINEKE H: Ueber die Einwirkung der Roentgenstrahlen auf Tiere. München med Wchnschr 50: 2090, 1903
32. MINOT and SPURLING.[26a] MARTLAND HS: Occupational poisoning in manufacture of luminous watch dials: General review of hazard caused by ingestion of luminous paint, with special reference to the New Jersey cases. JAMA 92: 466, 552, 1929; The occurrence of malignancy in radioactive persons. Amer J Cancer 15: 2435, 1931
33. (a) DUFF.[6] (b) WEECH AA, GOETTSCH E, REEVES EB: Nutritional edema in the dog: 1. Development of hypoproteinemia on a diet deficient in protein. J Exper Med 61: 299, 1935
34. WARREN and DUNLAP.[26f] BLOOM and JACOBSON.[26j] STEARNER, SIMMONS and JACOBSON.[26k]