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OPHTHALMOLOGIC CHANGES RELATED TO RADIATION EXPOSURE AND AGE IN THE ADULT HEALTH STUDY SAMPLE, HIROSHIMA AND NAGASAKI

放射線被曝と年齢に関連する眼科的所見の変化
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原爆の後影響を引き続いて正確に究明する目的をもって，原爆放射線被曝線量の質的・量的特質について定期的に改良を加えている．今後線量評価によって，その必要性が起これば，本報の資料を再解析の上，改めて報告する．

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SUMMARY

A two-year ophthalmologic study of age- and radiation-related ophthalmologic lesions among the Adult Health Study (AHS) population of Hiroshima and Nagasaki was conducted at RERF in 1978-80 by members of the departments of ophthalmology of Hiroshima University School of Medicine and Nagasaki University School of Medicine. The study population in both cities was composed of all persons in the AHS exposed to 100+ rad, their controls, and all other persons in the AHS sample with a previous record of axial opacities or posterior subcapsular changes, and the in utero clinical sample. The ophthalmologic examination was conducted on 1,582 persons in Hiroshima and 719 persons in Nagasaki belonging to the AHS sample, and 67 persons in Hiroshima and 17 persons in Nagasaki belonging to the in utero clinical sample. Participation in the study was 42% of the eligible AHS sample in Hiroshima and 21% in Nagasaki, and 24% of the eligible in utero sample in Hiroshima and 26% in Nagasaki. Most nonparticipation in the study was due to persons who refused or for

要 約

広島・長崎両大学医学部眼科学教室によって，広島・長崎成人健康調査集団における年齢及び放射線被曝に関連する眼科学的病変の調査が，1978年から80年までの2年間にわたり放影研で行われた．両市の調査集団は，成人健康調査集団のうち100 rad 以上の被爆者全員とその対照者，及び過去の調査において軸性混濁又は後嚢下変化の認められた者全員，並びに胎内被爆者臨床調査集団からなる．眼科検査は成人健康調査集団に対しては広島で1,582例，長崎で719例について行われ，また，胎内被爆者臨床調査集団では広島で67例，長崎で17例について行われた．この調査の参加率は，成人健康調査対象集団の適格者のうちでは広島42%，長崎21%であり，また，胎内被爆者集団の適格者のうちでは広島24%，長崎26%であった．この調査に参加しなかった大部分の者は，眼科検査への協力の要請を拒否した者，又は成人

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whom it was not possible to arrange for an ophthalmologic examination during the regularly scheduled AHS medical examinations. It should be emphasized, however, that the loss of participants in both the control and 100+ rad groups did not change systematically with increasing age by city.

Increased lenticular opacities, other lens changes, and loss of visual acuity and accommodation occurred with increasing age in both exposed and control subjects as manifestations of the normal aging process. A highly significant excess risk for all ages in the 300+ rad group in comparison to those in the control group was observed for both axial opacities and posterior subcapsular changes in Hiroshima, but not in Nagasaki. The relative risk of axial opacities for persons in Hiroshima exposed to 300+ rad was 4.8 in the <50 age-group, 2.3 in the 50-59 age-group, and 1.4 in the 60+ age-group. In order to evaluate age-related radiosensitivity for the same parameters, a comparison of ratios of relative risks (CRR) between the <50 and 60+ age-groups was made at three dose levels: 100-199 rad, 200-299 rad, and 300+ rad. A significant excess of 3.3 was observed only in the younger age-group who were exposed to 300+ rad. Analysis of relative risks and CRR also were made for posterior subcapsular changes in Hiroshima. The relative risk for the development of posterior subcapsular changes in Hiroshima for persons who were aged under 15 years at the time of the bomb (ATB) was 2.8 in the 100-199 rad group, 4.3 in the 200-299 rad group, and 5.3 in the 300+ rad group. Greater radiosensitive aging in the younger age-group in Hiroshima for posterior subcapsular changes was observed for both the 200-299 rad and 300+ rad groups with a significant elevation at the 5% level. The CRR values for both axial opacities and posterior subcapsular changes suggest a stronger radiosensitive aging effect in Hiroshima for persons who were aged under 15 years ATB. Measurements in the in utero clinical sample were not statistically evaluated because of the paucity of persons examined.

INTRODUCTION

One of the earliest radiation effects observed at ABCC was the occurrence of lenticular changes among the atomic bomb survivors of Hiroshima and Nagasaki.[1-3] The most frequently described lesion was a posterior lenticular plaque of

健康調査定期検診時に眼科検査のスケジュールができず，検査されなかった者であった．しかし対照群及び100 rad 以上群における被検者の損失は，都市別に年齢の増加とともに系統的に変化していないことを強調したい．

被爆者及び対照者ともに，水晶体混濁の増加やその他の水晶体変化，及び視力や調節力低下の発現が年齢の増加とともに観察された．これらの眼科的変化は正常な加齢現象と一致するものであった．広島の軸性混濁及び後嚢下変化の双方に関しては，全年齢群において対照群と比べて300rad 以上群の過剰リスクに高い有意差が認められたが，長崎ではこのようなリスクの増加は認められなかった．300 rad 以上群の広島被爆者に対する軸性混濁の相対的危険度は年齢50歳未満群では4.8で，50～59歳群では2.3，及び60歳以上群では1.4であった．同じパラメーターで年齢関連の放射線感受性を評価するために三つの線量群，すなわち100～199 rad 群，200～299rad 群及び300 rad 以上群別に年齢50歳未満群と60歳以上群間の相対的危険度を比較し検討した．300rad 以上被曝した若年齢群においてのみ3.3の有意な過剰リスクが認められた．相対的危険度分析及び相対的危険度の比較分析が，同様に広島の後嚢下変化に関しても検討された．原爆時年齢15歳未満の広島対象者の後嚢下変化に関連する相対的危険度は，100～199 rad 群では2.8，200～299 rad 群では4.3，更に，300 rad 以上群では5.3であった．広島若年齢群の後嚢下変化において，放射線感受性による加齢増進が200～299rad 及び300rad 以上の両群に5％水準で有意な増加をもって認められた．軸性混濁及び後嚢下変化の双方に対する相対的危険度の比較統計量は，広島の原爆時15歳未満の年齢群に加齢影響による放射線感受性の増大を示唆する．胎内被爆者臨床集団に関する測定値については，被検者数が極めて少ないために統計的に評価しなかった．

緒　言

ABCC で観察された最初の放射線影響の一つは，広島・長崎の原爆被爆者に発生した水晶体変化である．[1-3] 頻度の最も高い病変は，高線量被爆者に

polychromatic sheen in heavily irradiated individuals, but very few discreet "radiation cataracts" were observed. Miller et al[3,4] in a 1963-64 Hiroshima and Nagasaki comprehensive ophthalmologic study were able to corroborate the occurrence of posterior lenticular lesions in the more heavily irradiated individuals and noted that there had been very little progression in these radiation-related lesions in comparison to the observations made about 10 years previous. An ophthalmologic follow-up of 97 individuals in Nagasaki with radiation cataracts was conducted in 1966.[5] Preliminary analysis of the unpublished data showed that about 60% were unchanged, about 30% had improved, and about 7% had progressed. The details are unclear as to which types of lesions had changed.

A number of earlier studies have been criticized for defects in sampling and clinical methodology, but nonetheless all these reports have indicated some radiation-related lenticular changes, particularly in the axial posterior subcapsular region. In the research protocol for the last ophthalmologic study, Miller et al[3] summarized the previously noted changes as follows: 1) Severe effects of radiation include marked lenticular changes which are recognized early. This group includes a few with complete opacities, and more specifically those with a large posterior subcapsular plaque, doughnut, or bivalve opacity with resultant diminution of central visual acuity. 2) Moderate effects of radiation may produce a small iridescent posterior subcapsular granular opacity which is visible with an ophthalmoscope as a tiny axial dot. There is no significant reduction of visual acuity. 3) Minimal radiation effects consist of a polychromatic sheen which seems to be in the plane of the posterior capsule of the lens and can be seen only with a slitlamp biomicroscope.

Miller et al then went on to point out that only 20 of all the persons examined in Hiroshima and Nagasaki belong to category 1. The number in category 2 also is probably relatively small, but may have been as high as 15% among the small group of survivors within 500 m from the hypocenter. It was suggested that those in categories 1 and 2 could have radiation cataracts. Certainly the majority of those with abnormalities are in category 3. The minimal posterior lenticular lesions were not noted in the first study conducted at ABCC by Cogan et al.[6] It

おける多色性光彩の水晶体後嚢下円板状混濁であったが，明確な"放射線白内障"は非常に少なかった．1963－64年に広島・長崎で行った広範な調査によって，Miller ら[3,4]は，高線量被爆者における水晶体後嚢病変の発生を確認できたが，放射線関連病変は約10年前の観察所見と比べてほとんど進行していないことを認めた．1966年には，放射線白内障を有する長崎の対象者97人に関する眼科学的追跡調査が行われた．[5] 未発表のデータの予備解析では約60%には変化がなく，約30%は改善し，約7%は進行していたことを示している．変化のあった病変の種類についての詳細は明らかではない．

幾つかの初期の調査は，対象集団の抽出及び検査方法に不備があったとして批判を受けているが，これらの報告ではいずれも放射線と関連のある水晶体変化，特に水晶体軸性後嚢下部の変化が認められている．Miller ら[3]はその眼科学的調査の研究計画書で，以前に認められた変化を次のように要約している．1) 強度の放射線影響としては，初期に認められた顕著な水晶体変化が挙げられる．この群には完全な混濁のある少数の患者が含まれており，更に特異的な例では大きな水晶体後嚢下円板状混濁，ドーナツ形混濁又は二弁混濁を有し，その結果，中心視力の減退を認める．2) 中等度の放射線の影響としては，検眼鏡によって認められる小さな量光性の顆粒状混濁が水晶体後嚢下に発生することがある．これは視力には有意な減退を示さない．3) ごく軽微の放射線影響としては，多色性光彩がみられるが，これは水晶体後嚢面にあるようであり，細隙灯生体顕微鏡によってのみ認めることができる．

更に，Miller らは広島・長崎での受診者のうち，分類1に属するものはわずか20例であると指摘した．分類2の該当者も恐らく比較的少ないであろうが，爆心地から500m未満の被爆者の小集団では15%程度に達しているかもしれない．分類1及び2の者は放射線白内障を有していたと考えることができる．もちろん，異常が認められた者の大半は分類3に属するものである．Cogan ら[6]が ABCC で行った最初

has been suggested that the lesions either were not present at that time or that their significance was not appreciated. It now is clear that the posterior lenticular changes are not radiation specific. They may be seen in healthy individuals at any age without a history of radiation exposure, but the significance of the findings is that the incidence appears to be greatly increased among the heavily exposed survivors. The latent period for the development of lenticular changes may vary inversely with dose and may be related to age ATB.

In the study conducted by Miller et al[3,4] on 2,468 A-bomb survivors and controls in Hiroshima and Nagasaki, the only findings which appeared to be related to ionizing radiation were the occurrence of axial opacities, visible with the ophthalmoscope, and polychromatic changes of the posterior subcapsule, visible only with the slitlamp biomicroscope. Comparison with previous ophthalmologic studies seems to indicate a decrease in the prevalence of radiation-induced lens changes and no evidence that the minimal polychromatic changes progressed to axial opacities. Although the number was small, it was suggested that the youngest individuals studied (those in utero ATB) had some diminution of visual acuity in relationship to radiation exposure.

The major objectives of the current study were to determine what changes, if any, have occurred with time in radiation-induced lenticular lesions, the effect of radiation on age-related ophthalmologic changes and on age-related prevalence of certain ophthalmologic lesions. Information of this type is believed to be of importance in understanding the natural history of age- and radiation-related ophthalmologic changes and their interactions.

MATERIALS AND METHODS

The study population in both cities consisted of all persons in the AHS sample exposed to 100+ rad, their controls, all other persons in the AHS sample with a previous record of axial opacities or posterior subcapsular changes, and the in utero clinical sample. Participants in the study were restricted to individuals living within the RERF contacting area on 1 January 1978. In the AHS, the A-bomb surviyors in the 100+ rad group numbered 1,855 in Hiroshima and 1,658 in

の調査では，水晶体後嚢の軽微な病変は認められなかった．この病変が当時は存在していなかったか，あるいはその有意性が認められなかったかのいずれかであると示唆されている．水晶体後嚢の変化が放射線特異的でないことは現在明らかである．この変化は，放射線被曝歴のないいずれの年齢の健常者にも認められるが，これらの所見の有意性は，高線量被爆者の発生率が非常に増大していることにある．水晶体変化発生の潜伏期は線量と逆比例し，また原爆時年齢とも関係があり得ると考えられている．

Miller ら[3,4]が広島・長崎における2,468人の被爆者及びその対照者について実施した調査において，電離放射線と関係があると思われた所見は，検眼鏡で認められる軸性混濁及び細隙灯生体顕微鏡によって初めて認められる水晶体後嚢下の多色性変化の発生のみであった．以前の眼科学的所見と比較すると，放射線誘発性水晶体変化の発現率に減少が認められ，軽度の多色性変化が軸性混濁にまで進行した徴候は認められないようであった．例数は少なかったが最も若年の対象者（胎内被爆者）では，放射線被曝と視力の若干の減退との間に関係のあることが示唆された．

本研究の主な目的は，放射線誘発性水晶体病変に時間の経過とともに，もしあるとすればどんな変化が起こったのかを調査し，また，年齢と関連する眼科的変化，並びに年齢と関連する特定の眼科的病変の発現率に対する放射線の影響を調査することである．この種の資料は，年齢及び放射線に関連する眼科学的変化とその相互作用の自然史を理解する上で重要であると思われる．

材料及び方法

両市の調査対象集団は成人健康調査対象者で100 rad以上の被爆者全員とその対照者，及び過去の調査において軸性混濁又は後嚢下変化の認められた者全員，並びに胎内被爆者臨床調査対象者からなる．調査対象者は1978年1月1日現在，放影研の連絡地域内に住んでいた人に限定した．成人健康調査対象者中100rad以上群に属する被爆者は，広島の1,855人と

TABLE 1 PERSONS SELECTED FOR THE OPHTHALMOLOGY STUDY FROM THE ADULT HEALTH STUDY SAMPLE AND IN UTERO CLINICAL SAMPLE, HIROSHIMA AND NAGASAKI

表1　広島・長崎の成人健康調査集団及び胎内被爆者臨床調査集団から眼科学的調査に選ばれた対象者

City	AHS Sample				In Utero Clinical Sample			
	Total	Control (0 rad)	Index (100+ rad)	Change in 1963-64 (1-99 rad)	Total	Control (0 rad)	(1-99 rad)	Index (100+ rad)
Hiroshima	3799	1855	1855	89	278	143	124	11
Nagasaki	3428	1658*	1658	112	66	37	20	9
Total	7227	3513	3513	201	344	180	144	20

**87 cases selected from NIC group.* 市内不在者群から87例を選んだ

Nagasaki (Table 1). Controls were selected from the daily schedule of clinical appointments on the basis of a simple random stratified sampling by age and sex, as far as possible, from among those in the distal group (0 rad) in Hiroshima and Nagasaki. In Nagasaki it was necessary to select 87 persons from the not-in-city (NIC) group in order to make the number of controls equivalent to that of the index cases. All other persons with previously demonstrated axial opacities or posterior subcapsular changes were selected without any sampling restriction, except for those with these abnormalities in the NIC group in Hiroshima. Except for the NIC group, all 1,021 persons (800 in Hiroshima and 221 in Nagasaki) constituting the in utero clinical sample were selected for the routine biennial examination. However, ophthalmologic examination of the in utero sample was conducted for only one year between 1 June 1979 and 31 July 1980 in both cities. This reduced the potential size of the in utero clinical sample to 404 persons in Hiroshima and 118 in Nagasaki, and contacting restrictions further reduced the size for routine examination to 278 in Hiroshima and 66 in Nagasaki (Table 1).

Ophthalmologic examinations were conducted whenever possible at the time of a regularly scheduled AHS biennial examinations. At the time of notification of a regularly scheduled AHS examination, persons selected for the ophthalmology study were provided complete information on the nature of the study and an invitation to participate. Mydriatics were seldom used in order to reduce the unpleasant side effects that have influenced participation in previous AHS ophthalmologic studies. The examinations were performed by ophthalmolo-

長崎の1,658人であった（表1）．対照者は，広島・長崎の遠距離被爆者（0 rad）の中からできる限り年齢，性別の単純無作為層化抽出法に従って，毎日の診察予定表から抽出した．長崎では指標例と対照例の人数を等しくするために，市内不在者群の中から87名を抽出する必要があった．広島の市内不在者群を除き，以前に軸性混濁又は後嚢下変化を認めた全異常者については，何ら制約を付けずにすべて抽出した．市内不在者群を除いて，胎内被爆者臨床調査集団を構成する1,021人（広島800人，長崎221人）をすべて2年ごとの通常検診の調査対象とした．しかしながら胎内被爆者の眼科学的調査は，両市において1979年6月1日から1980年7月31日の1年間だけ行われた．これにより，胎内被爆者臨床調査集団は広島で404人，長崎で118人に減少し，その上，連絡上の制限により通常検査数は広島で278人，長崎は66人にそれぞれ減少した（表1）．

眼科学的検査は，できる限り2年ごとの成人健康調査定期検診時に実施した．定期検診の連絡を行う際に，眼科学的調査対象者に調査の内容について十分な説明をしたうえ参加を求めた．過去の成人健康調査眼科学的調査の参加率に影響を与えた不快な副作用を避けるため，散瞳剤はほとんど使用しなかった．

gists from the departments of ophthalmology at Hiroshima University School of Medicine and Nagasaki University School of Medicine. Frequent comparisons of examination techniques between the two cities were made in order to assure uniformity. Photographs of lenticular lesions were taken to make objective comparisons of radiation- and age-related lesions, whenever possible.

Lenticular examinations and terminology employed closely followed those of the ABCC study conducted in 1963-64, so that valid comparisons of various radiation-induced lesions between the current and previous studies could be made. All findings were coded for data processing by the examining ophthalmologist on coding forms which were very similar to those previously used (Appendix 1).

The following examinations were conducted for ophthalmologic evaluation (Appendix 2): 1) Visual acuity, 2) Amplitude of accommodation, 3) External examination (cornea, iris-pupil), 4) Intraocular tension (Applanation tonometry, Schiøtz tonometry), 5) Gonioscopy, 6) Fundus examination by ophthalmoscope (cup-disc ratio, macula, macular drusen, microaneurysms and/or dot hemorrhages), and 7) Lens examination by slit-lamp biomicroscope.

Upon completion of each examination the physician provided the examinee with a brief summary of the findings. Advice concerning referral for follow-up diagnostic studies or therapy was given at that time.

RESULTS

Table 2 shows the results of contacts made between 1 April 1978 and 31 July 1980 for the AHS subjects and between 1 July 1979 and 31 July 1980 for the in utero clinical study subjects. Of the 7,227 AHS subjects, 328 (4.5%) were losses from "deceased," "too ill to come," and "moved away from city or out of contacting area;" there were 180 (4.7%) in Hiroshima and 148 (4.3%) in Nagasaki. A large number of subjects, 1,998 (27.6%) had to be dropped from the ophthalmologic examination, 477 (12.6%) in Hiroshima and 1,521 (44.4%) in Nagasaki, because the ophthalmologist was available only on a half-day basis in Hiroshima and three half-days per week in Nagasaki. Of the 344 in

検診は広島大学医学部及び長崎大学医学部の眼科学教室から派遣された眼科医が行った．両市の検査技法の画一化を図るため，技法の比較を頻回行った．放射線及び年齢に関連する病変の客観的な比較のために，可能な限り水晶体病変の写真を撮影した．

現在及び過去の調査における種々の放射線誘発性病変を適確に比較することができるように，1963—64年に行われたABCC検査に準じた水晶体検査及び用語を使用した．資料処理に使用する所見はすべて以前の調査に使用した書式と類似のコード用紙に，検査担当眼科医がコード化して記入した（付録1）．

眼科学的調査のため，下記の検査を行った（付録2）：1) 視力，2) 調節力，3) 外眼部検査（角膜，虹彩—瞳孔），4) 眼圧（圧平眼圧計，シェッツ眼圧計），5) 隅角検査，6) 眼底検査—検眼鏡（視神経乳頭陥凹比率，黄斑部，黄斑部ドルーゼ，微小血管瘤ないし斑点出血）及び 7) 水晶体検査—細隙灯生体顕微鏡．

検診の終了後，担当眼科医が被検者に所見の概要を説明した．そのときに，更に検診あるいは治療を必要とする者については，病院への紹介について助言を与えた．

結　果

表2は，1978年4月1日から1980年7月31日までの期間中に成人健康調査対象者に対して行った連絡結果，及び1979年7月1日から1980年7月31日までの期間中に胎内被爆者臨床調査対象者に対して行った連絡結果を示したものである．成人健康調査対象者7,227人のうち，328人（4.5%）が"死亡"，"病臥中で来診不能"及び"市外あるいは連絡地域外への転出"を理由に調査に参加しなかった．その内訳は広島180人（4.7%），長崎148人（4.3%）であった．また，1,998人（27.6%）という多数の対象者，広島477人（12.6%），長崎1,521人（44.4%），が眼科学的検査を受けなかったが，これは，眼科医が広島では半日ずつ，長崎では週3日半日ずつしか検査を行うこと

TABLE 2 OPHTHALMOLOGIC STUDY CONTACTING RESULTS BY CITY AND SAMPLE, 1978-80
表 2　眼科学的調査の連絡結果，都市及び調査集団別，1978－80年

Contacting Result	AHS Sample						In Utero Clinical Sample					
	Total		Hiroshima		Nagasaki		Total		Hiroshima		Nagasaki	
	Subjects	%	Subjects	%	Subjects	%	Subjects	%	Subjects	%	Subjects	%
Examined	2301	31.8	1582	41.6	719	21.0	84	24.4	67	24.1	17	25.8
Refused	2600	36.0	1560	41.1	1040	30.3	202	58.7	175	62.9	27	40.9
Dropped*	1998	27.6	477	12.6	1521	44.4	53	15.4	31	11.2	22	33.3
Deceased	42	.6	25	.7	17	.5	0	.0	0	.0	0	.0
Too ill to come	32	.4	30	.8	2	.1	2	.6	2	.7	0	.0
Moved away	254	3.5	125	3.3	129	3.8	3	.9	3	1.1	0	.0
Total	7227	100.0	3799	100.0	3428	100.0	344	100.0	278	100.0	66	100.0

Tab # 2992.2 and 2992.3

**Those who could not be scheduled because one ophthalmologist was available on a half-day basis in Hiroshima and three half-days per week in Nagasaki.*

広島では眼科医が毎日1名，各半日間，長崎では1週に3日，各半日間のみ検査を実施したため，検査を受けられなかった対象者

utero clinical subjects (278 in Hiroshima and 66 in Nagasaki), losses due to having moved away from the city or out of the contacting area were only 3 (1.1%) in Hiroshima and none in Nagasaki. Ophthalmology study refusals in Hiroshima were about 40% of the AHS sample and over 60% of the in utero sample. In Nagasaki, the refusals were about 30% in the AHS and 41% in the in utero sample, but many persons who would have refused the ophthalmologic examination were recorded as "dropped" because of the limited availability of the ophthalmologists.

The distribution of examinees among those who were contacted for the AHS ophthalmologic study is given by city and age in Table 3. This table indicates that there are no differences in the examination rates between the control (0 rad) and index (100+ rad) groups in Hiroshima and Nagasaki. Examination rates by age in the two comparison groups were similar in both cities. The examination rates of subjects in the 1-99 rad group in each city who had some ophthalmologic findings in the 1963-64 study were similar to those of their respective control and 100+ rad groups. The age-city distribution of non-respondents is, therefore, assumed to be similar in various comparison groups. Approximately 67% of the AHS examinations in Nagasaki were made by one ophthalmologist and the remainder

ができなかったためである．胎内被爆者臨床調査対象者344人（広島278人，長崎66人）のうち，市外あるいは連絡地域外への転出による損失は広島では3人（1.1%）のみであり，長崎では1人もいなかった．広島における眼科学的調査拒否率は，成人健康調査対象者で約40%，胎内被爆対象者で60%以上を占めた．長崎においては検査拒否者は成人健康調査対象者で30%，胎内被爆対象者で41%を占めたが，眼科医が検査できる時間が限られていたので，検査を拒否するであろうと思われた対象者も多くは"脱落"と記録された．

成人健康調査眼科学的調査のために連絡した対象者のうちの被検者を，都市及び年齢別に表3に示した．この表は，広島・長崎の対照（0 rad）群及び指標（100 rad 以上）群の間の受診率に差はないことを示している．両比較群における年齢別の受診率は両市とも類似していた．1963－64年の調査で眼科学的有意所見を示した両市の1－99 rad 群対象者の受診率は，それと対応する対照群及び100 rad 以上群の受診率と類似していた．したがって，非受診者の年齢－市別分布はそれぞれの比較群間で類似していると仮定した．長崎における成人健康調査時検査の約67%は1人の眼科医によって行われ，残りは他の

TABLE 3 COMPARISON OF THE EXAMINATION RATES BETWEEN CONTROL AND INDEX GROUPS CONTACTED FOR OPHTHALMOLOGIC STUDY BY CITY AND AGE

表 3　眼科学的調査のため連絡した対照群及び指標群の受診率の比較，都市及び年齢別

Age ATE	Control (0 rad)			Index (100+ rad)			Change in 1963-64 (1-99 rad)		
	Contacted*	Examined	%	Contacted*	Examined	%	Contacted*	Examined	%
				Hiroshima AHS					
<40	180	55	30.6	187	64	34.2	1	1	100.0
40-49	354	165	46.6	342	146	42.7	12	5	41.7
50-59	460	247	53.7	491	260	53.0	28	16	57.1
60-69	333	147	44.1	329	152	46.2	20	12	60.0
70 +	442	158	35.7	412	146	35.4	28	8	28.6
Total	1769	772	43.6	1761	768	43.6	89	42	47.2
				Nagasaki AHS					
<40	138	32	23.2	130	30	23.1	3	0	.0
40-49	454	101	22.2	445	110	24.7	24	12	50.0
50-59	471	126	26.8	517	114	22.1	31	8	25.8
60-69	267	50	18.7	243	50	20.6	26	6	23.1
70 +	264	44	16.7	239	34	14.2	28	2	7.1
Total	1594	353	22.1	1574	338	21.5	112	28	25.0

**Those who were contacted and invited to participate in the ophthalmologic study.*
眼科学的調査に参加するよう連絡及び要請した対象者

by several other ophthalmologists. The 1,582 examinations in Hiroshima were conducted by eight ophthalmologists. The number of examinations per ophthalmologist ranged from a low of 60 (4%) to a high of 311 (20%).

眼科医数人によって行われた．広島における1,582件の検査は８人の眼科医によって行われた．眼科医１人当たりの検査数は，最低60件（４%）から最高311件（20%）にわたった．

General Evaluation

Axial Opacities. The prevalence of persons who had axial opacities of one or both eyes in the control and index (100+ rad) groups is given by city, age at time of examination (ATE), and sex in Table 4. In both groups and in both cities, the prevalence of axial opacities increased with age. When the relationship between the control and 100+ rad groups for both sexes combined is examined by age ATE, there is an increasing trend in the 100+ rad group for all age-groups less than 70. A highly significant difference within the 60-69 age-group for both sexes combined in Hiroshima was noted with an excess risk of about two in the 100+ rad group; 19.9% in the control group vs 39.7% in the 100+ rad group ($P < .001$). Such an excess is observed in females, but in males there also is an increasing trend in the 100+ rad group, although no significant difference was noted.

一般的評価

軸性混濁． 対照群及び指標（100 rad 以上）群の，片眼ないし両眼に軸性混濁を有する者の発現率を都市，受診時年齢及び性別に表４に示した．両群並びに両市において，軸性混濁の発現率は年齢とともに増加した．男女合計による対照群及び100 rad 以上群との関係を受診時年齢別に検討すると，100 rad 以上群で70歳以下のすべての年齢群に増加傾向が認められる．広島において，男女合計した60－69歳群に対して顕著な有意差が100 rad 以上群に認められ，その過剰リスクは約２倍，すなわち，対象群19.9%，100rad 以上群39.7%であった（$p < .001$）．このような過剰リスクは女性に認められるが，男性においても，有意差はないが，100rad 以上群に増加傾向を認める．

TABLE 4 PREVALENCE OF AXIAL OPACITIES IN CONTROL GROUP AND 100+ RAD GROUP BY CITY, AGE, AND SEX

表 4　対照群及び100 rad 以上群における軸性混濁の発現率，都市，年齢及び性別

Age ATE	Control			(1-99 rad)	Index (100+ rad)			χ^2 value
	Examined	Positive	Prevalence %	(Prevalence only %)	Examined	Positive	Prevalence %	
				HIROSHIMA				
				Sexes Combined				
<40	55	1	1.8		64	6	9.4	3.05 Sug
40-49	164	10	6.1		146	20	13.7	5.11 *
50-59	243	27	11.1		258	40	15.5	2.08 NS
60-69	141	28	19.9		146	58	39.7	13.49 ***
70 +	151	87	57.6		141	73	51.8	1.00 NS
Total	754	153	20.3	(16.7)	755	197	26.1	7.13 **
				Male				
<40	24	0	.0		29	1	3.4	.84 NS
40-49	64	4	6.3		51	10	19.6	4.74 *
50-59	62	7	11.3		98	15	15.3	.52 NS
60-69	36	5	13.9		49	13	26.5	1.99 NS
70 +	67	38	56.7		62	36	58.1	2.39 NS
Total	253	54	21.3	(14.3)	289	75	26.0	1.58 NS
				Female				
<40	31	1	3.2		35	5	14.3	2.43 NS
40-49	100	6	6.0		95	10	10.5	1.33 NS
50-59	181	20	11.0		160	25	15.6	1.55 NS
60-69	105	23	21.9		97	45	46.4	13.54 ***
70 +	84	49	58.3		79	37	46.8	2.16 NS
Total	501	99	19.8	(17.9)	466	122	26.2	5.64 *
				NAGASAKI				
				Sexes Combined				
<40	32	1	3.1		30	1	3.3	.002 NS
40-49	101	3	3.0		110	3	2.7	.01 NS
50-59	126	7	5.6		112	5	4.5	.15 NS
60-69	50	12	24.0		48	7	14.6	1.39 NS
70 +	43	29	67.4		32	19	59.4	.52 NS
Total	352	52	14.8	(11.1)	332	35	10.5	2.75 Sug
				Male				
<40	14	0	.0		17	1	5.9	.85 NS
40-49	48	2	4.2		45	1	2.2	.28 NS
50-59	44	3	6.8		40	0	.0	2.83 Sug
60-69	25	3	12.0		20	1	5.0	.67 NS
70 +	18	11	61.1		21	11	52.4	.30 NS
Total	149	19	12.8	(25.0)	143	14	9.8	.64 NS
				Female				
<40	18	1	5.6		13	0	.0	.75 NS
40-49	53	1	1.9		65	2	3.1	.17 NS
50-59	82	4	4.9		72	5	6.9	.30 NS
60-69	25	9	36.0		28	6	21.4	1.38 NS
70 +	25	18	72.0		11	8	72.7	2.01 NS
Total	203	33	16.3	(.0)	189	21	11.1	2.18 NS

The rate in 1-99 rad group is shown only for all ages combined because of the paucity of cases.

1 —99 rad 群は症例不足のため全年齢を合計したものだけを示した

*NS - P > .10, Sug - P < .10, * - P < .05, ** - P < .01, *** - P < .001*

A significant excess risk for the occurrence of axial opacities in the 100+ rad group with ages and sexes combined in Hiroshima was observed; 20.3% in the control group vs 26.1% in the 100+ rad group ($P < .01$). The excess risk was significant for females but not for males. The males in the 70+ age-group constitute 70% (38/54) of all cases with any axial opacity in the control group and 48% (36/75) of such cases in the 100+ rad group. However, a comparison between the control and 100+ rad groups for persons less than age 70 ATE (i.e., age 33-69 ATE) showed a highly significant excess risk in males ($P < .01$). Variation was observed in the relationship between males and females, but the trend was not always consistent. No sex differences for all ages combined within the control and 100+ rad groups were noted; 21.3% males vs 19.8% females in the control group and 26.0% males vs 26.2% females in the 100+ rad group in Hiroshima. An excess risk could not be demonstrated in the high dose group in Nagasaki with all ages and sexes combined, since the number examined probably was too small.

A strong excess risk for axial opacities in the 100+ rad group was observed for the youngest age-group in comparison with those of the older age-groups. Axial opacity risk comparisons in the 100+ rad exposure groups were made for three age ATE categories, <50, 50-59, and 60+. Such comparisons were made only for Hiroshima since excess risks for the various age-groups were not observed in Nagasaki. The relative risk of the 100+ rad group for <50 ATE age-group was 2.5 with significance at about the 1% level (χ^2=6.78 with 1 df). The relative risks for the 50-59 and the 60+ ATE age-groups were 1.4 and 1.2, respectively, but the risks were not statistically significant. CRR between the <50 and the 60+ ATE age-groups was estimated to be 2.1 by using (2) in Appendix 3. CRR was found to be significant at less than the 5% level (χ^2=4.40 with 1 df) using (5) in Appendix 3. Such a significant excess risk found only for individuals aged 33-49 ATE (or aged <15 ATB) in the 100+ rad group, suggests strongest radiation sensitivity in the exposed young population in Hiroshima. The result of such lens findings thus supports the hypothesis that the lenses of the young are more sensitive to radiation than are the lenses of older individuals.

Posterior Subcapsular Changes. Table 5 shows

広島において，年齢と性を合計した対照群で20.3%と100rad 以上群で26.1%に示されるように，100rad 以上群の軸性混濁発生率に有意な過剰リスクを認めた（$p < .01$）．この過剰リスクは女性においては有意であったが，男性では有意でなかった．70歳以上群の男性は，対照群で軸性混濁を有する全例の70%（38/54）を占め，100rad 以上群では同例の48%（36/75）を占める．しかしながら，受診時年齢70歳以下（すなわち受診時33－69歳）の人で対照群と100rad 以上群を比較すると，男性で非常に有意な過剰リスクが認められた（$p < .01$）．男性と女性ではこの関係に差がみられたが，その傾向は一定していなかった．対照群及び100rad 以上群で全年齢を合計して検討すると，性による差異は認められなかった．すなわち，広島の対照群では男性21.3%，女性19.8%であり，100rad 以上群では男性26.0%，女性26.2%であった．長崎では，全年齢及び性を合計した高線量群で過剰リスクは観察されなかったが，これは恐らく被検査者数が少な過ぎたためであろう．

100rad 以上群における軸性混濁の過剰リスクは，高年齢群と比べて若年齢群により強く認められた．100rad 以上群における軸性混濁リスクの比較を三つの受診時年齢区分，すなわち50歳未満，50－59歳，60歳以上群に対して行った．長崎では各年齢群に過剰リスクは認められなかったので，上記の比較は広島についてのみ行った．受診時50歳未満の100rad 以上群の相対的危険度は2.5で，有意水準は約1%であった（1 df で$\chi^2 = 6.78$）．受診時50－59歳群及び60歳以上群の相対的危険度はそれぞれ1.4及び1.2であったが，統計的に有意ではなかった．受診時50歳未満群と60歳以上群との相対的危険度の比較は，付録3の(2)式から2.1と推定される．付録3の(5)式を用いると，この相対的危険度推定値は5%水準以下（1 df で$\chi^2 = 4.40$）の有意差を認めた．100rad 以上群の受診時33－49歳群（すなわち原爆時年齢15歳未満）にのみこのような有意な過剰リスクが認められるということは，広島においては原爆時若年齢群の放射線感受性が最も高いことを示唆する．このような水晶体所見の結果は，若年齢者の水晶体が高年齢者の水晶体よりも放射線感受性が高いという仮説を支持するものである．

後嚢下変化． 表5は，対照群及び100rad 以上群に

TABLE 5 PREVALENCE OF POSTERIOR SUBCAPSULAR CHANGES IN CONTROL GROUP AND 100+ RAD GROUP BY CITY, AGE, AND SEX

表 5　対照群及び100 rad 以上群における後嚢下変化の発現率，都市，年齢及び性別

Age ATE	Control			(1-99 rad)	Index (100+ rad)			χ^2 value
	Examined	Positive	Prevalence %	(Prevalence only %)	Examined	Positive	Prevalence %	
				HIROSHIMA				
				Sex Combined				
<40	55	1	1.8		64	16	25.0	12.98 ***
40-49	165	11	6.7		145	28	19.3	11.22 ***
50-59	243	23	9.5		256	66	25.8	22.65 ***
60-69	141	27	19.1		144	57	39.6	14.31 ***
70 +	144	45	31.3		135	57	42.2	3.62 Sug
Total	748	107	14.3	(24.4)	744	224	30.1	53.96 ***
				Male				
<40	24	0	.0		29	5	17.2	4.57 *
40-49	64	4	6.3		51	16	31.4	12.47 ***
50-59	63	7	11.1		96	27	28.1	6.55 *
60-69	36	7	19.4		47	13	27.7	.75 NS
70 +	63	21	33.3		58	26	44.8	1.68 NS
Total	250	39	15.6	(21.4)	281	87	31.0	17.25 ***
				Female				
<40	31	1	3.2		35	11	31.4	8.79 *
40-49	101	7	6.9		94	12	12.8	1.89 NS
50-59	180	16	8.9		160	39	24.4	14.98 ***
60-69	105	20	19.0		97	44	45.4	16.13 ***
70 +	81	24	29.6		77	31	40.3	1.97 NS
Total	498	68	13.7	(25.9)	463	137	29.6	36.30 ***
				NAGASAKI				
				Sex Combined				
<40	32	1	3.1		30	2	6.7	.42 NS
40-49	101	4	4.0		110	4	3.6	.02 NS
50-59	125	7	5.6		113	9	8.0	.53 NS
60-69	50	10	20.0		48	12	25.0	.35 NS
70 +	41	20	48.8		31	19	61.3	1.11 NS
Total	349	42	12.0	(7.7)	332	46	13.9	.50 NS
				Male				
<40	14	0	.0		17	1	5.9	.85 NS
40-49	48	2	4.2		45	1	2.2	.28 NS
50-59	44	4	9.1		40	1	2.5	1.63 NS
60-69	25	1	4.0		21	5	23.8	3.95 *
70 +	18	8	44.4		20	11	55.0	.42 NS
Total	149	15	10.1	(9.1)	143	19	13.3	.74 NS
				Female				
<40	18	1	5.6		13	1	7.7	.06 NS
40-49	53	2	3.8		65	3	4.6	.05 NS
50-59	81	3	3.7		73	8	11.0	3.05 Sug
60-69	25	9	36.0		27	7	25.9	.62 NS
70 +	23	12	52.2		11	8	72.7	1.30 NS
Total	200	27	13.5	(20.0)	189	27	14.3	.05 NS

See Footnote Table 4. 表 4 の脚注参照

TABLE 6 PERCENTAGE OF SUBJECTS WITH CORRECTED VISUAL ACUITY LESS THAN 0.6 ASSOCIATED WITH POSTERIOR SUBCAPSULAR CHANGES BY CITY, AGE ATE, AND DOSE

表6　後嚢下変化を有する対象者で矯正視力0.6以下の百分率，都市，受診時年齢及び線量別

Age ATE	Visual Acuity less than 0.6	Total			Posterior Subcapsular Changes								
					None			Small			Moderate and Large		
		Control	100+ rad	1-99 rad	Control	100+ rad	1-99 rad	Control	100+ rad	1-99 rad	Control	100+ rad	1-99 rad
						Hiroshima							
<50	Examined	220	210	6	208	166	4	11	41	2	1	3	0
	%	3.6	5.2	.0	2.4	4.2	.0	27.3	9.8	.0	.0	.0	.0
50-59	Examined	246	257	16	223	191	13	20	62	3	3	4	0
	%	19.1	16.0	.0	19.3	13.1	.0	10.0	21.0	.0	66.7	75.0	.0
60+	Examined	290	283	19	219	169	14	64	96	5	7	18	0
	%	46.6	44.5	52.6	45.2	40.2	42.9	45.3	42.7	80.0	100.0	94.4	.0
Total	Examined	756	750	41	650	526	31	95	199	10	11	25	0
	%	25.1	23.7	24.4	22.6	19.0	19.4	35.8	29.1	40.0	81.8	80.0	.0
						Nagasaki							
<50	Examined	133	140	12	128	134	10	2	5	2	3	1	0
	%	10.5	10.0	16.7	9.4	9.0	10.0	.0	40.0	50.0	66.7	.0	.0
50-59	Examined	125	114	8	118	105	7	5	7	1	2	2	0
	%	11.2	15.8	12.5	8.5	13.3	.0	40.0	28.6	100.0	100.0	100.0	.0
60+	Examined	92	82	7	62	51	6	24	27	1	6	4	0
	%	39.1	34.1	14.3	29.0	23.5	16.7	50.0	48.1	.0	100.0	75.0	.0
Total	Examined	350	336	27	308	290	23	31	39	4	11	7	0
	%	18.3	17.9	14.8	13.0	13.1	8.7	41.9	43.6	50.0	90.9	71.4	.0

the prevalence of posterior subcapsular changes for one or both eyes in the control group and the 100+ rad group by city, age, and sex. The prevalence of these lesions in the 100+ rad group in Hiroshima always was higher than that of the control groups in all age classifications, but this was not found in Nagasaki. The relative risk in the 100+ rad group by age ATE in Hiroshima was 13.8 for the under-40 age-group, 2.9 for the 40-49 age-group, 2.7 for the 50-59 age-group, 2.1 for the 60-69 age-group, and 1.4 for the 70+ age-group. The excess was highly significant for all groups other than the 70+ age-group ($P < .001$). The most remarkable risk was for the under-40 age-group.

Table 6 shows the relationship between corrected visual acuity and posterior subcapsular changes. The data are consistent with previous observations that development of posterior subcapsular changes as well as loss of visual acuity and accommodation are part of the normal aging

おける片眼又は両眼の後嚢下変化の発現率を都市，年齢及び性別に示したものである．広島では100rad以上群におけるこの病変の発現率は，すべての年齢区分において対照群よりも常に高かったが，長崎ではこのような傾向は認められなかった．広島の100 rad以上群における受診時年齢別の相対的危険度は，40歳未満群で13.8，40－49歳群で2.9，50－59歳群で2.7，60－69歳群で2.1，70歳以上群で1.4であった．70歳以上群以外のすべての年齢群において，この過剰リスクは高い有意差を認めた（$p < .001$）．最も顕著なリスクは40歳未満群であった．

表6は矯正視力と後嚢下変化との関係を示したものである．このデータは視力及び調節力の喪失と同様に，後嚢下変化の発現が正常な老化過程の一環であるという過去の所見と一致している．このデータはまた，

TABLE 7 PERCENTAGE OF SUBJECTS WITH REFRACTIVE ERROR EXCEEDING 1.00 DIOPTER ASSOCIATED WITH POSTERIOR SUBCAPSULAR CHANGES BY CITY, AGE ATE, AND DOSE

表7　後嚢下変化を有する対象者で，屈折誤差が屈折度1.00を越える百分率，都市，受診時年齢及び線量別

Age ATE	Refractive Error Exceeding 1.00 Diopter	Total			Posterior Subcapsular Changes								
					None			Small			Moderate and Large		
		Control	100+ rad	1-99 rad	Control	100+ rad	1-99 rad	Control	100+ rad	1-99 rad	Control	100+ rad	1-99 rad
					Hiroshima								
<50	Examined	219	209	6	207	165	4	11	41	2	1	3	0
	%	26.9	29.2	16.7	24.6	26.7	.0	63.6	41.5	100.0	100.0	.0	.0
50-59	Examined	244	256	16	222	190	13	19	62	3	3	4	0
	%	40.6	40.2	56.3	41.0	37.9	46.2	31.6	45.2	100.0	66.7	75.0	.0
60+	Examined	289	281	19	218	168	14	64	95	5	7	18	0
	%	50.9	47.3	52.6	47.2	49.4	50.0	59.4	42.1	60.0	85.7	55.6	.0
Total	Examined	752	746	41	647	523	31	94	198	10	11	25	0
	%	40.6	39.8	48.8	37.9	38.0	41.9	54.3	42.9	70.0	81.8	52.0	.0
					Nagasaki								
<50	Examined	131	140	12	126	134	10	2	5	2	3	1	0
	%	38.9	26.4	33.3	38.9	25.4	20.0	.0	60.0	100.0	66.7	.0	.0
50-59	Examined	125	114	8	118	105	7	5	7	1	2	2	0
	%	44.8	55.3	25.0	41.5	55.2	14.3	100.0	57.1	100.0	100.0	50.0	.0
60+	Examined	88	82	7	62	51	6	22	27	1	4	4	0
	%	51.1	62.2	83.3	50.0	64.7	50.0	50.0	51.9	100.0	75.0	100.0	.0
Total	Examined	344	336	27	306	290	23	29	39	4	9	7	0
	%	44.2	44.9	37.0	42.2	43.1	26.1	55.2	53.8	100.0	77.8	71.4	.0

processes. The data also indicate that the greatest evidence of a possible radiation-induced increased aging effect, as manifested by the occurrence of posterior subcapsular changes, is present in Hiroshima individuals aged 33-49 ATE (i.e., aged <15 ATB). With regard to posterior subcapsular changes an evaluation was made for the <50, 50-59, and 60+ ATE age-groups in a fashion similar to that made for axial opacities. The relative risk for the 100+ rad group in comparison to controls was 3.9 for the 33-49 ATE age-group, 2.7 for the 50-59 ATE age-group, and 1.6 for the 60+ ATE age-group. These values are highly significant below the 1% level. Comparisons between these groups and older exposed persons also were made for evidence of an age-related synergistic effect. The CRR for the relative risks of the <50 and 60+ ATE age-groups was 2.4. This value is consistent with radiation enhancement of aging effect for posterior subcapsular change in the <50 ATE age-group ($P < .01$). The CRR for

後嚢下変化の発生に示されるように，放射線誘発性と思われる加齢促進効果の最も明瞭な証拠が，広島の受診時年齢33—49歳群（すなわち原爆時年齢15歳未満）に認められることを示している．受診時50歳未満群，50—59歳群及び60歳以上群に対して，後嚢下変化に関する評価が軸性混濁と同様の方法で行われた．対照群と比較して100rad 以上群の相対的危険度は，受診時33—49歳群で3.9，受診時50—59歳群で2.7，受診時60歳以上群で1.6であった．これらの値は1%水準以下で高い有意差がある．相乗的年齢効果を観察するために，これらの群と高年齢被爆群を比較した．診察時50歳未満群及び60歳以上群の相対的危険度の比較値は2.4である．この値は診察時50歳未満群における後嚢下変化に対する加齢の影響が，放射線により増加することに一致する（$p < .01$）．診察時60歳

the relative risk of the 50-59 ATE age-group in comparison to the 60+ ATE age-group was 1.7. The value is significant at the 5% level.

The relationship between posterior subcapsular changes and both visual acuity and refractive error was examined by city, age, and dose (Tables 6 and 7). There is a close correlation between visual acuity and the degree of posterior subcapsular change as judged from the percentage distribution of persons whose corrected visual acuities were less than 0.6. These observations, however, are qualified since few persons had moderate or large posterior subcapsular changes. The frequency of occurrence of both reduced visual acuity and subcapsular changes increased with age. No significant differences in reduced visual acuity for persons with the same degree of posterior subcapsular change in the control and 100+ rad groups were noted, however. The percentage of persons whose refractive error was exceeding 1.00 diopter increased with age. An age relationship for posterior subcapsular changes, however, was not suggested (Table 7).

Other Lens Opacities and Findings. Tables 8 and 9 show the occurrence rates for persons in the study with cortical and nuclear opacities. A remarkable increase in both types of opacities is observed with age. Differences in the prevalence of these lesions for the 100+ rad and control groups by city, age, and sex are not remarkable. The prevalence of other findings by city and radiation dose in the current ophthalmologic examinations is shown in Figure 1. None appear to be radiation related.

DISCUSSION

Radiation damage to the human lens usually appears after a latent period of several months to several years. Sometimes radiation-related changes first appear during later life. The latent period for lens opacities from the time of treatment with X- or gamma-radiation to the time of appearance has varied from six months to 35 years, with an approximate average of 2 to 3 years.[7-9] In 1975 Marriam and Szechter[10] investigated the effect of age on the development of radiation cataracts in the lenses of rats. They made three interesting observations: 1) with doses of about 200-300 rad the early lens changes occurred sooner and progressed faster in the adult lenses than in the lenses of

以上群と比較して50—59歳群の相対的危険度の比較値は1.7であった．この値は5％水準で有意である．

後嚢下変化と視力及び屈折誤差との関係を都市，年齢及び線量別に検討した（表6及び7）．矯正視力が0.6以下である人の百分率分布から判断すると，視力と後嚢下変化の度合いには密接な相関関係がある．しかしながら，中程度又は強度の後嚢下変化を有する対象者はほとんどいないので，上記の所見は限定された結果である．視力の低下と後嚢下変化の両発現頻度は年齢とともに増加した．しかし対照群及び100rad以上群において，同程度の後嚢下変化を有する者では視力低下に有意な差異は認められなかった．1.00屈折度を超える屈折誤差は年齢とともに増加した．しかしながら，後嚢下変化の年齢との関係は示唆されなかった（表7）．

その他の水晶体混濁及び所見． 表8及び9には，本調査における皮質及び核の混濁を有する対象者の発現率を示した．加齢に伴って両種の混濁に顕著な増加が認められる．100rad以上群と対照群におけるこれらの病変の都市，年齢及び性別発現率の差異は顕著ではない．今回の眼科学的調査におけるその他の所見の都市及び放射線量別発現率を図1に示した．いずれも放射線との関連は示唆されない．

考　察

ヒトの水晶体に対する放射線障害は，通常数か月ないし数か年の潜伏期間を経て発現する．しばしば，放射線関連の変化は後年になって初めて現れる．X線又はガンマ線治療時から水晶体混濁発現時までの潜伏期間は，6か月から35年にわたり，平均して約2ないし3年である．[7-9] 1975年にMarriamとSzechter[10]は，ラットの水晶体における放射線白内障の発生に対する年齢の影響を調査した．彼らは次の三つの興味深い観察を行っている．すなわち 1) 200—300radの線量では，初期水晶体変化は若年ラットの水晶体よりも成長したラットの水晶体に早く発現し，

TABLE 8 PREVALENCE OF CORTICAL OPACITIES IN CONTROL GROUP AND 100+ RAD GROUP BY CITY, AGE, AND SEX

表 8　対照群及び100 rad 以上群の皮質混濁の発現率，都市，年齢及び性別

Age ATE	Control			(1-99 rad)	Index (100+ rad)			χ^2 value
	Examined	Positive	Prevalence %	(Prevalence only %)	Examined	Positive	Prevalence %	
				HIROSHIMA				
				Sexes Combined				
<40	55	0	.0		64	3	4.7	2.64 NS
40-49	164	13	7.9		146	20	13.7	2.71 NS
50-59	242	36	14.9		256	54	21.1	3.25 Sug
60-69	144	49	34.0		148	72	48.6	6.43 *
70 +	156	123	78.8		143	103	72.0	1.88 NS
Total	761	221	29.0	(22.0)	757	252	33.3	3.19 Sug
				Male				
<40	24	0	.0		29	1	3.4	.84 NS
40-49	64	4	6.3		51	7	13.7	1.83 NS
50-59	61	6	9.8		99	16	16.2	1.27 NS
60-69	37	11	29.7		49	18	36.7	.46 NS
70 +	69	53	76.8		63	47	74.6	.09 NS
Total	255	74	29.0	(7.1)	291	89	30.6	.16 NS
				Female				
<40	31	0	.0		35	2	5.7	1.83 NS
40-49	100	9	9.0		95	13	13.7	1.07 NS
50-59	181	30	16.6		157	38	24.2	3.04 Sug
60-69	107	38	35.5		99	54	54.5	7.54 **
70 +	87	70	80.5		80	56	70.0	2.46 NS
Total	506	147	29.1	(25.9)	466	163	35.0	3.92 *
				NAGASAKI				
				Sexes Combined				
<40	31	1	3.2		30	3	10.0	1.14 NS
40-49	101	6	5.9		110	12	10.9	1.67 NS
50-59	125	20	16.0		113	19	16.8	.03 NS
60-69	50	24	48.0		49	24	49.0	.01 NS
70 +	43	40	93.0		34	29	85.3	1.22 NS
Total	350	91	26.0	(33.3)	336	87	25.9	.001 NS
				Male				
<40	13	0	.0		17	2	11.8	1.64 NS
40-49	48	3	6.3		45	6	13.3	1.33 NS
50-59	44	6	13.6		40	3	7.5	.82 NS
60-69	25	10	40.0		21	8	38.1	.02 NS
70 +	18	16	88.9		21	17	81.0	.47 NS
Total	148	35	23.6	(33.3)	144	36	25.0	.07 NS
				Female				
<40	18	1	5.6		13	1	7.7	.06 NS
40-49	53	3	5.7		65	6	9.2	.53 NS
50-59	81	14	17.3		73	16	21.9	.53 NS
60-69	25	14	56.0		28	16	57.1	.01 NS
70 +	25	24	96.0		13	12	92.3	.23 NS
Total	202	56	27.7	(33.3)	192	51	26.6	.07 NS

See Footnote Table 4. 表 4 の脚注参照

TABLE 9 PREVALENCE OF NUCLEAR OPACITIES IN CONTROL GROUP AND 100+ RAD GROUP BY CITY, AGE, AND SEX

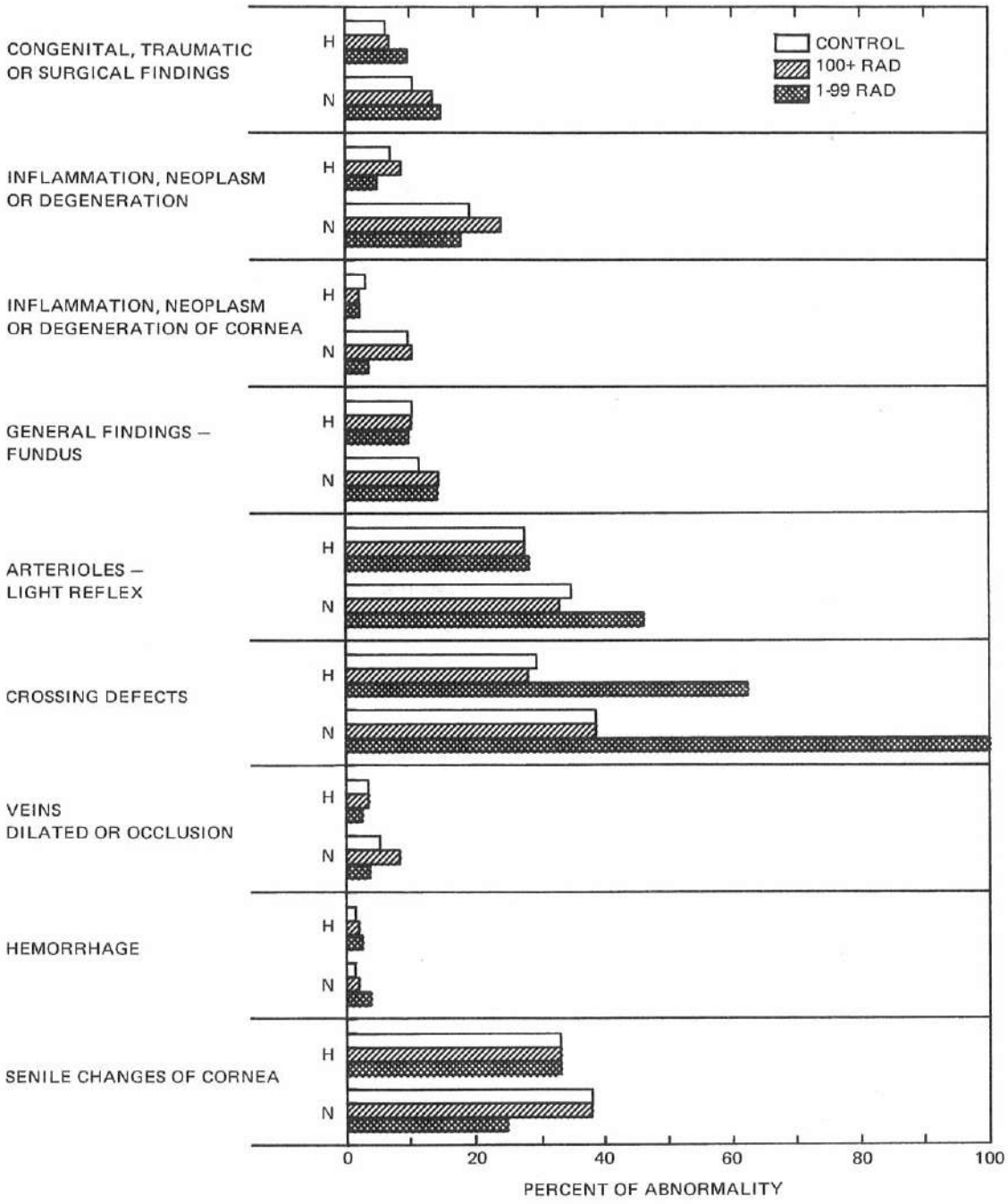
表 9　対照群及び100 rad 以上群の核混濁発現率，都市，年齢及び性別

Age ATE	Control			(1-99 rad)	Index (100+ rad)			χ^2 value
	Examined	Positive	Prevalence %	(Prevalence only %)	Examined	Positive	Prevalence %	
				HIROSHIMA				
				Sexes Combined				
<40	55	2	3.6		64	2	3.1	.02 NS
40-49	162	6	3.7		144	6	4.2	.04 NS
50-59	240	12	5.0		252	12	4.8	.02 NS
60-69	142	43	30.3		144	38	26.4	.53 NS
70 +	149	98	65.8		134	71	53.0	4.80 *
Total	748	161	21.5	(17.1)	738	129	17.5	3.87 *
				Male				
<40	24	0	.0		29	0	.0	–
40-49	61	2	3.3		50	1	2.0	.17 NS
50-59	61	4	6.6		96	4	4.2	.44 NS
60-69	35	12	34.3		48	7	14.6	4.45 *
70 +	63	43	68.3		57	27	47.4	5.37 *
Total	244	61	25.0	(7.1)	280	39	13.9	10.35 **
				Female				
<40	31	2	6.5		35	2	5.7	.02 NS
40-49	101	4	4.0		94	5	5.3	.20 NS
50-59	179	8	4.5		156	8	5.1	.08 NS
60-69	107	31	29.0		96	31	32.3	.26 NS
70 +	86	55	64.0		77	44	57.1	.79 NS
Total	504	100	19.8	(22.2)	458	90	19.7	.01 NS
				NAGASAKI				
				Sexes Combined				
<40	32	0	.0		30	0	.0	–
40-49	101	4	4.0		108	4	3.7	.01 NS
50-59	126	8	6.3		111	5	4.5	.39 NS
60-69	50	12	24.0		49	9	18.4	.47 NS
70 +	43	34	79.1		33	26	78.8	.001 NS
Total	352	58	16.5	(14.8)	331	44	13.3	1.36 NS
				Male				
<40	14	0	.0		17	0	.0	–
40-49	48	2	4.2		44	2	4.5	.01 NS
50-59	44	3	6.8		40	2	5.0	.12 NS
60-69	25	3	12.0		21	3	14.3	.05 NS
70 +	18	12	66.7		21	15	71.4	.10 NS
Total	149	20	13.4	(16.7)	143	22	15.4	.23 NS
				Female				
<40	18	0	.0		13	0	.0	–
40-49	53	2	3.8		64	2	3.1	.04 NS
50-59	82	5	6.1		71	3	4.2	.27 NS
60-69	25	9	36.0		28	6	21.4	1.38 NS
70 +	25	22	88.0		12	11	91.7	.11 NS
Total	203	38	18.7	(13.3)	188	22	11.7	3.70 Sug

See Footnote Table 4. 表 4 の脚注参照

FIGURE 1 PREVALENCE OF OTHER ABNORMAL FINDINGS BY DOSE AND CITY

図 1　他の幾つかの異常所見の発現率，線量及び都市別



the young, 2) at doses of about 300-900 rad opacities developed sooner in young lenses, but progression was faster and severe opacities developed sooner in adult lenses, and 3) at about 900 rad cataracts appeared sooner in young lenses and progressed faster to severe opacification. Their data, however, could not statistically support the hypothesis that the lenses of young persons are more sensitive to radiation than are those of older persons. Thirty-five of 233 cases studied by Langham[11] in 1967 had received high intensity doses that ranged from 23 to 2,400 rad. No opacities were observed with doses of less than 200 rad. There were two cases of minimum stationary opacities found at an estimated dose of 200 rad. For all doses above 200 rad some patients showed a degree of opacification which increased with increasing dose. In a reanalysis of the lenticular opacity data obtained by Miller et al[4] in 1963-64, the "best" model with two thresholds (linear gamma and linear neutron) in the statistical sense yielded an estimated gamma threshold of 147 rad (95% confidence intervals, 59-248 rad), a value very similar to that commonly conjectured.[12]

Two of the problems addressed in this study were whether the lenses of young persons are particularly susceptible to radiation aging and whether there is an excess risk of lenticular opacities at doses less than 200 rad. A remarkable increase of abnormal lens findings was observed with age. The development of lenticular opacities and the loss of both visual acuity and accommodation, as observed in the present study, have been established to be part of the normal aging process. Trends for the development of axial opacities and posterior subcapsular changes suggest a relatively stronger aging effect for persons exposed early rather than late in life in Hiroshima, but not in Nagasaki.

The prevalence of axial opacities and posterior subcapsular changes in exposed persons and their controls was evaluated by age and radiation dose (Tables 10-13). In all three age-groups, the risk of opacities in the 300+ rad group was significantly higher than that for the controls (Table 12). The relative risk of axial opacification was 4.8 in the <50 age-group, 2.3 in the 50-59 age-group, and 1.4 in the 60+ age-group. In order to evaluate lenticular radiosensitivity in relationship to age, a CRR between the younger

より速く進行した．2) 300－900rad の線量では，混濁は若年ラットの水晶体に早く発現したが，成長したラット水晶体の方が混濁の進行が速く，しかも強度の混濁が早期に発現した．3) 900 rad 前後では，白内障は若年ラットの水晶体により早期に発現し，より速く強度の混濁化が進行した．しかしながら，彼らのデータは若年齢層の水晶体の方が，高年齢層の水晶体より放射線に対する感受性が高いという仮説を統計的に支持することはできなかった．1967年に Langham[11] により研究された233例中35例は，23 rad から 2,400 rad にわたる高線量照射を受けた．200 rad 以下の線量では水晶体混濁は認められなかった．推定線量 200 rad で 2例に極小の不変性混濁が認められた．200rad 以上の線量に被曝した一部の者において，混濁が線量とともに増加した．1963－64年に Miller ら[4] によって得られた水晶体混濁に関するデータを再解析した．統計的意味での二つの閾値（線型ガンマ線及び線型中性子線）を含む"最適"モデルによると，推定されたガンマの閾値は147 rad（95%信頼区間：59－248rad）であり，一般に推測した値に極めて近かった![12]

本研究において取り上げた二つの問題は，若年齢層の水晶体が放射線による加齢に対して特に感受性が高いかどうか，また，200 rad 以下の線量において水晶体混濁の過剰リスクが認められるかどうかという点であった．年齢の増加とともに水晶体異常所見に顕著な増加を認めた．本研究に見られた水晶体混濁の発現並びに視力及び調節力の低下は，正常な加齢過程の一環であることが認められた．軸性混濁及び後嚢下変化の発現傾向は，広島においては，高年齢被爆群よりも若年齢被爆群で比較的強度の加齢影響を示唆するが，長崎の場合このような所見は得られなかった．

被爆群及びその対照群における軸性混濁並びに後嚢下変化の発現率を，年齢及び放射線量別に評価した（表10－13）．三つの年齢群すべてにおいて，300 rad 以上群の混濁リスクは対照群の場合よりも有意に高い（表12）．軸性混濁の相対的危険度は，50歳未満群では 4.8，50－59歳群で 2.3，60歳以上群で1.4であった．水晶体の放射線感受性と年齢との関係を

TABLE 10 PREVALENCE OF AXIAL OPACITIES BY DOSE AND AGE, HIROSHIMA

表10 軸性混濁の発現率，線量及び年齢別，広島

Dose Group (rad)	Mean Dose in rad			Total			<50 years old			50-59 years old			60+ years old		
	Total	Gamma	Neutron	Examined	Positive	%	Examined	Positive	%	Examined	Positive	%	Examined	Positive	%
Control	0	0	0	754	153	20.3	219	11	5.0	243	27	11.1	292	115	39.4
100-199	140.9	110.2	30.7	388	78	20.1	105	6	5.7	125	12	9.6	158	60	38.0
200-299	246.0	186.2	59.8	149	43	28.9	38	4	10.5	51	7	13.7	60	32	53.3
300-499	379.3	279.5	99.8	142	47	33.1	42	10	23.8	54	11	20.4	46	26	56.5
500-600*	576.6	414.4	162.2	76	29	38.2	25	6	24.0	28	10	35.7	23	13	56.5
(300-600*)	(448.0)	(326.5)	(121.5)	(218)	(76)	(34.9)	(67)	(16)	(23.9)	(82)	(21)	(25.6)	(69)	(39)	(56.5)
Total	–	–	–	1509	350	23.2	429	37	8.6	501	67	13.4	579	246	42.5

**Dose estimate in Hiroshima for those exceeding 600 rad total dose was arbitrarily set at 428 rad of gamma and 172 rad of neutron.*

広島における総線量600 rad 以上の対象者の推定線量は，任意にガンマ線428 rad，中性子線172 rad とした

TABLE 11 PREVALENCE OF POSTERIOR SUBCAPSULAR CHANGES BY DOSE AND AGE, HIROSHIMA

表11 後嚢下変化の発現率，線量及び年齢別，広島

Dose Group (rad)	Mean Dose in rad			Total			< 50 years old			50-59 years old			60+ years old		
	Total	Gamma	Neutron	Examined	Positive	%	Examined	Positive	%	Examined	Positive	%	Examined	Positive	%
Control	0	0	0	748	107	14.3	220	12	5.5	243	23	9.5	285	72	25.3
100-199	141.0	110.1	30.9	384	88	22.9	105	16	15.2	125	21	16.8	154	51	33.1
200-299	245.7	186.0	59.7	146	47	32.2	38	9	23.7	49	14	28.6	59	24	40.7
300-499	379.9	280.0	99.9	139	57	41.0	41	11	26.8	54	20	37.0	44	26	59.1
500-600*	576.3	414.2	162.1	75	32	42.7	25	8	32.0	28	11	39.3	22	13	59.1
(300-600*)	(444.9)	(325.5)	(119.4)	(214)	(89)	(41.6)	(66)	(19)	(28.8)	(82)	(31)	(37.8)	(66)	(39)	(59.1)
Total	–	–	–	1492	331	22.2	429	56	13.1	499	89	17.8	564	186	33.0

See Footnote Table 10. 表10の脚注参照

TABLE 12 RELATIVE RISK BY AGE-GROUP AND COMPARISON OF RELATIVE RISKS BETWEEN YOUNGER AGE-GROUPS AND OLDEST AGE-GROUP FOR AXIAL OPACITIES, HIROSHIMA

表12 軸性混濁の年齢群別相対的危険度並びに若年齢群及び高年齢群の相対的危険度の比較，広島

Dose Group (rad)	< 50 years old				50-59 years old				60+ years old		
	RR	χ^2	CRR	χ^2	RR	χ^2	CRR	χ^2	RR	χ^2	CRR
100-199	1.14	.07 NS	1.18	.11 NS	.86	.20 NS	.90	.10 NS	.96	.09 NS	1.00
200-299	2.10	1.77 NS	1.55	.58 NS	1.24	.29 NS	.91	.05 NS	1.35	4.63 *	1.00
300+	4.75	18.15 ***	3.31	9.54 **	2.30	10.20 **	1.61	2.65 NS	1.44	7.95 **	1.00

RR – Relative risk 相対的危険度　　*CRR – Comparison of relative risks* 相対的危険度比較値

TABLE 13 RELATIVE RISK BY AGE-GROUP AND COMPARISON OF RELATIVE RISKS BETWEEN YOUNGER AGE-GROUPS AND OLDEST AGE-GROUP FOR POSTERIOR SUBCAPSULAR CHANGES, HIROSHIMA

表13 後嚢下変化の年齢群別相対的危険度並びに若年齢群及び高年齢群の相対的危険度の比較，広島

Dose Group (rad)	< 50 years old				50-59 years old				60+ years old		
	RR	χ^2	CRR	χ^2	RR	χ^2	CRR	χ^2	RR	χ^2	CRR
100-199	2.79	8.01 **	2.13	3.69 Sug	1.77	4.17 *	1.35	.90 NS	1.31	3.12 Sug	1.00
200-299	4.34	13.18 ***	2.70	4.95 *	3.02	13.50 ***	1.87	3.15 Sug	1.61	6.46 *	1.00
300+	5.28	23.80 ***	2.26	4.83 *	3.99	32.27 ***	1.71	3.57 Sug	2.34	34.60 ***	1.00

See Footnote Table 12 表12の脚注参照

age-groups and the oldest age-group was made for persons exposed to 300+ rad. The observed CRR of 3.3 for the youngest age-group suggests an increased radiation-induced aging effect in heavily exposed persons who were aged <15 ATB. A similar effect could not be demonstrated in the young persons belonging to either the 100-199 or 200-299 rad groups. The same analyses of relative risks and CRR also were made for posterior subcapsular changes (Table 13). The results indicate that the relative risk of developing posterior subcapsular changes for persons aged 33-49 ATE is significantly increased to 2.8 in the 100-199 rad group, 4.3 in the 200-299 rad group, and 5.3 in the 300+ rad group. A similar significant relative risk also was noted in the 50-59 and 60+ age-groups. The strong radiosensitive aging effect, however, was more evident in the exposed young persons than in those aged 60+ for both the 200-299 and 300+ rad groups. There was also, a suggestive aging effect for persons aged 50-59 in the 200-299 and 300+ rad groups.

評価するために，300 rad 以上で被曝した若年齢群と高年齢群の相対的危険度の比較を行った．若年齢群における観察相対的危険度の比較値が3.3であるということは，原爆時年齢15歳未満の高線量被爆者に放射線誘発性加齢影響の増加を示唆している．100－199rad 又は200－299rad 群に属する若年齢者には同様の影響は認められなかった．後嚢下変化に対しても同様の相対的危険度及び比較値の解析を行った（表13）．その結果，受診時33－49歳群に後嚢下変化が発生する相対的危険度は100－199rad 群で2.8，200－299rad 群で4.3，300 rad 以上群で5.3とそれぞれ有意に増加している．50－59歳群及び60歳以上群にも，同様に有意な相対的危険度が認められた．しかし，200－299rad 及び300 rad 以上の両群において，強度の放射線感受性加齢影響は，60歳以上群よりも若年齢群においてより顕著に認められる．また，200－299rad 群及び300 rad 以上群の50－59歳の対象者にも加齢影響が示唆された．

It is unclear as to why a stronger aging effect appears to be present in the exposed survivors in the 33-49 ATE age-group in Hiroshima but not in Nagasaki. Some of the possible explanations include observer bias or qualitative differences in types of radiation exposure in the two cities.

In the Framingham Eye Study[13,14] about 45% of the population aged 75-85 had at least one eye aphakic or with senile cataract and associated visual disability. The results of the Framingham Eye Study have been compared with fragmentary information of a similar type from other areas of the world. It was emphasized that very little useful similar data are available but that the prevalence of these disorders varies widely in different parts of the world. The Framingham Eye Study Monograph[15] described selected findings with respect to cataract, glaucoma, diabetic retinopathy, and macular degeneration in a general population of 2,631 adults.

It has not been possible to conduct a study at RERF which is completely comparable to that of the Framingham Eye Study. However, for lenticular opacities and posterior subcapsular changes, the current study yielded results very similar to the results observed between 1963-64 (Appendix 4). About 67% of the ophthalmologic examinations in Nagasaki were conducted by one ophthalmologist. In Hiroshima, eight ophthalmologists were engaged in the determination of the lens findings. A large number of subjects had to be dropped from the ophthalmologic examination schedules in both cities due to the fact that there was only half-time ophthalmologic coverage in Hiroshima and even less in Nagasaki. These losses, however, in the control and 100+ rad groups do not change systematically with increasing age by city. For small axial opacities and small posterior subcapsular changes, observer variability among the ophthalmologists in the study was large. The examinations in both cities were conducted by ophthalmologists who had no knowledge of the individual's radiation exposure history.

Appendix 4 lists the Master File number by age, sex, and radiation dose of all examinees with axial opacities or posterior subcapsular changes in either or both the 1963-64 study or the present study. Data on corrected visual acuity, refraction, astigmatism, and accommodation also

強度の加齢影響が広島の受診時33—49歳群の被爆者に発現しながら，長崎では発現しない理由については明らかではない．考えられる説明としては観察者による偏り，あるいは両市の放射線の種類の質的差異が挙げられる．

Framingham眼科調査[13,14]では，75—85歳群の約45%が少なくとも片眼に無水晶体症又は老人性白内障があり，視力障害を伴うことが認められた．Framingham眼科調査の結果は，世界の他地域で行われた同種調査の断片的な資料と比較されている．有用である同様な資料はほとんど入手されていない上，これらの障害の発現率は，世界の各地域で大きく異なることが強調されている．Framingham眼科調査報告集[15]は，2,631人の一般人口集団の対象者に見られる白内障，緑内障，糖尿病性網膜症並びに黄斑部変性に関する選択的所見を述べている．

Framingham眼科調査に完全に匹敵する調査を放影研で行うことは不可能であった．しかしながら水晶体混濁及び後嚢下変化に関しては，本調査で得られた結果は1963—64年に観察されたものと非常に類似している（付録4）．長崎における眼科学的調査の約67%が1人の眼科医によって行われた．広島では8人の眼科医が水晶体所見の確認に従事した．眼科学的検査は広島で毎日半日，長崎ではそれ以下の割合でしか行われなかったので，両市で多くの対象者が同検査を受けることができなかった．しかし，対照群及び100 rad以上群におけるこのような調査対象者の損失は，都市別に年齢の増加に伴って系統的に変化していない．微小の軸性混濁及び後嚢下変化については，眼科医間の差異は大きかった．両市の検査で，眼科医は対象者の放射線被曝歴に関しては何の知識ももたずに検査した．

付録4は，1963—64年の調査と今回の調査の両方，又は一方において軸性混濁あるいは後嚢下変化が認められた被検者全員の原簿記録番号を年齢，性，放射線量別に示したものである．矯正視力，屈折，乱視

are included. The proportion of persons who did not have posterior subcapsular changes to all cases with any axial opacity was 32% in Hiroshima and 44% in Nagasaki. However, it is noted that almost all were persons with a small opacity only.

及び調節力に関するデータも含まれている．後嚢下変化をもたない対象者と，何らかの軸性混濁を有する全例との比率は，広島では32%，長崎では44%であった．しかしながら，そのほとんどの対象例は微小の混濁のみを有していた．

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APPENDIX 付録 1a

OPH. Exam. Not Done ☐

OPHTHALMOLOGY RECORD 眼科記録

1. Acuity

OD	OS	
0	0	1.0 or better
1	1	0.8-0.9
2	2	0.6-0.7
3	3	0.4-0.5
4	4	0.2-0.3
5	5	0.1-0.19
6	6	0.05-0.09
7	7	C.F. or H.M.
8	8	L.P.
9	9	No L.P.
X	X	Pinhole acuity
b	b	Not recorded

2. Refraction

OD	OS	
0	0	Plano to 1.00
1	1	1.12 to 3.00
2	2	3.12 to 5.00
3	3	5.12 to 7.00
4	4	7.12 to 9.00
5	5	9.12 to 11.00
6	6	11.12 to 15.00
7	7	15.12 to 18.00
8	8	18.12 plus
9	9	Can't determine
–	–	Minus sign
b	b	Not recorded

3. Astigmatism- (Plus cylinder)

OD	OS	
0	0	<0.5
1	1	0.5-1.00
2	2	1.01-2.00
3	3	2.01-3.00
4	4	3.01-5.00
5	5	>5.01
9	9	Can't determine
b	b	Not recorded

4. Accommodation OU (Dioptors)

A	≤0.50	M	7.01-7.50
B	0.51 to 1.00	N	7.51-8.00
C	1.01 to 1.50	O	8.00-8.50
D	1.51 to 2.00	P	8.51-9.00
E	2.01 to 2.50	Q	9.01-9.50
F	2.51 to 3.00	R	9.51-10.00
G	3.01 to 3.50	S	10.01-10.50
H	3.51 to 4.00	T	10.51-11.00
I	4.01 to 5.00	U	11.01-11.51
J	5.01 to 5.50	V	11.51-12.00
K	6.01 to 6.50	W	≥12.01
L	6.51 to 7.00	X	Can't determine

5. Tension(5.5gms)

OD	OS	
0	0	≤ 10
1	1	11
2	2	12
3	3	13
4	4	14
5	5	15
6	6	17
7	7	18
8	8	20
9	9	22
X	X	24
V	V	≥ 25

6. Congenital, Traumatic, Surgical

0 No abnormalities
1 Lid or orbit
2 Conjunctive or cornea
3 Iris or pupil
4 Lens or vitreous
5 Retina or optic nerve
6 Macula
7 Neuromuscular
8 Absence or gross deformity of eye
9 More than one of positions 1-7
X Other abnormality
V Heterochromia
b Not recorded

7. Inflammation, Neoplasm, Degeneration

0 No abnormality
1 Lid or orbit
2 Naso-lacrimal system
3 Conjunctiva
4 Cornea
5 Uvea
6 Retina
7 Macula
8 Nerve head
9 Neuromuscular
X More than one of positions 1-8
V Other abnormality
b Not recorded

OPHTHALMOSCOPE

8. Cortical or Nuclear Opacities

0 None

OD
1 Slight
2 Moderate

OS
3 Slight
4 Moderate

Both eyes
5 Slight
6 Moderate
7 One slight, one moderate

X Poor or absent red reflex
b Not recorded

9. Axial Opacities

OD	OS	
0	0	None
1	1	Slight
2	2	Moderate
3	3	Large
4	4	'Do-nut'
b	b	Not recorded

SLIT LAMP

10. General Findings

OD	OS	
0	0	Normal lens
1	1	Aphakia
2	2	Subluxation
3	3	Luxation
4	4	Anterior capsular poly-chromatic sheen
5	5	Other
b	b	Not recorded

11. Cortical Opacities

Development

OD	OS	
0	0	None
1	1	Incipient
2	2	Immature
3	3	Mature
4	4	Hypermature
X	X	Congenital
b	b	Not recorded

Type

OD	OS	
0	0	None
1	1	Few or moderate
2	2	Many

Coronary

OD	OS	
3	3	Few or moderate
4	4	Many
5	5	Positions 1 and 3 above
6	6	Positions 1 and 4 above
7	7	Positions 2 and 3 above
8	8	Positions 2 and 4 above
X	X	Flakes
b	b	Not recorded

11. Cortical Opacities (Continued)

Type

OD	OS	
0	0	None
1	1	Lamellar sep. or water clefts
2	2	Cloud-like or radial
3	3	Both 1 and 2 above
X	X	Anterior sub-capsular opacity
V	V	Anterior 'Disjunction' opacity
b	b	Not recorded

12. Nuclear Opacities

OD	OS	
0	0	None
1	1	Slight
2	2	Moderate
3	3	Brunescent
4	4	Other
X	X	Congenital
b	b	Not recorded

13. Posterior Subcapsular Changes

Size

OD	OS	
0	0	None
1	1	Equivocal
2	2	Minimal (<1.0 mm)
3	3	Small (1.0 to 2.4 mm)
4	4	Moderate (2.5 to 4.9 mm)
5	5	Large (>5.0 mm)
b	b	Not recorded

Type

OD	OS	
0	0	None
1	1	Polychromatic sheen
2	2	Polychromatic granular sheen
3	3	Flat plaque
4	4	Projects into posterior cortex
5	5	'Disjunction' zone
6	6	'Bi-valve'
X	X	Indistinct margins
V	V	Vacuoles
b	b	Not recorded

14. Pupil dilated

1 Yes
2 Patient refused
3 Contraindicated
b Not recorded

Page 1 of 2 pages — OPHTHALMOLOGY RECORD — MED 66 378

APPENDIX 付録 1b

OPHTHALMOLOGY RECORD 眼科記録

15. General Findings - Fundus

0 No abnormality
1 Abnormal pigmentation
2 Cotton wool exudate
3 Waxy ecudate
4 Edema residue
5 Cholesterol crystals
6 Combinations of positions 1-4
7 Other findings
8 Not seen adequately
X Abnormality-'indirect' scope
b Not recorded

16. Arterioles

Light reflex

0 Normal
1 Slight irregularity
2 Moderate irregularity
3 Marked irregularity or 'Copper wire'
X Occlusion central retinal artery or branch
b Not recorded

Crossing defects

0 None
1 Mild
2 Moderate
3 Severe
X Sheathing of arteriole
b Not recorded

17. Veins

0 Normal
1 Dilated
2 Occlusion
3 Combination of pos. 1 and 2
X Sheathing
b Not recorded

18. Hemorrhage

0 None
1 Flame
2 Punctate (Microaneurism)
3 Pre-retinal
4 White center
5 Flame and punctate
6 Flame and white center
7 Other hemorrhages
X Retinitis proliferans
b Not recorded

19. Cornea (Senile changes)

Arcus senilis

0 None
1 Early
2 Moderate
3 Marked
X Guttate changes
b Not recorded

20. Pertinent Health Questionnaire Items

Need glasses to read?
0 No answer
1 Yes
2 No

Need glasses for distance?
0 No answer
1 Yes
2 No

Vision ever blurred?
0 No answer
1 Yes
2 No

21. Examining Ophthalmologist

1 Takase
2 Mishima
3 Ogita
4 Sakata
5 Hasebe
6 Inoue
7 Kondo
8 Oinaka
9 Okimoto
b Not recorded

22. Findings

Dr. Miller R.J.

0 Normal
1 'RADIATION CATARACT'
2 Posterior sub-capsular vacuoles
3 Post-sub-capsular 'PLAQUES'

4 Findings 1 and 2 above
5 Findings 1 and 4 above
6 Findings 2 and 4 above
7 Findings 1,2 and 4 above
8 Other eye abnormalities
9 Other lens opacities
b Not recorded

23. Photography

1 Fundus photography
2 Anterior Segment Photography

Page 2 of 2 pages OPHTHALMOLOGY RECORD MED 66 378

APPENDIX 付録 2a

OPHTHALMOLOGY EXAMINATION 眼科検査

	without R 裸眼視力	with R 矯正視力	with pinhole ピンホールによる視力	with lens & pinhole レンズとピンホールによる視力
VOD	( )			
VOS	( )			

Old Glasses 現用眼鏡

V.a. 矯正視力

OD	D ⊃ cyl	DA.	( )
OS	D ⊃ cyl	DA.	( )

Amp Accom 調節力 OD / OS ⁻/c

Add = レンズ OD cm / OS cm

Corrected Amp = 調節幅 OD D / OS D

Hirshberg ヒルシュベルク検査

NPC 輻輳近点 cm

Skiascopy (Retinoscopy) 検影法

OD OS

Ocular Tension 眼圧

TOD: mmHg

TOS: mmHg

Eye ball 眼球	OD	N
	OS	N
Lids 眼瞼	OD	N
	OS	N
Conjunctiva 結膜	OD	N
	OS	N
Sclera 強膜	OD	N
	OS	N
Cornea 角膜	OD	N
	OS	N
Anterior Chamber 前房	OD	N
	OS	N
Iris 虹彩	OD	N
	OS	N
Pupil 瞳孔	OD	N
	OS	N

OD OS

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OPHTHALMOLOGY EXAMINATION

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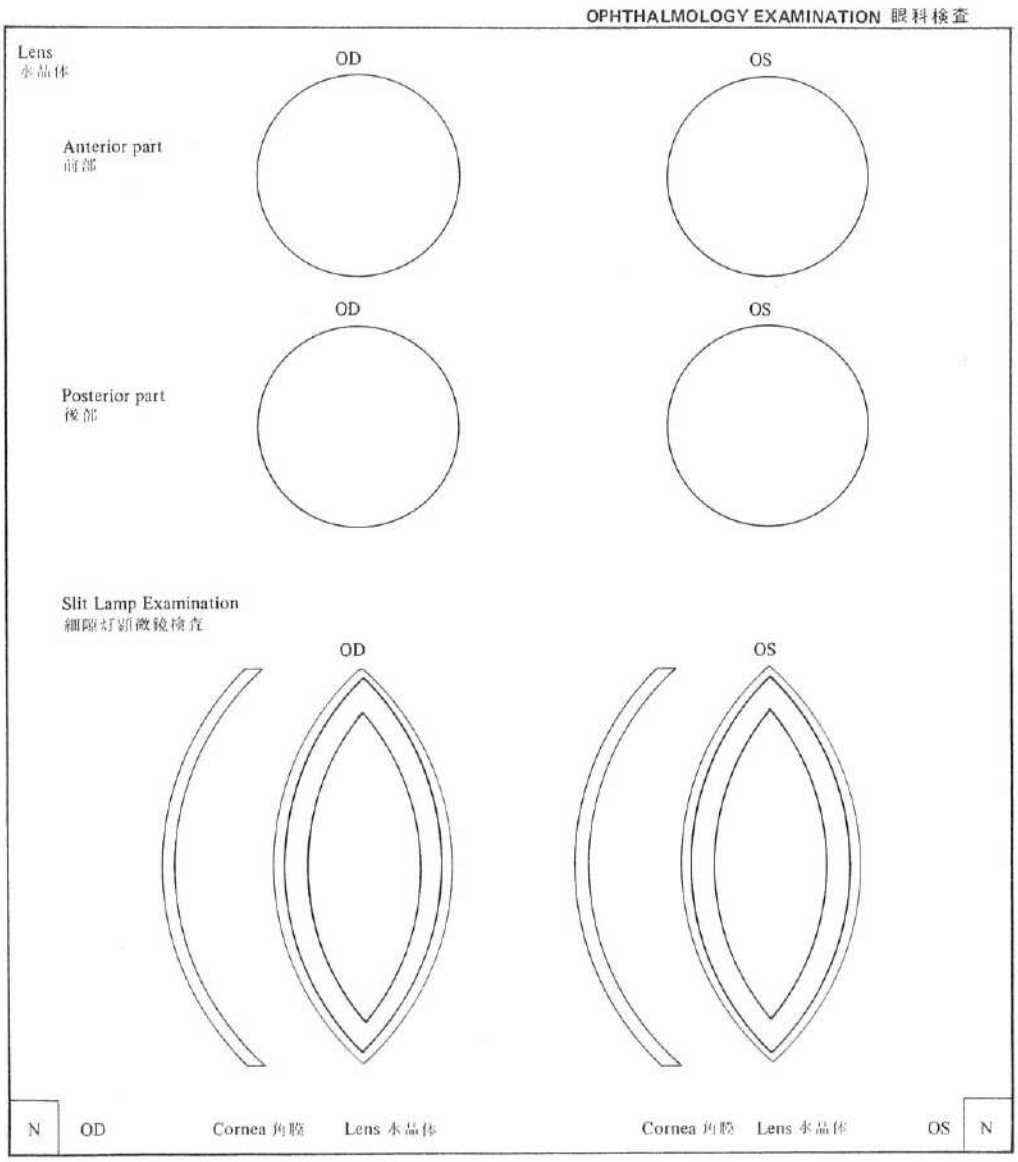
APPENDIX 付録 2b



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OPHTHALMOLOGY EXAMINATION

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APPENDIX 付録 2c

OPHTHALMOLOGY EXAMINATION 眼科検査

Vitreous
硝子体

OD N
OS N

Fundus 眼底

		OD		OS
Optic Disc 視神経乳頭 C/D Ratio	Horizontal 水平	/		Horizontal 水平 /
	Vertical 垂直	/	N	Vertical 垂直 / N
Vessels 血管			N	N
Retina 網膜			N	N
Macula 黄斑部			N	N

Other Examinations
その他の検査

Remarks
備考

Photograph 写真					Examiner 診察医師名
	Ant. Seg. 前眼部	Yes		No	
	Lens 水晶体	Yes		No	
	Fundus 眼底	Yes		No	

Page 3 of 3 pages

OPHTHALMOLOGY EXAMINATION

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APPENDIX 3 COMPARISON OF RELATIVE RISKS IN A 2 × 2 × 2 TABLE

付録3　2×2×2表における相対的危険度の比較

Let 2×2×2 contingency tables be denoted for i=1, 2 by

一つの2×2×2分割表をi＝1，2で示す．

Control	Exposed
x_{i1}	x_{i2}
$n_{i1} - x_{i1}$	$n_{i2} - x_{i2}$
n_{i1}	n_{i2}

We shall assume that the number of cases with any positive finding, x_{ij} (i, j=1, 2), has independently a binomial distribution with parameters n_{ij} and p_{ij} $(0<p_{ij}<1)$, where the subscripts i=1, 2 denote the younger age-group and the older age-group, respectively. The estimate, $\hat{\Psi}_i$, of the relative risk is defined by the ratio of rates as a measure of the degree of association between the control group and the exposed group, i.e.,

何らかの有所見の症例数，x_{ij}(i，j＝1，2)は，パラメーターn_{ij}及びp_{ij}($0<p_{ij}<1$)をもって二項分布に従うと仮定する(このとき，添え字i＝1，2は，若年齢群及び高年齢群を示す)．相対的危険度の推定値，$\hat{\Psi}_i$は，対照群と被爆群との関連度を測る量として異常率の比によって定義される．すなわち，

$$\hat{\Psi}_i = \frac{\hat{p}_{i2}}{\hat{p}_{i1}} \tag{1}$$

where $\hat{p}_{i1} = x_{i1}/n_{i1}$ and $\hat{p}_{i2} = x_{i2}/n_{i2}$.

ただし，$\hat{p}_{i1}=x_{i1}/n_{i1}$であり，$\hat{p}_{i2}=x_{i2}/n_{i2}$である．

We are interested in comparison of relative risk (CRR) between the younger age-group and older age-group, because there may be a difference in radiation sensitivity between the two age-groups. The estimate of CRR, $\hat{\Psi}$, is defined by the ratio of the relative risks, i.e.,

若年齢群と高年齢群の間に，放射線感受性に差異があるかもしれない両年齢群の相対的危険度の比較に興味がある．相対的危険度比較の推定値，$\hat{\Psi}$は，相対的危険度の比によって求められる．すなわち，

$$\hat{\Psi} = \frac{\hat{\Psi}_1}{\hat{\Psi}_2} \tag{2}$$

where $\hat{\Psi}_1$ is an estimate of relative risk in the younger age-group for i=1, and $\hat{\Psi}_2$ in the older age-group for i=2.

ただし，$\hat{\Psi}_1$は，i＝1における若年齢群の相対的危険度の推定値であり，$\hat{\Psi}_2$は，i＝2における高年齢群の相対的危険度の推定値である．

The logarithm of the estimated CRR (2) is expressed by

相対的危険度比較推定値(2)の対数は，

$$\hat{\lambda} = \log(\hat{\Psi}_1) - \log(\hat{\Psi}_2) \tag{3}$$

The asymptotic variance of the estimate $\hat{\lambda}$ of λ for $n \to \infty$ is given by

で与えられる．$n \to \infty$ における λ の推定値 $\hat{\lambda}$ の漸近分散は，

$$V(\hat{\lambda}) = \frac{(n_{11} - x_{11})}{n_{11} x_{11}} + \frac{(n_{12} - x_{12})}{n_{12} x_{12}} + \frac{(n_{21} - x_{21})}{n_{21} x_{21}} + \frac{(n_{22} - x_{22})}{n_{22} x_{22}} \tag{4}$$

Hence, the value of χ^2 under the hypothesis $H_0:\lambda=0$ when we have no difference between two groups, i.e.,

として求められる．したがって，両群に差がないとする仮説 $H_0:\lambda=0$ のもとでの χ^2 統計値は，

$$\chi^2 = \frac{\hat{\lambda}^2}{V(\hat{\lambda})} \tag{5}$$

has approximately chi-square distribution with one degree of freedom.

で，近似的に自由度1のカイ自乗分布に従う．

The quantity (5) is the same as the test statistic for the relative dominant lethal frequency introduced by Ratnayake[1] and Otake[2].

統計量(5)は，Ratnayake[1] 及び大竹[2] によって提示された相対的優性致死頻度の検定統計量と同じである．

REFERENCES TO APPENDIX 3
付録3の参考文献

1. RATNAYAKE WE: Effects of storage on dominant lethals induced by alkylating agents (triethylene melamine and ethyleneimine). Mutat Res 5:271-78, 1968

2. OTAKE M: Comparison of relative risk, attributable risk and logistic response procedures for 2×2×2 and c 2×2×2 contingency tables. Ann Inst Statist Math 33(B):475-86, 1981

APPENDIX 4 SUBJECTS WITH AXIAL OPACITIES OR POSTERIOR SUBCAPSULAR CHANGES IN ONE OR BOTH STUDIES (1963-64 AND 1978-80), HIROSHIMA AND NAGASAKI

付録4　一方又は両方の調査（1963－64年と1978－80年）で軸性混濁あるいは後嚢下変化を有した対象者，広島及び長崎

HIROSHIMA

MF No.	Sex	Age		Dose			1963-1964 Study						Present Study					
		ATB	ATE	Gam.	Neu.	Tot.	Axi	Pos.	Acu.	Ref.	Ast.	Acc.	Axi.	Pos.	Acu.	Ref.	Ast.	Acc.
[redacted]	2	18	52	0000	0000	0000	00	20	11	!!	00	N	00	00	00	00	01	05
	1	39	72	0080	0023	0103	00	00	00	11	00	G	10	20	20	11	00	01
	1	16	51	0408	0110	0518	00	01	00	00	00	N	00	00	00	00	00	02
	2	22	56	0096	0018	0114	00	00	11	LJ	10	H	11	00	10		00	09
*	2	32	66	0267	0202	0469	01	44	01	!!	00	C	11	33	44	13	00	06
	2	27	61	0106	0026	0132	00	22	00	!!	11	G	11	22	10	00	00	01
	2	28	62	0233	0054	0287	00	33	00	!!	11	I	22	44	13	00	22	05
	2	19	52	0049	0020	0069	00	30	00	00	00	L	00	00	00	00	00	08
	1	20	54	0250	0062	0312	00	22	15	00	00	K	22	33	57	99	99	99
	2	27	61	0117	0021	0138	00	22	00	JJ	00	K	00	00	21	10	01	05
	2	31	66	0144	0031	0175	00	22	00	!!	00	D	00	02	12	00	00	08
	1	38	72	0127	0085	0212	00	00	0D	0	0	B	00	22	44	00	00	07
	2	25	60	0067	0027	0094	00	33	10	!!	00	H	00	02	00	00	00	03
*	1	07	42	0619	0379	0998	11	33	10			Z	22	44	00	00	10	09
	1	08	42	0204	0108	0312	00	22	10	KJ	00	P	00	00	00	10	10	13
	1	10	43	0161	0038	0199	00	00	20	ML	21	T	00	11	00	22	20	09
	2	10	45	0166	0031	0197	00	33	00	!!	00	W	00	00	00	00	00	06
	2	30	64	0035	0014	0049	00	22	00	!!	00	F	00	00	02	00	01	03
	1	23	58	0203	0048	0251	00	12	00	!0	00	J	00	00	00	00	00	03
	2	22	56	0079	0018	0097	00	22	00	JJ	10	K	00	22	00	01	10	06
	2	27	61	0151	0040	0191	00	00	00	!!	00	J	00	11	00	00	00	04
	2	32	66	0180	0057	0237	00	00	00	00	00	D	12	32	00	00	00	03
	1	21	56	0307	0090	0397	00	33	00	00	00	J	00	00	20	00	10	03
	2	37	72	0203	0146	0349	00	33	00	!0	00	C	11	22	31	00	01	07
	2	35	68	0284	0066	0350	00	00	00	!!	00	D	10		01	00	01	02
	2	12	46	0184	0130	0314	00	22	00	!!	00	R	00	00	00	00	00	08
	1	17	51	0351	0084	0435	00	33	00	00	00	N	01	02	00	00	00	04
*	1	18	52	0305	0086	0391	11	33	00	00	00	N	11	22	01	00	01	05
	2	46	78	0087	0053	0140	00	00	00	01	00	A	11	33	23	11	00	02
	2	13	48	0199	0139	0338	00	01	00	00	00	P	00	22	00	00	00	05
	2	22	56	0145	0024	0169	00	00	00	JJ	22	J	11	33	32	00	11	06
	2	13	47	0180	0104	0284	00	22	00	00	00	P	00	00	00	00	00	04
	1	38	72	0118	0043	0161	00	22	14			C	00	00	33	32	00	09
	1	18	52	0218	0047	0265	00	22	00	!J	01	N	00	00	00	00	1	05
	2	46	81	0142	0065	0207	00	21	00	!!	00	H	11	00	33	11	00	01
	2	25	60	0138	0032	0170	00	00	00	00	00	H	01	03	03	11	10	01
	1	30	64	0047	0010	0057	00	22	11	JJ	33	F	00	00	12	11	00	06
	2	03	37	0189	0094	0283	00	33	00	!!	00	W	00	22	00	00	00	11
	2	42	75	0046	0025	0071	00	22	11	00	00	B	11	11	32	00	01	06
	1	37	71	0109	0020	0129	00	00	00	10	00	A	00	22	70	10	10	03
	1	36	71	0149	0101	0250	00	20	00	!!	00	D	00	00	23	00	00	07
	1	18	53	0050	0008	0058	00	10	03	JN	15	K	00	00	02	13	00	05
	2	16	51	0311	0096	0407	00	33	00	00	00	O	00	00	00	00	00	02
	1	29	63	0089	0049	0138	00	22	00	00	00	B	00	00	12	11	00	01
	2	45	79	0364	0129	0493	00	00	10	JJ	00	E	00	11	11	10	11	07
	2	49	83	0226	0166	0392	00	00	11	11	00	F	11	33	43	11	00	99
	2	43	76	0103	0021	0124	00	22	00	00	00	D	00	30	32	01	10	03
	2	50	83	0160	0038	0198	00	20	00	00	00	D	11	00	11	00	00	01
	2	15	50	0250	0066	0316	00	22	00	00	00	Q	00	00	01	11	00	04
	2	31	66	0067	0027	0094	00	10	00	!!	00	G	00	00	11	00	11	05
	2	34	67	0119	0024	0143	00	00	44	42	22	E	03	4	77	99	99	99
	1	14	48	0035	0006	0041	00	10	00	00	00	Q	00	11	00	00	00	06
	2	24	58	0150	0031	0181	00	20	21	OK	00	L	00	00	53	83	00	04
*	2	35	68	0239	0061	0300	11	44	00	10	00	E	11	11	22	00	00	10
	2	20	54	0507	0128	0635	00	22	00	00	00	J	00	22	00	11	10	02
	1	41	76	0117	0027	0144	00	20	11	!!	12	C	1	22	33			99
	2	06 -	40	0335	0070	0405	00	22	00	JJ	00	R	00	00	00	11	11	09

MF No.	Sex	Age		Dose			1963-1964 Study						Present Study					
		ATB	ATE	Gam.	Neu.	Tot.	Axi	Pos.	Acu.	Ref.	Ast.	Acc.	Axi.	Pos.	Acu.	Ref.	Ast.	Acc.
[redacted]	2	39	73	0239	0047	0286	00	33	00	!!	00	F	00	00	11	00	00	04
	2	25	59	0206	0046	0252	00	22	00	LL	00	P	11	00	20	33	00	16
	2	40	74	0221	0047	0268	00	02	11	00	00	G	00	00	21	00	22	01
	1	18	51	0061	0035	0096	00	22	01	!!	00	M	00	00	00	00	21	07
	2	17	51	0210	0068	0278	00	31	00	00	00	N	00	00	00	01	00	01
	1	48	82	0348	0112	0460	00	22	00	11	00	C	11	32	54	00	00	99
	2	40	74	0276	0069	0345	00	22	00	00	00	E	00	00	00	00	02	07
	2	18	52	0075	0015	0090	00	32	00	00	01	N	00	02	00	11	00	07
	1	43	77	0100	0055	0155	0	3	E-	99	++	Z	20	0	79	00	00	99
	2	26	61	0239	0056	0295	00	00	00	!!	00	J	11	22	00	00	00	04
	2	19	53	0262	0063	0325	00	33	00	!!	00	T	00	00	00	01	11	06
*	1	12	46	0249	0112	0361	11	33	01	KK	01	Y	00	00	00	23	00	07
	2	38	72	0040	0007	0047	00	33	00	00	00	C	01	00	33	00	11	03
*	2	26	60	0218	0131	0349	22	44	81	NO	02	K	22	44	76	55	00	99
	2	33	67	0147	0031	0178	00	00	11	!!	00	F	11	03	23	00	12	02
	2	19	53	0573	0148	0721	00	33	00	JJ	00	M	22	33	00	11	11	03
	2	21	56	0271	0067	0338	00	00	00	JJ	00	R	00	33	33	33	00	04
	2	41	75	0424	0084	0508	00	00	01	00	00	F	11	00	22	11	00	07
	2	32	67	0265	0092	0357	00	00	11	00	00	C	11	00	32	00	11	07
	1	15	50	0134	0047	0181	10	00	00	00	00	M	10	11	12	00	11	02
	2	25	59	0270	0160	0430	00	11	11	KJ	10	J	11	22	11	22	11	06
	2	45	78	0121	0030	0151	00	33	00	00	11	C	00	00	21	00	00	04
	2	37	71	0088	0018	0106	00	22	00	!0	00	G	32	52	60	00	00	04
	2	06	41	0073	0013	0086	00	20	00	!!	00	U	00	00	00	00	00	99
	2	12	46	0264	0048	0312	00	33	00	00	00	N	00	00	00	00	00	06
	1	18	53	0138	0025	0163	00	20	00	00	00	O	00	00	00	00	00	02
	1	12	47	0117	0045	0162	00	21	00	JJ	00	Q	00	00	00	21	01	11
	2	48	82	0093	0040	0133	00	02	11	00	10	C	00	00	12	00	11	03
*	2	40	74	0496	0398	0894	01	33	1D	J9	2+	D	00	33	47	00	00	99
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	2	34	67	0190	0040	0230	00	00	11	00	00	D	11	22	02	01	00	02
	1	49	82	0100	0027	0127	00	33	21	00	11	D	1	3	73	91	90	02
	1	35	68	0089	0051	0140	00	02	66	KK	00	Z	00	00	55	22	00	04
	2	46	80	0339	0085	0424	00	00	11	JJ	22	E	11	00	36	00	11	10
*	2	13	48	0538	0173	0711	11	44	00	!!	11	T	22	00	00	00	01	05
	2	35	69	0202	0046	0248	00	11	00	JJ	33	E	11	00	00	00	00	02
	2	28	62	0313	0063	0376	00	30	00	!!	00	G	00	22	12	00	00	06
	2	44	79	0115	0024	0139	00	00	11	01	00	D	11	00	34	00	00	99
	2	34	68	0236	0106	0342	00	22	00	00	00	D	10	00	30	10	00	01
	2	36	70	0176	0042	0218	00	2	31	5J	02	E	1	3	53	20	00	08
	1	18	52	0036	0006	0042	00	22	00	!!	11	T	00	00	00	00	01	06
*	1	40	74	0403	0206	0609	1	4	F1	92	+0		2	4	52	41		19
	2	20	54	0150	0034	0184	00	22	41	LM	00	H	00	00	32	24	00	06
	2	25	59	0201	0085	0286	00	12	00	00	00	G	00	22	00	00	11	06
*	2	22	56	0379	0103	0482	11	33	00	00	00	I	00	32	12	11	00	01
	1	23	57	0060	0023	0083	00	33	00	JJ	00	J	00	00	10	11	1	03
	2	38	72	0152	0103	0255	00	33	11	JJ	00	B	00	00	10	10	00	09
	2	07	41	0105	0054	0159	00	12	10	00	00	Y	00	00	10	00	00	07
	1	16	50	0000	0000	0000	00	02	00	00	00	N	00	00	00	00	00	05
	2	26	60	0124	0036	0160	00	20	00	JJ	11		11	22	00	00	10	06
	2	22	55	0135	0029	0164	00	01	11	KK	11	N	00	00	12	22	10	06
	2	36	71	0000	0000	0000	00	00	00	00	00	E	11	22	10	11	00	04
	2	41	75	0000	0000	0000	00	12	00	!!	01	F	00	00	22	10	11	09
*	1	15	48	0445	0369	0814	11	33	00	JJ	00	S	11	33	00	11	00	05
	2	45	79	0000	0000	0000	00	33	11	JJ	00	D	00	00	24	00	00	03
	2	04	38	0100	0019	0119	00	32	00	!!	00	Q	00	22	00	00	11	08
	2	37	71	0134	0026	0160	00	00	00	00	00	D	00	22	21	00	00	04
	2	44	78	0000	0000	0000	00	02		99	++	Z	11	00	55	12	00	11
	2	24	59	0013	0005	0018	00	01	00	!!	00	J	00	00	10	00	00	05
	1	18	52	0116	0028	0144	00	11	11	LK	12	S	00	00	11	32	00	10
	1	07	41	0010	0004	0014	00	22	00	00	00	W	00	00	00	00	10	07

MF No.	Sex	Age		Dose			1963-1964 Study						Present Study					
		ATB	ATE	Gam.	Neu.	Tot.	Axi	Pos.	Acu.	Ref.	Ast.	Acc.	Axi.	Pos.	Acu.	Ref.	Ast.	Acc.
[redacted]	2	14	49	0095	0018	0113	00	21	00	00	00	V	00	00	00	00	00	05
	1	18	53	0194	0078	0272	00	33	00	00	00	P	00	00	00	00	00	04
	2	32	66	0091	0040	0131	00	22	00	JJ	32	G	11	00	10	00	11	06
	2	15	49	0412	0113	0525	00	22	11	MM	00	Z	11	00	22	42	00	23
	1	19	53	0364	0141	0505	00	00	00	KK	00	N	00	22	00	22	00	03
	1	17	51	0235	0060	0295	00	33	00	!J	00	I	00	00	00	00	00	03
	2	29	62	0030	0004	0034	00	11	22	LM	00		00	00	22	44	00	01
	2	04	38	0347	0094	0441	00	33	00	0J	00	W	00	00	03		10	15
	2	16	50	0140	0029	0169	00	10	00	!!	00	K	00	00	0	01	00	04
	2	23	57	0079	0018	0097	00	23	02			Z	00	23	12	02	1	05
	2	44	79	0173	0036	0209	00	00	00	00	00	B	11	33	00	00	11	02
	2	45	80	0103	0027	0130	00	00	11	00	20	D	11	00	42	11	00	01
	1	46	81	0086	0018	0104	00	00	00	!!	00	A	22	33	41	11	00	08
	2	44	78	0107	0026	0133	00	33	14	!K	10	B	12	00	27	00	00	07
	1	17	52	0215	0079	0294	00	22	D0	NK	00	H	00	32	42	45	00	01
	1	17	51	0314	0078	0392	00	22	00	JJ	00	N	00	00	1	11	10	04
	1	18	52	0300	0076	0376	00	31	00	!!	00	M	00	30	00	00	00	03
	2	48	81	0165	0048	0213	00	00	11	10	01	F	11	00	45	11	00	99
	2	11	44	0402	0123	0525	00	23	00	00	00	Y	00	00	00	00	00	06
	1	30	64	0002	0000	0002	00	33	00	00	00	F	00	00	11	10	00	03
*	1	17	52	0232	0063	0295	11	44	00	00	00	K	3		70	5	1	99
	1	44	78	0000	0000	0000	00	00	00	!!	22	B	00	11	01	00	11	
	1	39	73	0000	0000	0000	00	22	52	OK	00	B	12	11	53	21	20	11
	1	38	71	0127	0026	0153	00	00	90	0	0	C	30	0	83	00	00	02
	2	41	75	0026	0013	0039	00	03	00	10	00		11	10	43	01	00	03
	1	18	52	0204	0057	0261	00	33	00	!!	00	L	22	44	32	00	00	05
	1	17	51	0134	0034	0168	00	30	10	J0	20	J	00	00	01	10	00	03
	1	50	84	0002	0001	0003	00	02	00	J0	22	C	31	00	73	00	00	01
	2	35	68	0330	0063	0393	00	00	01	00	00	H	11	00	00	11	1	01
	2	38	73	0000	0000	0000	00	00	41	O!	01	C	11	00	13	00	00	03
	1	34	68	0191	0045	0236	00	00	11	JJ	00	D	11	00	10	10	00	06
	2	39	72	0000	0000	0000	00	00	00	J!	00	G	00	02	02	00	00	10
	1	37	70	0095	0017	0112	00	00	00	JJ	00	B	10	10	30	00	01	03
	2	38	71	0509	0394	0903	00	33	00	11	00		21	32	32	01	10	02
	2	15	47	0344	0070	0414	00	20	10	!!	01	Q	00	00	00	00	00	06
*	1	18	53	0304	0089	0393	11	33	00	KL	00	O	22	22	00	13	10	06
	2	30	65	0002	0000	0002	00	01	11	!!	10	F	00	00	20	00	01	01
	2	16	50	0002	0000	0002	00	22	22	NM	21		00	00	12	44	00	07
	2	12	45	0103	0065	0168	00	30	00	00	00	T	00	00	00	00	00	04
	2	39	73	0080	0021	0101	00	23	42	NJ	01	Z	00	00	52	40	00	05
	1	16	50	0000	0000	0000	00	02	0D	!9	0+	N	00	00	05	08	09	06
	1	10	43	0369	0094	0463	00	33	00	00	00	N	11	32	00	00	00	08
	2	34	68	0070	0034	0104	00	00	00	!0	10	G	22	00	22	00	00	04
	1	17	52	0117	0028	0145	00	22	00	00	00	T	00	13	00	00	00	04
	2	34	67	0169	0040	0209	00	04	66	O9	++	Z	03	04	67	77	00	99
	2	29	64	0149	0033	0182	00	33	00	!!	00	H	00	01	00	10	11	04
	2	33	68	0043	0008	0051	00	02	00	JJ	22	B	00	00	42	11	11	04
	1	13	47	0200	0058	0258	00	33	00	00	00	N	00	00	11	00	00	05
	2	35	69	0324	0108	0432	00	23	11	!–	1+	J	00	30	33	10	11	06
	1	31	65	0000	0000	0000	00	00	00	!!	11	F	11	22	00	00	02	06
	2	34	67	0327	0098	0425	00	00	00	00	11	E	00	11	12	00	12	05
*	2	16	50	0465	0115	0580	01	23	11	MM	33	J	00	00	34	35	00	07
*	2	39	74	0305	0204	0509	01	44	00	!J	02	D	00	22	22	11	00	08
	1	18	53	0119	0029	0148	00	00	00	00	00	L	11	11	00	00	00	04
	1	39	73	0000	0000	0000	00	31	11	KK	11	B	21	50	54	33	00	
	2	22	57	0257	0059	0316	10	00	00	00	00	J	00	00	00	01	00	02
	2	18	53	0086	0018	0104	00	11	11	LK	00	J	00	22	00	22	00	04
	2	27	61	0026	0012	0038	00	20	80	JK	20	K	00	00	72	92	90	07
	1	29	62	0074	0018	0092	00	22	11	00	00	E	11	33	13	11	00	05
	2	21	56	0096	0023	0119	00	33	00	00	00	F	00	00	00	00	00	02
	2	19	53	0010	0004	0014	00	10	00	00	00	M	00	00	00	00	00	03
*	2	29	63	0230	0169	0399	11	33	00	00	00	G	11	32	10	01	00	02
	2	26	60	0192	0037	0229	00	00	31	NN	12	J	11	32	32	44	00	05

MF No.	Sex	Age		Dose			1963-1964 Study						Present Study					
		ATB	ATE	Gam.	Neu.	Tot.	Axi	Pos.	Acu.	Ref.	Ast.	Acc.	Axi.	Pos.	Acu.	Ref.	Ast.	Acc.
[redacted]	1	34	69	0040	0018	0058	00	22	00	00	00	D	00	00	00	00	11	01
	2	30	64	0126	0049	0175	00	00	00	!!	00	E	11	44	55	10	11	99
	1	29	64	0174	0055	0229	00	44	00	KK	00	E	01	02	00	11	12	09
	2	33	66	0326	0095	0421	00	22	00	00	00	E	00	00	00			
	2	20	54	0141	0039	0180	00	22	00	00	00	M	00	00	00	00	00	03
	1	37	72	0468	0100	0568	00	10	00	J!	00	D	00	00	00	00	00	02
	2	19	53	0024	0011	0035	00	11	00	00	00	J	00	00	00	00	11	01
	2	18	51	0038	0008	0046	00	01	11	00	00		00	00	10	00	00	05
	2	16	51	0169	0041	0210	00	00	00	00	00	R	00	03	01	00	00	05
	2	13	48	0121	0027	0148	00	22	00	00	00	J	11	21	00	00	01	08
	1	18	52	0216	0060	0276	00	22	01	!M	00	J	00	00	04	05	00	08
	1	28	62	0180	0064	0244	00	33	00	01	00	G	00	05	03	00	10	01
	1	18	52	0102	0024	0126	00	22	31	NK	41	L	00	44	51	51	02	09
	1	18	53	0203	0044	0247	00	00	00	00	00	L	00	12	00	10	00	03
	1	07	40	0228	0088	0316	00	02	00	00	00	Y	00	11	00	00	00	13
	2	13	47	0203	0146	0349	00	22	00	!!	00	M	00	00	22	00	00	07
	2	43	76	0083	0018	0101	00	23	11	!!	00		11	00	44	00	00	04
	1	09	43	0094	0018	0112	00	33	00	LL	00	N	10	21	20	43	00	09
	1	18	51	0318	0118	0436	00	33	00			Z	11	33	00	00	01	02
	2	21	55	0066	0011	0077	00	33	00	00	00	H	00	00	00	11	00	01
	1	09	43	0397	0125	0522	00	22	00			Z	00	00	00	00	00	04
	2	25	59	0013	0005	0018	00	01	11	JK	01	F	00	00	22	01	10	04
	1	17	51	0451	0110	0561	00	33	00	!0	10	L	10	20	00	00	00	04
	1	42	76	0101	0023	0124	00	00	01	11	00	C	11	00	43	10	11	06
	1	19	52	0074	0015	0089	00	21	00	KK	00	U	00	00	11	33	11	20
	1	29	64	0106	0023	0129	00	02	00	!!	11	H	00	00	00	00	00	04
	1	47	81	0376	0195	0571	00	33	11	00	10	E	11	22	74	00	00	99
	1	18	53	0183	0087	0270	00	22	00	00	01	L	11		02	11	00	03
	2	12	47	0068	0027	0095	00	20	00	00	00	S	00	00	10	00	00	07
	2	08	43	0222	0055	0277	00	33	11	KK	00	N	01	00	01	32	00	09
	1	41	75	0167	0046	0213	00	22	12	LM	02	C	00	00	35	44	00	99
	2	42	76	0043	0009	0052	00	22	00	00	00	C	11	32	53	11	00	01
	2	44	78	0328	0239	0567	00	32	10	00	00		11	22	31	11	00	06
	2	12	46	0198	0041	0239	00	33	00	!!	00	Y	00	33	00	00	00	07
	2	46	81	0165	0042	0207	00	00	10	!0	00	D	22		43	01	00	10
	1	02	36	0046	0009	0055	00	21	00	KK	00	Y	00	22	00	22	00	11
	1	21	55	0220	0160	0380	00	33	00	!!	00	L	00	00	22	00	00	08
	2	37	71	0159	0028	0187	00	00	0A				00	22	22	00	12	05
	1	30	65	0083	0016	0099	00	10	00	JJ	00	F	00	00	00	11	00	08
	1	13	48	0365	0091	0456	00	22	00	00	00	Q	00	00	00	00	00	04
	2	35	69	0156	0036	0192	00	00	00			Z	11	00	01	01	00	03
	2	32	67	0128	0039	0167	00	00	00	0!	00	D	00	33	33	10	11	03
	2	48	81	0000	0000	0000	00	00	11	KJ	44	G	11	00	32	00	00	11
*	2	19	53	0648	0196	0844	11	44	00	!0	00	J	10	20	01	00	00	01
	2	36	70	0140	0075	0215	00	00	00	00	00	I	11	00	33	11	00	99
	1	41	75	0279	0053	0332	00	00	00	!!	00	C	00	44	34	00	01	04
	1	16	51	0662	0177	0839	00	11	00	00	00	M	00	00	00	00	00	02
	2	46	80	0176	0038	0214	00	00	01	11		H	11	00	23	11	00	01
	1	14	48	0250	0066	0316	00	10	00	00	00	N	00	00	00	00	00	06
	1	31	65	0149	0100	0249	00	11	00	JJ	00	I	00	00	01	11	00	03
	2	37	70	0145	0031	0176	00	3	1D	J9	2+	J	00	00	34	00	20	06
	2	31	65	0140	0036	0176	00	22	11	JJ	11	J	00	00	42	11	00	06
	2	15	48	0057	0010	0067	00	10	00	!!	11	N	00	00	01	00	01	06

Total 235

NAGASAKI

MF No.	Sex	Age		Dose			1963-1964 Study						Present Study					
		ATB	ATE	Gam.	Neu.	Tot.	Axi	Pos.	Acu.	Ref.	Ast.	Acc.	Axi.	Pos.	Acu.	Ref.	Ast.	Acc.
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	4	18	53	0240	0002	0242	00	23	00	JJ	32	J	00	11	41	00	11	99
	4	27	59	0099	0001	0100	00	22	00	00	00	D	00	00	00	00	00	03
	4	21	56	0181	0001	0182	00	22	00	00	00	H	00	00	22	11	11	03
	3	36	70	0356	0003	0359	00	33	00	JJ	00	C	00	00	00	11	00	04
	3	36	70	0000	0000	0000	00	22	00	00	00	D	00	00	31	00	00	01
	4	23	56	0078	0001	0079	00	22	00	JJ	00	I	00	00	00	00	00	03
	4	32	67	0144	0001	0145	0	2	68	69	0+	Z	1	0	77	59	09	99
	4	17	51	0264	0003	0267	00	22	00	00	00	F	00	00	10	01	10	02
	4	30	64	0000	0000	0000	00	32	00	00	00	C	01	00	00	00	01	02
	4	28	63	0009	0000	0009	00	33	00			D	00	00	22	11	00	01
	3	26	60	0471	0007	0478	00	33	00	11	00	E	00	00	00	00	00	03
	4	16	51				00	10	01	JJ	10	K	00	00	00	00	10	03
	3	26	61	0191	0004	0195	00	33	00	00	00	F	00	00	00	00	10	02
	4	17	51	0117	0001	0118	00	22	00	00	00	I	00	00	21	00	00	02
	4	18	52	0542	0008	0550	00	33	00	JJ	00	H	00	00	21	00	00	09
	4	28	62	0284	0002	0286	00	22	00	0J	01	F	00	00	02	00	00	04
	4	28	62	0225	0003	0228	00	33	00	00	00	E	00	00	00	00	00	02
	4	28	62	0067	0000	0067	00	22	00	00	00	F	00	11	00	11	00	02
	4	17	49	0067	0001	0068	00	12	00	00	00	K	00	11	00	11	00	03
	4	22	57	0674	0013	0687	00	33	11	11	00	F	00	00	11	00	00	03
	4	19	53	0010	0000	0010	11	22	56	QQ	00		00	22	77	88	00	99
	4	21	56				00	22	00	00	00	F	00	00	00	11	00	03
	3	05	40	0000	0000	0000	00	22	00	00	00	N	00	00	00	00	10	09
	4	29	63	0163	0001	0164	00	33	00	JJ	00	D	00	00	20	11	00	03
	3	44	78	0001	0000	0001	11	44	36	NN	00	B	11	33	44	68	00	01
	4	21	56	0177	0003	0180	00	33	21	KJ	11	J	00	11	32	31	00	04
	4	15	50	0000	0000	0000	00	33	00	JJ	1	M	00	00	00	11	00	06
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	4	21	56	0161	0001	0162	11	33	00	KK	00	G	00	00	10	22	00	03
	4	15	49	0460	0007	0467	00	33	00	00	00	J	00	00	00	00	00	05
	4	17	51	0000	0000	0000	00	33	00	ML	00	J	00	00	10	33	00	04
	4	34	67	0233	0002	0235	00	33	00	00	00	B	00	11	13	11	00	03
	4	42	75	0000	0000	0000	00	00	01	00	00	F	11	43	42	21	00	18
	4	38	72	0000	0000	0000	00	00	00	00	00	B	11	00	00	00	00	06
	4	01	35	0118	0001	0119	00	02	00	00	00	Q	00	00	00	00	00	13
	4	06	40	0018	0000	0018	00	20	00	J0	30	P	00	00	20	10	21	10
	4	42	77	0205	0003	0208	11	33	22	KK	01	C	11	00	42	29	09	99
	4	37	72	0051	0000	0051	00	33	00	JJ	00	D	00	00	00	00	00	05
	4	14	48	0234	0002	0236	00	22	10	32	00	J	00	00	23	43	00	06
	3	17	51	0023	0000	0023	00	33	00	00	00	I	00	00	00	00	00	01
	4	15	49	0412	0005	0417	11	22	00	00	00	L	00	00	00	00	00	04
	4	14	46	0156	0001	0157	00	33	00	JJ	11	L	00	00	10	00	22	05
	4	33	67	0399	0008	0407	00	23	00	00	00	E	11	11	00	00	00	04
	3	14	48	0073	0001	0074	00	22	00	00	00	L	00	00	00	00	00	04
	4	24	58	0161	0003	0164	00	33	10	00	00	F	00	00	00	10	12	05
	3	05	38	0129	0002	0131	00	22	00	JK	00	P	00	00	00	12	00	11
	3	13	47	0074	0001	0075	00	33	00	00	00	L	00	00	00	00	00	03
	3	16	49	0065	0001	0066	00	32	00	00	00	H	00	00	00	00	00	07
	3	12	45	0156	0001	0157	00	20	00	00	00	O	00	00	00	00	00	05
	4	11	45	0038	0000	0038	00	03	00	00	00	P	00	00	00	00	00	06
	4	05	39	0369	0004	0373	11	33	00	KJ	10	P	00	11	01	10	11	11
	3	26	60	0098	0001	0099	00	33	00	11	00	E	00	00	00	00	00	03
	4	28	62	0252	0006	0258	00	33	01	11	10	E	00	00	21	11	00	05
	3	17	51	0047	0000	0047	00	02	00	00	00	K	00	00	00	00	00	01
	4	16	51	0155	0001	0156	00	23	22	KJ	00	I	00	00	33	33	00	07
	3	15	48	0076	0001	0077	00	33	01	0J	02	I	10	00	02	00	00	06
	4	25	58	0435	0006	0441	00	33	00	00	00	E	00	00	11	00	00	04
	4	22	55	0106	0001	0107	00	33	00	00	00	H	00	00	00	10	00	03
	4	12	46	0046	0000	0046	00	20	00	00	00		00	00	00	00	00	05

MF No.	Sex	Age		Dose			1963-1964 Study						Present Study					
		ATB	ATE	Gam.	Neu.	Tot.	Axi	Pos.	Acu.	Ref.	Ast.	Acc.	Axi.	Pos.	Acu.	Ref.	Ast.	Acc.
[redacted]	4	22	56	0000	0000	0000	00	33	00	KK	00	I	00	00	00	11	00	05
	4	01	35	0153	0001	0154	00	33	00	KK	00	T	00	00	00	22	00	05
*	3	16	49	0403	0006	0409	11	33	00	00	00	G	00	00	00	00	00	03
	4	34	67	0000	0000	0000	00	00	00	00	00	C	22	22	21	00	00	05
	4	45	80	0276	0003	0279	00	33	11	00	00	A	00	00	33	00	00	99
	4	29	62	0000	0000	0000	00	33	00	00	00	E	00	22	10	00	00	05
	4	15	48	0074	0000	0074	00	33	00	00	00	K	00	00	00	00	00	04
*	4	36	70	0295	0004	0299	10	34	01	11	00		11	00	23	01	00	03
*	3	15	49	0435	0009	0444	11	44	00	JJ	00	N	00	00	03	11	01	04
	4	10	44	0166	0002	0168	00	22	00	00	00	K	00	52	00	00	10	07
	3	25	59	0000	0000	0000	00	03	00	00	00	D	01	00	00	11	10	02
	3	15	49	0027	0000	0027	00	03	44	00	00	I	11	23	55	77	00	99
	3	39	73	0303	0004	0307	00	22	00	00	01	A	00	33	20	11	10	04
	3	06	40	0000	0000	0000	00	02	00	JK	20	P	00	00	00	11	20	13
	4	25	58	0213	0002	0215	00	33	00	NK	20	E	00	00	62	63	01	04
	3	13	47	0026	0000	0026	00	40	10	!	0	I	30	0	70	91	90	05
	4	15	50	0028	0000	0028	00	02	00	00	00	H	00	00	00	11	00	03
	3	05	39	0000	0000	0000	00	33	00	00	00	O	00	00	00	00	00	09
*	3	14	48	0280	0006	0286	11	32	31	PO	33	I	00	00	42	86	00	15
	4	30	63	0057	0000	0057	00	23	13	0L	00	D	00	00	14	04	11	99
	4	29	62	0000	0000	0000	00	33	01	0J	00	F	00	00	04	11	11	04
	4	26	61	0158	0001	0159	00	32	00	10	00	F	00	00	11	11	11	04
	4	40	73	0115	0002	0117	00	22	21	11	00	B	11	11	32	00	00	09
	3	19	53	0081	0000	0081	00	33	00	00	00	G	00	00	00	00	00	03
	4	17	52	0559	0011	0570	00	22	00	00	00	J	00	00	00	00	00	05
	3	41	74	0282	0003	0285	11	33	00	00	00	A	11	33	21	11	00	06
	3	13	47				00	10	00	JJ	00	K	00	00	00	11	00	02
	4	39	72				00	33	00	00	00	C	10	11	22	11	00	05
	3	32	66				00	33	00	00	00	C	00	00	00	00	00	01
	3	13	47				00	20	00	KK	10	M	00	00	00	22	00	05
	4	18	53				00	22	11	JJ	00	J	00	00	00	22	00	02
	4	26	60				00	33	00	JJ	11	E	00	00	00	00	00	02
	4	43	77				00	22	01	00	00	D	00	00	22	00	00	02
	3	16	50				00	30	00	00	00	N	00	00	00	00	00	05
	3	14	47				00	02	00	0J	00	K	00	00	00	00	00	04
	4	09	43	0000	0000	0000	00	20	00	00	00	I	00	00	10	11	00	03
*	4	36	69				11	00	00	00	00	B	00	01	00	01	00	03
	3	15	48				00	22	DB	00	00	H	00	00	33	22	01	10
	3	16	50	0016	0000	0016	00	22	00	00	00	K	00	00	00	00	00	05
	4	30	64				00	23	40	10	00	D	11	00	42	20	10	02
	4	36	70				00	02	00	JJ	10	C	00	00	03	00	00	02
	4	11	45	0443	0011	0454	00	33	00	JJ	11	O	00	00	34	22	00	09
	4	04	38	0257	0002	0259	00	33	00	JJ	00	M	00	00	00	00	00	14
	3	13	47	0060	0001	0061	00	30	00	00	00	L	00	00	00	00	00	06
	3	17	51				00	30	00	00	00	K	00	00	00	00	00	04
	4	14	48				00	01	00	00	00	M	00	00	33	99	99	07
	4	16	49	0820	0014	0834	11	22	00	00	00	L	00	00	00	00	11	04

Total 109

*Persons who had the axial opacities observed and confirmed by Miller et al[4] in 1963-64.
1963－64年に Miller ら[4]により観察され，確認された軸性混濁を有する対象者

SEX: 1-Hiroshima, male; 2-Hiroshima, female; 3-Nagasaki, male; 4-Nagasaki, female
性：1-広島，男性；2-広島，女性；3-長崎，男性；4-長崎，女性

ATB－Age at the time of A-bombing; ATE－Age at the time of examination; AXI－Axial opacities; POS－Posterior subcapsular changes; ACU－Visual acuity; REF－Refraction (Code for 1963-64 study used a combination between numerical digit and minus sign. They correspond to $!=\bar{0}$, $J=\bar{1}$, ..., $R=\bar{9}$); AST－Astigmatism (plus cylinder); ACC－Accommodation (Codes in 1963-64 study correspond to A=01, B=02, ..., W=23, and X=99)
ATB：原爆時年齢；ATE：受診時年齢；AXI：軸性混濁；POS：後嚢下変化；ACV：視力；REF：屈折率（1963－64年の調査におけるコードは数とマイナス記号の組み合わせを用いた．これらは $I=\bar{0}$，$J=\bar{1}$，…，$R=\bar{9}$ に相当する）．AST：乱視（プラス円柱）；ACC：調節力（1963－64年の調査におけるコードは A＝01，B＝02，…，W＝23及び X＝99に相当する）．