LIFE SPAN STUDY REPORT 9
寿 命 調 査　第 9 報

PART 1

CANCER MORTALITY AMONG ATOMIC BOMB SURVIVORS, 1950-78

第 1 部

原 爆 被 爆 者 に お け る 癌 死 亡 率, 1950 － 78 年

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PART 1
CANCER MORTALITY AMONG ATOMIC BOMB SURVIVORS, 1950-78

第 1 部
原爆被爆者における癌死亡率，1950 － 78 年

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SUMMARY

The present study extends an earlier one by 4 years from 1975 to 1978. Leukemia as a cause of death among survivors has continued to decrease and now differs from the control group only in Hiroshima. For cancer other than leukemia the increase in absolute risk has become more marked as the cohort has aged and especially so in Nagasaki where it is now statistically significant for the first time. In addition to previously demonstrated sites (i.e., lung, breast, stomach, esophagus, and urinary tract) colon cancer and multiple myeloma can now be shown to be significantly related to exposure. No significant relationship to radiation can as yet be established for malignant lymphoma, rectum, pancreas and uterine cancer.

It has not been possible with the present data to determine statistically whether the dose response to gamma rays is linear or nonlinear. The relative biological effectiveness value of neutrons for leukemia and lung, breast, and stomach cancer ranges from 2 to 7 under the linear model for gamma rays.

The time from exposure to death is shortened for leukemia depending on dose but not for other cancers, and radiation-induced cancers other than leukemia seem to develop proportionally to the

要 約

本調査は前報に1975～78年の4年間の資料を追加したものである．被爆者の死因の一つである白血病は引き続き減少しており，1978年現在でも対照者との差が見られるのは広島のみである．白血病以外の癌の絶対危険度の増加は，対象集団の高齢化と共に顕著になってきており，特に長崎では今回初めて統計的に有意となった．前報で既に述べた肺癌，乳癌，胃癌，食道癌，泌尿器癌に加えて，今回の解析では結腸癌と多発性骨髄腫も放射線被曝と有意な関連を示した．しかし悪性リンパ腫，直腸癌，膵臓癌及び子宮癌については放射線との有意な関係は今のところ認められない．

本資料を用いてガンマ線の線量反応が線形か非線形かを統計的に決定することはできなかった．中性子線の白血病，肺癌，乳癌及び胃癌に関する相対的生物学的効果比はガンマ線の線形モデルにおいては2～7である．

被曝から死亡までの期間は白血病については高線量になるに従って短縮されているが，他の癌についてはこの傾向は見られず，白血病以外の放射線誘発癌はその年齢における癌の自然発生率に比例して発現する

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natural cancer rate for the attained age. For specific age-at-death intervals, both relative and absolute risks tend to be higher for younger age-at-time-of-bomb individuals.

INTRODUCTION

ABCC and RERF have used, for several decades now, a fixed cohort of A-bomb survivors and suitable comparison subjects, the so-called Life Span Study (LSS) sample,[1] to ascertain possible effects of A-bomb exposure on mortality. Periodic analyses of the results of this surveillance continue; the most recently published account (in 1978) spanned the years 1950-74.[2] The present report covers the 28-year period 1950-78.

As earlier reports have indicated, the late effects of A-bomb radiation on mortality appear to be limited to an increase in malignant tumors. In these additional 4 years there have been 5,103 more deaths of which 1,193 have been ascribed to cancer, an increase of 24% in such deaths since the last report. This study examines anew the dose-response relationships examined in previous reports; however, it also addresses problems which these publications were able to treat less well because of a smaller number of deaths, such as the estimation of the form of the dose-response curve and the relative biological effectiveness (RBE) of neutrons, the latent period for radiation-related malignancies, and the effects of age at the time of the bomb (ATB) and carcinogens other than radiation. Indeed, this study focusses upon these problems. An analysis of mortality from causes other than malignant tumors will be reported separately.[3]

METHODS

Exposure Dose

Recently, after further analysis of the physical evidence, the hypocenter in Nagasaki has been relocated 37 m to the southwest of the location used in computing the original T65 Dose[4] and the dose estimates based on this new hypocenter have been used here. The effect of this relocation on the number of individuals within the dose categories previously used is generally small, being 0.1%-6.2% for the nine dose groups as shown in Table 1. This table also sets forth a further methodological change, namely, the standardization of the rounding process used in the calculation of individual doses. Different rounding conventions have been used from time to time, but here (and hereafter) the

ものと思われる．死亡時年齢群別に見ると，相対的危険度と絶対危険度の双方とも被爆時年齢の若い者ほど高い傾向がある．

緒 言

ABCC 及び放影研では原爆被爆の死亡率に現れる影響を確認するために数十年にわたって寿命調査集団[1] と呼ばれる原爆被爆者と対照者からなる固定集団について調査を行ってきた．この調査の結果は定期的に解析されており，最も新しい報告[2] は1950～74年の期間について1978年に発表された．本報はその後1975～78年の死亡を加えて解析し1950～78年の28年間についての報告である．

以前の報告書でも指摘されているように，死亡率における原爆放射線の後影響は今までのところ悪性腫瘍の増加に限られているようである．新しく追加された4年間に5,103件の死亡がありそのうち癌によるものは1,193件で，前報以来24％の増加となっている．また，本報では以前の報告書で調べた線量反応関係も検討し直すとともに，線量反応曲線の形状の推定，中性子線の相対的生物学的効果比（RBE），放射線誘発悪性腫瘍の潜伏期間，及び被爆時年齢及び放射線以外の発癌要因の影響など，以前の報告書において死亡例数が少ないために十分な解析ができなかった問題についても検討を加えた．本報ではこれらの問題に重点を置いて解析した．悪性腫瘍以外の死因による死亡率の解析は別に報告する．[3]

方 法

被曝線量

最近，従来測定されていた種々の物理学的資料を更に解析した結果，長崎の爆心地が1965年暫定線量（T65D）[4] 算定の際に用いられた地点から南西37mの地点に変更された．本報ではこの新しい爆心地に基づいた線量推定値を用いた．この変更に伴って以前に使用した線量区分の対象者数に与えた影響は概して小さく，表1に示すように9線量群で0.1％～6.2％程度である．表1には，また個人線量の算定における四捨五入方式の標準化に伴う変更も付け加えられている．算定された数値の端数を処理するのに従来はときによって異なった方法が採用されてきたが，本報

TABLE 1 THE EFFECT OF ROUNDING PROCESS AND RELOCATION OF THE NAGASAKI HYPOCENTER ON NUMBER OF SUBJECTS

表 1　被曝線量の端数の四捨五入の方法（広島・長崎）と長崎の爆心地の変更による
被曝線量群別対象者数の変更

					T65DR in Rad				
	Total	0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Unk

HIROSHIMA

	Total	0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Unk
Number in previous report[2]	61911	29943	13796	10761	2718	1721	656	370	505	1441
Revised number associated with change in rounding process		27577	15933	10911	2783	1740	659	369	510	1429

NAGASAKI

	Total	0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Unk
Number in previous report	20331	4700	6706	3759	1314	1391	748	270	378	1065
Revised number associated with change in rounding process		4010	7288	3904	1358	1394	761	272	379	965
Revised number associated with change in the rounding process and the relocation of hypocenter		4004	7140	4031	1442	1388	722	270	377	957

method of half adjustment will be used.[5] Previously it has been common to drop fractional values of a rad, that is, to round down. This seemed justifiable when our investigative efforts were focussed largely on the presence or absence of an effect of radiation at moderate or high doses. However, as interest has mounted in the possible consequences of exposure to doses of less than 10 rad, this practice, could obscure an effect through the systematic underestimation, admittedly small but possibly nonnegligible, of the exposure of individuals in the low dose groups. The revised dose is called the "T65 revised dose" (T65DR). The change in number of subjects associated with this revision in Nagasaki is fairly large in the 0 and 1-9 rad dose groups, being 14.7% and 8.7%, respectively, but is small in the high dose groups, generally less than 1%, as shown in Table 1. In Hiroshima, where no relocation of the hypocenter has occurred, the change in the number of subjects associated with the revised rounding process is not dissimilar, as shown in Table 1.

Individuals for whom a dose cannot be estimated by present methods, either for lack of shielding data or because the attenuation factors are unknown, number 2,386 or 2.9% of A-bomb

以降は四捨五入法を用いる.[5] 以前は 1 rad 以下の値は切り捨てる方法，すなわち「切り下げ」が普通であった．この方法は中等度若しくは高線量における放射線影響の有無に重点を置いた調査を行っていた当時は妥当な方法と考えられたが，10 rad 未満の線量に被曝した場合の影響の可能性に関心が持たれるようになってきたため，この方法では，一貫して線量を過少に推定することになり，低線量被爆者の個人線量が量的に僅かではあっても無視できないほどのものであれば，それにより影響が不明確になる可能性がある．前述の修正された線量を「改訂 T 65線量」（T 65 DR）と呼称することにした．長崎におけるこの修正に伴う対象者数の変動は表 1 に示すように，0 rad 群及び 1〜9 rad 群ではかなり大きく，それぞれ14.7％及び8.7％であるが，高線量群では小さく，概して 1 ％未満である．爆心地に変更のなかった広島では，表 1 に示すように四捨五入法の修正に伴う対象者数の変動は長崎の場合と同様の傾向が見られる．

遮蔽に関する資料の不足や，減弱係数が不明なために

survivors in the Hiroshima and Nagasaki cohorts. They have been excluded in this analysis. The "not-in-city" group of the cohort has also been excluded in this analysis as in the most recent previous one.

It must be borne in mind that some uncertainty continues to surround both the quantity and quality of the radiation released by these two nuclear devices, particularly, the Hiroshima bomb. Only one weapon of the latter type has ever been detonated and thus its yield has had to be reconstructed. Different reconstructions have led to different estimates of the prompt gamma and neutron exposures. A recent such reassessment suggests that the gamma estimates used in the T65 calculations may be too low and the neutron too high, and that total kerma may have been greater than previously supposed. Note this would have the effect of diminishing the slope of the dose-response curve based on total kerma and would make the results seen in the two cities more similar if the reassessment is correct.

Ascertainment of Death

Ascertainment of death is based on an inspection of the koseki. This system of household registration and the events which affect household composition have been described fully elsewhere.[2] Suffice it here to state that numerous lines of evidence suggest that few, if any, deaths escape the registration system. There is, then, almost no failure to ascertain the fact of death through this procedure. Causes of death have been transcribed from schedules based on death certificates kept in the Health Centers throughout Japan. To ascertain the accuracy of the causes of death, a comparison has been made with autopsy diagnoses in autopsied cases.[6] Though accuracy depends upon the cause of death and differs by site of cancer, it is generally high. Some 70% of cancer deaths, all sites, can be confirmed, and for specific malignancies such as leukemia, and stomach, breast, and lung cancers, where the role of radiation seems clear, confirmation and detection rates are 60%-95%. These findings support the validity of an analysis based on death certificates in this cohort.

Statistical Methods

The same statistical methods are used here as in the previous report.[2] Briefly, the exposed individuals in the cohort (excluding the "not-in-city" and "dose unknown" groups) were divided

現在の方法では個人線量が推定できない者は，広島及び長崎のコホートで2,386人で，被爆者の2.9%に当たる．これらの者は本解析から除外した．コホート中の「市内不在者」群も前報同様本解析でも除外した．

これら二つの核爆弾，特に広島の爆弾から放出された放射線については線量，線質ともにまだ若干不明確な点がある．広島型の爆弾は1回しか爆発されていないので，そのエネルギー線量は復元して求めなければならなかった．復元方法によって初期ガンマ線及び中性子線の線量推定値も異なる．最近行われた被曝線量の再検討から，T65D線量推定に用いた推定ガンマ線量は低すぎ，中性子線量が高すぎたため，総kerma線量は以前考えられていたより大きいかもしれないということが示唆されている．これは総kerma線量に基づく線量反応曲線の傾きを少なくする効果があり，この再検討が正しければ，両市の線量反応曲線はより等しくなるものと思われる．

死亡の確認

死亡の確認は戸籍照合をもとに行った．この戸籍制度つまり家族構成員の動態の登録制度については別に詳述してある．[2] ここでは，多くの資料から戸籍に記載されない死亡はあったとしてもごく少数にすぎないことを指摘するにとどめる．したがって，戸籍の調査を行えば死亡の確認にはほとんど漏れはない．死因は全国の保健所に保管されている死亡診断書に基づく死亡票から転記している．死因の正確性を確認するために剖検例について，剖検診断との比較を行った．[6] 正確性は死因によっても，また，癌の部位によっても異なるが，総体的に高い．全部位の癌死亡の約70%が確認できており，白血病，胃癌，乳癌，肺癌など，放射線影響の明らかな特定の悪性腫瘍については，確認率及び発見率は，60%～95%である．これらの所見はこのコホートについての死亡診断書に基づく解析が有効であることを裏付けるものである．

統計的解析方法

統計的解析方法は前報[2]と同様のものを用いた．要約すると，コホート内の被爆者（「非被爆者」及び「線量

into eight dose categories and a contingency table analysis was made adjusting for age ATB, sex, city, and period (year of death) using the Mantel-Haenszel method based on person-years at risk. In addition to the usual chi-square test, Cochran's linear trend chi-square test was calculated for the summary contingency table. Relative risks are based in the latter table; they are, by definition, the ratios of two quotients, namely, the observed to expected deaths in the 100+ (or 200+) rad group and the observed to expected deaths in the 0 rad group where dose is the simple arithmetic sum of the estimated kerma from gamma rays and neutrons. The absolute risk was calculated from a linear regression of the excess deaths (observed − expected deaths) in each dose group in the contingency table using the mean for each dose group as the independent variable.[2]

The cumulative death rates for specific sites of cancer were calculated by the life table method considering the competing risk of death from other causes.[3]

The number of subjects in the eight dose categories together with the mean of the T65DR are shown in Appendix Table 1, and the person-years at risk during 1 October 1950 − 31 December 1978 by T65DR group, city, age ATB, sex, and time period are shown in Appendix Table 2. The number of observed and expected deaths for specific cancer sites by T65DR group, city, age ATB, sex, and time period are also included in Appendix Tables 3-16.

RESULTS AND DISCUSSION
Changes with time in cancer mortality
One of the main purposes of the present analysis is to examine the mortality in 1975-78, the 4 years following the previous report on deaths in 1950-74. Table 2 shows the yearly changes in the absolute risk - excess deaths per million person-year per rad (PYR) - of cancer of various sites during 1950-78 divided into seven equal intervals and the observations were extended further by city for selected site of cancer (Table 3). The excess in leukemia deaths has continued to decrease from the peak in 1950-54, and in 1975-78 an increased mortality with dose is observed only in Hiroshima (Table 3).

Cancers other than leukemia have increased yearly from about 1960 and, averaged over all periods,

不明」群を除く）は八つの線量区分に分け，観察人年をもとに Mantel-Haenszel 法を用いて，被爆時年齢，性，市，及び年度（死亡年）を訂正して分割表解析を行った．通常のカイ二乗検定に加えて，総括分割表について Cochran の線形傾向カイ二乗検定も行った．相対的危険度は後者の表に基づいたもので，100 rad 以上（又は 200 rad 以上）の群における死亡の観察数対期待数の比と 0 rad 群における死亡の観察数対期待数の比との比である．この場合線量はガンマ線及び中性子線量の単純算術和である推定 kerma 線量を用いた．絶対危険度は各線量群における死亡数増加（観察死亡数—期待死亡数）と各線量群の平均値を独立変数として用いた分割表について線形回帰を当てはめて算出した．[2]

特定の癌部位の累積死亡率は，他の死因による死亡の競合危険度を考慮して，生命表を用いて算出した．[3]

8個の線量区分の対象者数とその平均 T 65 DR 推定線量（付表 1），及び T 65 DR 推定線量群，市，被爆時年齢，性，及び年度別に1950年10月1日から1978年12月31日までの観察人年数（付表 2）を示した．また，特定の癌部位による観察死亡数及び期待死亡数も T 65 DR 推定線量群，市，被爆時年齢，性，及び年度別に付表 3 −16に示した．

結果及び考察
癌死亡率の経時的変化
本解析の主たる目的の一つは前報で報告した1950〜74年以降1975〜78年の 4 年間の死亡率を解析することである．表2に，1950〜78年を七つの等しい期間に分け，特定の部位の癌の絶対的危険度—100万人年rad（PYR）当たりの増加死亡数—の経年的変化を示した．更に，特定の部位については市別の観察所見も示した（表3）．白血病による増加死亡数は1950〜54年のピーク以後下降を続け，1975〜78年には線量に伴う死亡率増加は広島でのみ見られるにすぎない（表3）．

白血病以外の癌は1960年ごろから毎年増加しており，

TABLE 2 ABSOLUTE RISK (EXCESS DEATHS/10⁶ PYR) BY PERIOD AND SITE OF CANCER

表 2 絶対危険度（増加死亡数／100万人年 rad）— 年度及び癌の部位別

Cancer site	Total 1950-78	1950-54	1955-58	1959-62	1963-66	1967-70	1971-74	1975-78
Leukemia	1.72(1.57-1.87)*	4.13	2.20	1.79	0.92	1.13	0.42	0.44(−0.05- 0.93)*
All cancer except leukemia	3.03(2.29-3.77)	1.58	−0.09	2.58	3.00	3.24	3.70	9.17(6.49-11.85)
Esophagus	0.16(0.02-0.30)	0.04	0.29	0.28	0.37	−0.08	0.24	−0.12(−0.52- 0.29)
Stomach	0.79(0.34-1.24)	0.83	−0.20	0.50	1.20	1.14	0.71	1.62(0.11- 3.14)
Colon	0.30(0.16-0.43)	−0.09	−0.08	0.01	0.30	0.77	−0.26	1.81(1.24- 2.39)
Other digestive organs**	0.46(0.18-0.73)	0.14	−0.29	0.77	0.13	0.01	1.28	1.60(0.54- 2.66)
Lung	0.61(0.37-0.86)	−0.09	0.30	0.35	0.73	0.40	0.53	2.59(1.54- 3.64)
Breast	0.50(0.29-0.72)	−0.01	0.07	−0.25	0.70	1.70	−0.23	1.89(1.09- 2.69)
Uterus	0.10(−0.24-0.43)	0.70	−0.19	0.97	−0.48	−0.61	0.03	0.07(−0.88- 1.03)
Urinary tract	0.15(0.04-0.26)	−0.03	−0.01	−0.08	0.20	0.90	−0.19	0.35(−0.01- 0.72)
Malignant lymphoma	0.04(−0.07-0.15)	0.12	−0.09	0.08	−0.01	−0.01	0.51	−0.32(−0.79- 0.15)
Multiple myeloma	0.11(0.05-0.16)	−0.00	too few	0.29	−0.01	−0.03	0.31	0.21(−0.09- 0.50)

*90% confidence interval   90%信頼区間

**Digestive organs excluding esophagus, stomach, colon, rectum, and pancreas (ICD152, 155, 156, 158, 159, 197)

食道，胃，結腸，直腸及び膵臓以外の消化器官（ICD152, 155, 156, 158, 159, 197）

TABLE 3 ABSOLUTE RISK (EXCESS DEATHS/10⁶ PYR) BY PERIOD, CITY, AND SITE OF CANCER

表 3 絶対危険度（増加死亡数／100万人年 rad）— 年度，市及び癌の部位別

Cancer site	City	Total 1950-78	1950-54	1955-58	1959-62	1963-66	1967-70	1971-74	1975-78
Leukemia	H	2.12(1.91-2.34)*	4.10	3.55	1.27	1.49	1.72	0.80	0.96(0.19- 1.74)*
	N	1.27(1.05-1.49)	4.50	0.34	2.49	0.20	0.44	−0.13	−0.21(−0.77- 0.36)
All cancer except leukemia	H	4.32(3.28-5.36)	1.05	0.11	4.02	4.93	4.70	6.28	12.80(9.06-16.54)
	N	1.27(0.19-2.36)	2.39	−0.55	0.44	0.36	1.13	0.75	4.74(0.75- 8.74)
Stomach	H	1.01(0.35-1.66)	0.03	−0.23	1.41	1.76	1.64	1.19	1.92(−0.16- 4.00)
	N	0.48(−0.15-1.12)	2.06	−0.20	−0.94	0.39	0.31	0.20	1.26(−1.03- 3.56)
Colon	H	0.45(0.26-0.65)	−0.13	−0.10	0.03	0.56	0.98	−0.19	2.73(1.89- 3.58)
	N	0.09(−0.08-0.26)	−0.04	−0.06		0.01	0.45	−0.39	0.67(−0.12- 1.46)
Lung	H	0.83(0.50-1.16)	−0.06	0.58	0.08	0.75	0.93	1.34	3.10(1.69- 4.51)
	N	0.34(−0.04-0.72)	−0.14	−0.10	0.72	0.64	−0.23	−0.28	1.93(0.28- 3.57)
Breast	H	0.70(0.40-0.99)	−0.00	−0.02	−0.16	1.21	1.80	−0.33	2.91(1.72- 4.10)
	N	0.23(−0.10-0.57)	−0.03	0.20	−0.45	−0.00	1.65	−0.09	0.57(−0.47- 1.62)

*90% confidence interval   90%信頼区間

the risk of these cancers now exceeds that of leukemia. The risks of lung, breast, and stomach cancers, which have shown a definite increase up to the previous report, have continued to rise in 1975-78, but additional increase in risk is not apparent in 1975-78 for esophageal or urinary tract cancers which have increased previously. Besides these sites, an elevated risk of colon cancer has become newly evident. In the previous report,[2] "cancer of the lymphatic and hematopoietic tissue other than leukemia" (ICD 200-203, 208-209) was analysed as one rubric group and called "malignant lymphoma" since the majority of the cases (80%) consisted of malignant lymphoma (ICD200-202). The number of deaths in this category has increased by 28 in the period 1975-78, and the 105 deaths now available (1950-78) were analysed separating malignant lymphoma (ICD200-202) and multiple myeloma (ICD203). The numbers of deaths are 84 and 20, respectively (one death in this rubric was ascribed to polycythemia, ICD208). The confirmation rate for deaths in these categories as checked against the leukemia registry is high (86.1% for malignant lymphoma and 91.7% for multiple myeloma).

The trend statistic for the increased incidence with dose is not significant (P=0.29) for malignant lymphoma during 1950-78, whereas it is significant (P=0.0006) for multiple myeloma as shown in the contingency tables (Appendix Tables 11 and 12). In short, the significant increase with dose observed for malignant lymphoma in the previous report is spurious and stems from the inclusion of multiple myeloma. Malignant lymphoma itself (ICD200-202) does not show any relation to dose throughout 1950-78. However, a study based on pathology data[7] in the same cohort demonstrated an increase in malignant lymphoma among the heavily exposed especially in Hiroshima during the period up to 1965; further extension of this kind of study is called for.

Increased risk of uterine cancer has not yet been seen. Further study of leukemia and cancers of the stomach, lung, breast, and colon, which are clearly radiation related, reveals a greater excess in Hiroshima than in Nagasaki in all periods (Table 3). However, the increase in excess deaths in Nagasaki has been noteworthy in the last 4 years, 1975-78. The average age in the Hiroshima cohort is approximately 5 years older than in Nagasaki (in 1976, the estimated mean
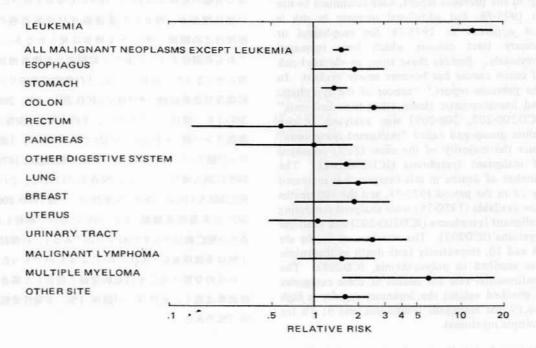
全期間を平均するとその絶対危険度は白血病を上回る. 前報の期間まで明らかな増加を示していた肺癌, 乳癌及び胃癌の危険度は1975～78年にも増加を続けたが, 以前に増加が示唆された食道癌及び泌尿器癌の危険度はこの期間に明らかな増加は見られなかった. これらの部位のほかに新たに結腸癌の危険度増加が明らかになった. 前報[2]では,「白血病以外のリンパ組織及び造血組織の悪性腫瘍(ICD 200～203, 208～209)」を一項目として解析し, その大部分(80%)が悪性リンパ腫(ICD 200～202)であったので,「悪性リンパ腫」として扱った. この分類の死亡数は, 1975～78年に28人増加しており, 現在までに判明している死亡105人(1950～78年)を悪性リンパ腫(ICD 200～202)と多発性骨髄腫(ICD 203)に分けて解析した. 各々の死亡数はそれぞれ84及び20である〔この項目中1例は多血球血症(ICD 208)によるものであった〕. これらの分類の死亡を白血病登録と照合した場合の確認率は高く, 悪性リンパ腫86.1%, 多発性骨髄腫91.7%である.

付表11及び12に示すように, 線量に伴う発生率の増加傾向は1950～78年では悪性リンパ腫については統計的に有意ではない(P＝0.29)が, 多発性骨髄腫については有意である(P＝0.0006). つまり, 前報で見られた悪性リンパ腫の線量に伴う有意な増加は見かけ上のもので, 多発性骨髄腫を含んでいたことに起因している. 悪性リンパ腫自体(ICD 200～202)は, 1950～78年の期間を通して線量との関係は認められない. しかしながら, 同じコホートの病理学的資料に基づいた調査[7]では, 1965年までの期間に特に広島の高線量被爆者に悪性リンパ腫の増加が認められており, この種の調査を更に期間を延長して行うことが必要であろう.

子宮癌の増加はまだ見られない. 明らかに放射線と関連のある白血病, 胃癌, 肺癌, 乳癌及び結腸癌について更に調査を行ったところ, すべての期間において長崎よりも広島の方が増加が大きいことが明らかになった(表3). しかし, 最近の4年間, すなわち1975～78年では長崎における死亡数増加が顕著である. 放射線誘発癌の発生に関する相対的危険度モデル[8]では100万人年rad当たりの死亡数増加は

FIGURE 1 RELATIVE RISK AND 90% CONFIDENCE INTERVALS FOR SPECIFIC SITES
OF CANCER 1950-78, 200+ rad vs 0 rad

図 1　特定部位の癌の相対的危険度，及び90％信頼区間，1950～78年，200 rad 以上対 0 rad

age was 63 in Hiroshima and 58 in Nagasaki). Under the relative risk model,[8] the excess deaths/10^6 PYR should be proportional to the death rate for the attained age. Age specific cancer death rates from all Japan increased by around 1.5-fold as attained age increased 5 years for ages 40 and over. The ratios of excess deaths during 1975-78 vs 1971-74 are 2.0 and 6.3 in Hiroshima and Nagasaki, respectively, for all cancers except leukemia (Table 3). Thus, the remarkable recent increase in excess deaths in Nagasaki as compared with Hiroshima is not entirely ascribable to the different age distributions in the two cities. Given the putative differences between Hiroshima and Nagasaki in radiation quality, it is tempting to ascribe this observation to this difference.

Mortality in the high dose group (200+ rad), in the entire period, 1950-78, is presented in Figure 1 as a relative risk based on site and the mortality in the 0 rad group. As with the absolute risk, an increase in the relative risk of colon cancer and multiple myeloma can now be seen, but no elevation is evident for pancreatic, rectal, or uterine cancers, or malignant lymphoma.

一般人口集団における年齢別死亡率に比例すると考えられるので，この理由の一つとして，広島のコホートの平均年齢が長崎より約5歳高いためであるかもしれない（1976年の平均年齢は広島63歳，長崎58歳であった）．全国の年齢別癌死亡率は年齢が40歳以上から5歳ずつ上昇するにつれて約1.5倍ずつ増加する．一方このコホートにおける白血病以外のすべての部位の癌の死亡数増加の1975～78年対1971～74年の比は広島2.0長崎6.3である（表3）．したがって，広島に比べて長崎における最近の顕著な死亡数増加は両市の年齢分布の違いだけによるものではない．広島と長崎の放射線の質に差異のあることが考えられるので，この観察所見はその差によるものかもしれない．

1950～78年の全期間における高線量群（200 rad 以上）の 0 rad 群の死亡率に対する相対的危険度を部位別に図1に示した．絶対危険度の場合と同様，結腸癌と多発性骨髄腫の相対的危険度に増加が見られるが，膵臓癌，直腸癌，子宮癌あるいは悪性リンパ腫については明らかな増加は見られない．

Other studies on the same fixed population have shown no increase in chronic lymphatic leukemia,[9] liver cancer,[10] or intracranial tumors.[11] Thus, the sensitivity to radiation differs according to the organ. However, since the risk of cancers other than leukemia has increased in the exposed group compared with the controls only after the exposed individuals reach the age at which cancer of the site is prone to develop,[2] and that age differs according to the organ, an increased risk for these cancers may be observed in the future. We have used the magnitude of the relative risk of cancer of a particular site as a base, and examined radiation sensitivity by site. As shown in Figure 1, the 90% confidence limits of the relative risks of breast, stomach, lung, and colon cancers overlap each other and the relative risk of cancers of all sites combined (except leukemia) is within that confidence limit, so, statistically, it cannot be said that the relative risk differs according to target organ. As the risk can be expected to increase in the future, careful follow-up will be necessary before any conclusion regarding differences in the risk of carcinogenesis by site can be drawn.

The Dose-response Curve and the Relative Biological Effectiveness of Neutrons
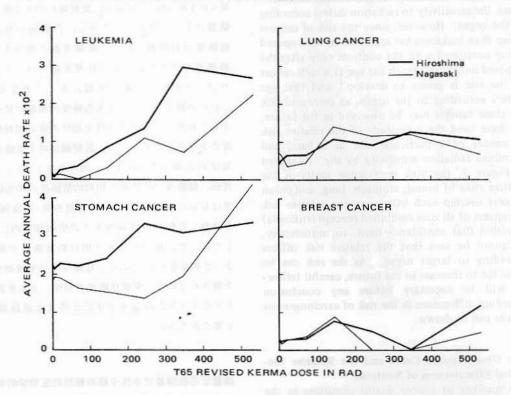
The number of cancer deaths occurring in the 4-year period following the previous report has increased approximately 25%. Thus, the relative importance of the gamma and neutron components of dose for the induction of leukemia, and lung, breast, and stomach cancer, and cancer of all sites except leukemia where a dose-effect relationship is clear, should be more evident, and we have estimated these relationships under a number of different dose-response models. The details of the methods of calculation and the results are presented elsewhere.[12] The average annual mortality rate, sex and age adjusted by T65DR, is shown for cancers of four specific sites in Figure 2. Cancers of these sites as well as all sites collectively (data not shown) exhibit a higher mortality in Hiroshima than in Nagasaki for the same dose. This has frequently been attributed to the radiation in Nagasaki being mostly gamma ray whereas the neutron component was large in Hiroshima and the neutron effect may be greater than the gamma ray effect per unit exposure. Contemporary radiation biology provides no compelling general model of the relationship of exposure to the magnitude of the carcinogenic effect (see Land[13]

同じ固定集団についての他の調査では，慢性リンパ球性白血病，[9] 肝臓癌，[10] 頭蓋内腫瘍[11] の増加は見られなかった．このように放射線に対する感受性は臓器によって異なる．しかし，白血病以外の癌の危険度が対照群と比べて被爆者群で増加するのは被爆者がその部位の癌の好発年齢に達した後であり，[2] その好発年齢は臓器によって異なるので，これらの癌については将来危険度の増加が見られるかもしれない．本報では特定部位の癌の相対的危険度の大きさを基準として，放射線に対する感受性を部位別に調べた．図1から明らかなように，乳癌，胃癌，肺癌及び結腸癌の相対的危険度の90%信頼限界は互いに重複しており，全部位の癌（白血病以外）を合計した相対的危険度もその信頼限界内にある．したがって，統計的にみて相対的危険度が臓器によって異なるとはいえない．危険度は将来増加すると予測されるので，発癌危険度の部位による差異に関してなんらかの結論を下すには慎重な追跡調査が必要であろう．

線量反応曲線及び中性子線の相対的生物学的効果比

前報以後の4年間における癌死亡数は約25%増加した．したがって，線量反応関係が明らかな白血病，肺癌，乳癌，胃癌及び白血病以外の全部位の癌の放射線による誘発における中性子のガンマ線に対する相対的生物学的効果比はより明らかになるはずである．これらの関係を多くの異なる線量反応モデルを用いて推定した．詳しい計算法や結果は別に報告した．[12] 四つの特定部位の癌について，性及び年齢を訂正した平均年間死亡率をT65DR推定線量別に図2に示した．これらの部位の癌のみならず全部位合計（資料省略）でも同一線量では長崎より広島の方が死亡率が高かった．これはしばしば引用されているように，長崎の放射線はそのほとんどがガンマ線であるのに対して広島では中性子の量が多く，中性子の単位被曝線量当たりの影響はガンマ線より大きいと考えられるからであるかもしれない．現在の放射線生物学では被曝線量と発癌効果の大きさとの間の関係について確固たる総括的モデルは得られていない（この問題についてのLand[13] の論理的考察を参照）．

FIGURE 2 AVERAGE ANNUAL DEATH RATE (AGE, SEX-ADJUSTED) BY T65 REVISED
KERMA DOSE FOR SPECIFIC SITES OF CANCER, 1950-78
図 2　特定部位の癌の平均年間死亡率（年齢・性訂正），T 65 DR kerma 線量別，1950－78年

for a reasoned discussion of this issue). Utility, rather than an inherent understanding of the mechanism involved, has generally guided the choice of models which have been fitted. Clearly, a number of different models can be invoked, but the following are mathematically simple and biologically parsimonious and, therefore, were used:

$$\text{Model 1.} \quad P = a_H(a_N) + bD_\gamma + cDn$$
$$\text{Model 2.} \quad P = a_H(a_N) + bD_\gamma^2 + cDn$$
$$\text{Model 3.} \quad P = a_H(a_N) + b_1 D_\gamma + b_2 D_\gamma^2 + cDn$$

where P is cancer mortality, D_γ is the gamma dose, Dn is the neutron dose, and $a_{(H,N)}$, b, and c are fitted constants. The value of a is presumed to differ between Hiroshima and Nagasaki. All parameters were fitted subject to the restriction that they not be negative. Use of these models in no way should be interpreted as an implicit belief in the simplicity of the biological process involved. These are descriptors of convenience. All assume that cancer mortality increases linearly with neutron dose, but for

適合性を検討したモデルの選択は，概してモデルの基礎となっている発癌機構を考慮してというよりも，その実用性を基準にして行った．確かに，別の幾つかのモデルを使用することはできるが，以下に述べるモデルが数学的に簡単で生物学的にみてもむだが少ないので本解析で使用した．

ただし，Pは癌死亡率，D_yはガンマ線量，Dn は中性子線量，$a_{(H,N)}$，b及びcは当てはめた定数である．aの値は広島と長崎で異なるものとした．パラメーターはすべて負でないとの条件で，モデルの適合を行った．これらのモデルを使用するのは決して関与している生物学的過程が単純であることを絶対的に信じているからではなく，便宜上そうしたまでである．すべてのモデルで，癌死亡率は中性子線量に

gamma dose the effect may be linear, quadratic, or both. This accords with experimental radiobiologic evidence and the generally greater cellular damage ascribed to neutrons. The regression coefficients were estimated by a maximum likelihood method, assuming that mortality follows a binomial distribution. The goodness of fit of the models was assessed by the probabilities of the associated chi-square tests. The mortality rate (P) was calculated based on the number of subjects and adjusted for age and sex.

Table 4 shows the goodness of fit of each cancer to the above-mentioned three models using kerma dose. For leukemia the fit is better with Model 2 (quadratic model), but cancers of all sites other than leukemia, including lung and breast cancers fit Model 1 (linear model) or Model 3 (linear-quadratic model) better than Model 2 (quadratic model). For stomach cancer, though the pattern is similar to that of leukemia, the goodness of fit is virtually the same with each of the three models. These statements are based, of course, upon face value interpretation of the test probabilities; however, in no instance can it be said statistically that the dose-response curve fits one of the models significantly better than the others.

Accordingly, the RBE function has been estimated under all of the models: the resultant values are shown in Table 4. Under the simplest linear model the RBE is c/b, a constant. It is higher for leukemia (7), than for stomach, lung, and breast cancers which show similar values (2-5). Under Model 2, the RBE becomes $\sqrt{c/b}/\sqrt{Dn}$ (i.e., a function of the neutron dose). Only the value of $\sqrt{c/b}$ is shown in the table. When the neutron dose is 100 (or 10) rad, the Model 2 estimate of RBE is 5.0 (16.1) for leukemia, 3.1 (9.9) for stomach cancer, 8.3 (26.1) for lung cancer, and 11.6 (36.8) for breast cancer, with some difference according to site, but the variances of the estimates are large and statistically there are no significant differences by site. All attempts to fit Model 3 resulted in one of the coefficients associated with gamma exposure being negative, and thus the "true" value is presumably zero or nearly so. In these instances, the upper 95% limit value of the regression coefficients has been used to estimate RBE. Since the RBE value depends on the neutron dose, the RBE at 10 and 100 rad of neutron are shown for convenience in Table 4. The RBE is closer to Model 1 than

対して直線的に増加することを仮定しているが, ガンマ線量に関しては癌死亡率は線形, 二次関数的あるいはその双方であるかもしれない. これは放射線生物学の実験的所見や中性子線が一般により大きい細胞学的障害をもたらすという事実と一致する. 回帰係数は最尤法を用い, 死亡数が二項分布すると仮定して推定した. モデルの適合度はカイ二乗検定の確率で評価した. 死亡率 (P) は対象者数をもとに年齢及び性を訂正して算出した.

表4に前述の三つのモデルに対する適合度を karma 線量を用いて各部位の癌について示した. 白血病についてはモデル2 (二次関数モデル) の適合度が良いが, 肺癌及び乳癌を含む白血病以外の全部位の癌ではモデル2 (二次関数モデル) よりもモデル1 (線形モデル) 若しくはモデル3 (線形・二次関数モデル) の方がよく適合した. 胃癌の場合はそのパターンは白血病と同様であるが, 適合度は実質的にはどのモデルも同じであった. むろんこれらの記述は検定確率の表面的な値の解釈に基づいたものである. しかし, 線量反応曲線がこれらのモデルのいずれか一つに他のモデルよりも統計的に有意によく適合するとは言えない.

したがってすべてのモデルに基づいて RBE 関数を推定した. その結果は表4に示した. 最も単純な線形モデルでは RBE は定数 c/b である. RBE が類似の値 (2～5) を示す胃癌, 肺癌及び乳癌よりも白血病 (7) の方が高い. モデル2を用いた場合, RBE は $\sqrt{c/b}/\sqrt{Dn}$ (中性子線量の関数) となる. 表には $\sqrt{c/b}$ の値のみを示した. 中性子線量が100 (又は10) rad のときは, モデル2による推定 RBE は白血病が5.0 (16.1), 胃癌が3.1 (9.9), 肺癌が8.3 (26.1), 乳癌が11.6 (36.8) となり, 部位によって若干の差はあるが, 推定値の分散が大きく, 部位による統計的に有意な差はない. モデル3に適合させようとすると必ずガンマ線被曝線量と関係ある係数の一つが負になる. したがって「真の」値は恐らく0若しくは0に近いであろう. このような場合, RBE 値を推定するのに回帰係数の95%信頼限界の上限値を用いた. RBE 値は中性子線量に依存するので, 中性子線が10 rad 及び100 rad のときの RBE 値を参考のために表4に示した. この RBE 値はモデル2よりモデル1に

TABLE 4 MODEL FITNESS AND RBE ESTIMATION FOR SPECIFIC SITES OF CANCER
表 4 特定の部位の癌に関するモデルの適合性及び RBE 値推定

Model 1: $P = a_H(a_N) + bD\gamma + cDn$; $RBE = c/b$

Cancer site	c/b (RBE)	Coefficients		Model fitness
		$b \times 10^5$	$c \times 10^5$	P value
Leukemia	7.3 (4.3)	2.0 (0.62)	14.7 (3.8)	0.12
All except leukemia	5.1 (4.4)	5.2 (2.1)	26.6 (9.9)	0.36
Stomach	3.0 (7.0)	1.7 (1.2)	5.2 (5.7)	0.92
Lung	2.2 (4.3)	1.7 (0.89)	3.8 (4.1)	0.082
Breast	4.6 (16.9)	0.88 (0.90)	4.0 (4.2)	0.31

Model 2: $P = a_H(a_N) + bD\gamma^2 + cDn$; $RBE = \sqrt{c/b} / \sqrt{Dn}$

	$\sqrt{c/b}$ (RBE $\sqrt{Dn}$)	Coefficients		Model fitness
		$b \times 10^5$	$c \times 10^5$	P value
Leukemia	50.8 (35.9)	0.0065 (0.0020)	16.8 (3.5)	0.32
All except leukemia	68.5 (71.8)	0.0077 (0.0048)	36.2 (8.6)	0.14
Stomach	31.3 (40.5)	0.0056 (0.0030)	5.5 (5.2)	0.98
Lung	82.5 (192.8)	0.0012 (0.0020)	8.4 (3.4)	0.013
Breast	116.4 (538.8)	0.00049 (0.0016)	6.6 (3.4)	0.14

Model 3: $P = a_H(a_N) + b_1 D\gamma + b_2 D\gamma^2 + cDn$; $RBE = \sqrt{\dfrac{c}{b_2 Dn} + \left(\dfrac{b_1}{2b_2 Dn}\right)^2} - \dfrac{b_1}{2b_2 Dn}$

	RBE Dn = 10, Dn = 100		Coefficients			Model fitness
			$b_1 \times 10^5$	$b_2 \times 10^5$	$c \times 10^5$	P value
Leukemia	7.9	9.5	−0.32 (1.2)	0.0074 (0.0037)	17.4 (4.1)	0.23
All except leukemia	2.4	2.2	9.4 (4.2)	−0.0110 (0.0095)	23.5 (10.1)	0.40
Stomach	4.9	2.4	−1.9 (2.5)	0.0094 (0.0061)	8.0 (6.2)	0.99
Lung	1.5	1.4	4.3 (1.5)	−0.0079 (0.0034)	2.2 (3.7)	0.22
Breast	2.2	2.0	2.0 (1.4)	−0.0032 (0.0030)	3.2 (3.8)	0.38

Standard deviation in parentheses 括弧内は標準偏差

Model 2. Since the tissue dose has also been estimated for these sites, the RBE values based on tissue dose are shown in Table 5. It should be noted that the absorbed tissue doses are based on the "average man" concept, that is, they use an attenuation factor which ignores differences among individuals in size, changes in tissue density with age, and the like. Thus an individual's absorbed tissue dose is merely a weighted sum, with constant weights for all individuals, of the gamma and neutron components of his or her kerma dose. Clearly,

近い．これらの部位については組織線量も推定されているので，表5に組織線量に基づいた RBE 値を示した．この吸収組織線量は「平均的人間」の概念に基づいている．すなわち，体格の個人差，年齢による組織密度の変化などを無視した減弱係数を用いた．したがって各人の吸収組織線量は単にその kerma 線量のガンマ線及び中性子線成分の荷重値合計にすぎず，その荷重値も各人一定のものを使用した．こうした

TABLE 5 ESTIMATED RBE FOR DEATHS DUE TO CANCER
COMPARISON OF KERMA AND ORGAN DOSE
表5　癌死亡の推定 RBE 値 — Kerma 線量と
臓器線量との比較

Cancer site	Model 1 : c/b (RBE)		Model 2 : $\sqrt{c/b}$ (RBE $\sqrt{Dn}$)	
	Kerma	Organ	Kerma	Organ
Leukemia	7.3	14.7	50.8	54.6
	(4.3)	(8.6)	(35.9)	(38.2)
Stomach	3.0	7.4	31.3	33.5
	(7.0)	(18.4)	(40.5)	(45.2)
Lung	2.2	4.7	82.5	92.2
	(4.3)	(9.7)	(192.8)	(223.0)
Breast	4.6	6.5	116.4	126.5
	(16.9)	(24.6)	(538.8)	(592.0)

Standard deviation in parentheses　括弧内は標準偏差

under these circumstances the two analyses, based on absorbed and kerma doses, are inter-dependent. Under Model 1, the values derived for leukemia, and stomach and lung cancers are approximately twofold greater than those obtained using kerma dose, but for breast cancer the attenuation is less, of course. Under Model 2, there is hardly any difference in the RBE function whether tissue dose or kerma is used.

Because neither theory nor experimental evidence provides a persuasive dose-response model for radiation-related carcinogenesis in man, we must use models based either upon their simplicity or their apparent "reasonableness". Even for leukemia where the dose-response curve should be most clear, neither the data presented here, restricted to mortality, nor the data based upon the leukemia registry, which combines mortality and morbidity, are sufficient to distinguish statistically between a curvilinear and a linear relationship to gamma radiation.[14] A study using the Nagasaki Tumor Registry data of the estimated values derived for all A-bomb survivors resident in Nagasaki City in 1950 without limiting the cases to the RERF fixed population, has shown that the leukemia incidence approaches a linear model in Nagasaki. Although the appropriate base population is difficult to estimate, this warns against the too ready acceptance of a nonlinear dose-effect theory.[2]

条件の下では吸収線量に基づいた解析と kerma 線量に基づいた解析は明らかに密接な関連がある．モデル1を用いた場合，白血病，胃癌及び肺癌から得られる値は kerma 線量を用いたときの約2倍になるが，乳癌については当然ながら減少は少ない．モデル2では組織線量を用いた場合と kerma 線量を用いた場合で RBE の値にはほとんど差はない．

人間における放射線誘発悪性腫瘍について納得のゆく線量反応モデルは理論的にも実験結果からも得られないので，単純さ若しくはその「妥当性」を基にしたモデルを使用しなければならない．線量反応曲線が最も明白であるはずの白血病においてさえ，本報の死亡率に限定した資料も，死亡と罹病率を合わせた白血病登録に基づく資料も，ガンマ線に対して曲線関係となるのか線形関係となるのか統計的に区別するには十分でない．[14] 放影研の対象者に限定せず，長崎腫瘍登録資料を用いて1950年当時長崎市在住の全被爆者から得た推定値を使用した解析では，白血病発生率は長崎ではむしろ線形モデルに近い．適当な基盤となる母集団を推定するのは困難な欠点があるが，この所見は非線形線量効果理論を安易に受けいれることへの警告である．[2]

The number of deaths due to cancers other than leukemia has increased markedly with the aging of the cohort, but it has not yet been possible to determine whether the dose-effect response fits Model 1 (L-L) or Model 2 (Q-L) better for cancers of the lung, breast, or stomach where the dose-effect relationship appears the most clear.. To determine the form of the dose response, a reanalysis will be needed after a greater number of deaths have accumulated. Breast cancer has a low fatality rate; it is better, therefore, to estimate the dose-response curve from morbidity rather than mortality data. Land[13] reported that the dose-response curve for breast cancer gives the best fit for a linear-quadratic model for gamma rays and that the estimated RBE is close to one based on incidence data on the same cohort 1950-74.[15] The present report which is based on mortality, but extends the study period 4 years (1975-78) suggests the RBE is higher than one, though the estimated variance is large. Recent analysis on cancer incidence 1959-78 in the Nagasaki cohort[16] revealed that the dose-response curve for breast cancer fits a linear model better than a quadratic one.

Estimation of RBE on the basis of mortality data should suffice for lung and stomach cancers where fatality rates are high. The recent analysis of the Tumor Registry[16] data revealed that the dose-response curves for both stomach and lung cancers fit a linear or linear-quadratic model better than a pure quadratic model, though statistically one cannot distinguish among these three models for gamma rays. Nevertheless, it could not be demonstrated statistically that RBE differed by site, presumably because the variances are so large.

Temporal Distribution of Time from A-bomb to Cancer Death and the Effect of Age ATB

The period from exposure to A-bomb radiation to death from cancer can be regarded as the latent period for radiation-induced cancers although not for other cancers, assuming that survival from onset to death is generally uniform between the comparison groups. Land and Norman[17] have studied the relationship between the latent period, so defined, and dose based on the leukemia registry data and mortality data for 1950-74. They report that, although the radiation-induced leukemia apparently occurred sooner after the bomb than other leukemias, this difference was not seen for lung or breast cancers. Based on the more recent mortality

白血病以外の癌による死亡数はコホートの加齢と共に顕著に増加しているが，線量効果関係が最も明らかに現われている肺癌，乳癌あるいは胃癌について線量効果反応がモデル1（L-L）とモデル2（Q-L）のいずれによく適合するかを決定するのはまだ不可能である．線量反応の形状を決定するにはもっと多くの死亡例が集められた後に再び解析を行う必要がある．乳癌の致死率は低い．したがって線量反応曲線は死亡資料より罹病資料から推定する方が良い．Land[13]は同じコホートの1950～74年の発生率資料[15]に基づいて乳癌の線量反応曲線はガンマ線に対して線形・二次関数モデルの方が最もよく適合し，検定RBE値は1に近いと報告している．本報は死亡率をもとにしており，調査期間も4年間（1975～78年）追加され，推定分散は大きいがRBEは1より大きいことを示唆している．長崎のコホートにおける1959～78年の癌発生率に関する最近の解析から，乳癌の線量反応曲線は二次関数モデルよりも線形モデルによく適合することが示唆される．[16]
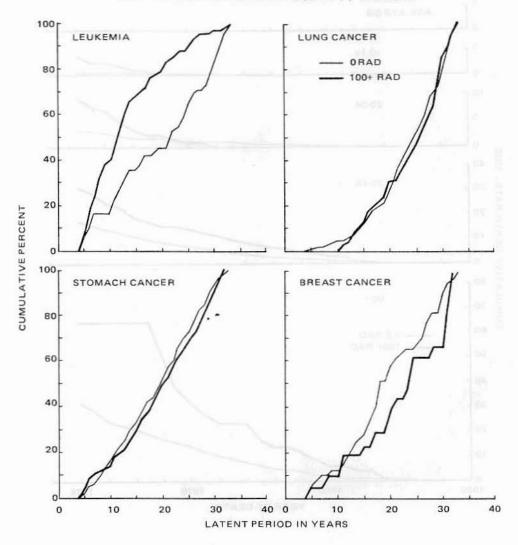
死亡率の高い肺癌及び胃癌については，RBEの推定は死亡資料に基づいたもので十分のはずである．最近の腫瘍登録の解析[16]によると，胃癌及び肺癌の線量反応曲線は双方とも二次関数モデルよりも線形又は線形・二次関数モデルによく適合することが示唆されている．しかし，統計的にはガンマ線についてのこれら三つのモデルの適合性に差はない．いずれにしても，分散が非常に大きいために，RBEの部位による差は統計的に認められなかった．

被爆時から癌による死亡までの期間の分布及び被爆時年齢の影響

原爆放射線被曝から癌による死亡までの期間は，発病から死亡までの期間が比較群の間で原則として同じであると仮定すると，放射線誘発癌については，その潜伏期間とみなすことができる．LandとNorman[17]はこのような定義による潜伏期間と線量との関係を1950～74年の白血病登録資料及び死亡率資料に基づいて調べ，放射線誘発白血病は原爆投下後他の白血病より明らかに早く発現したが，肺癌や乳癌についてはこうした差異はなかったと報告している．線量効果が明らかなすべての部位の癌についてより新しい

FIGURE 3 CUMULATIVE PERCENTAGE OF LATENT PERIOD FOR SPECIFIC SITES
OF CANCER BY RADIATION DOSE
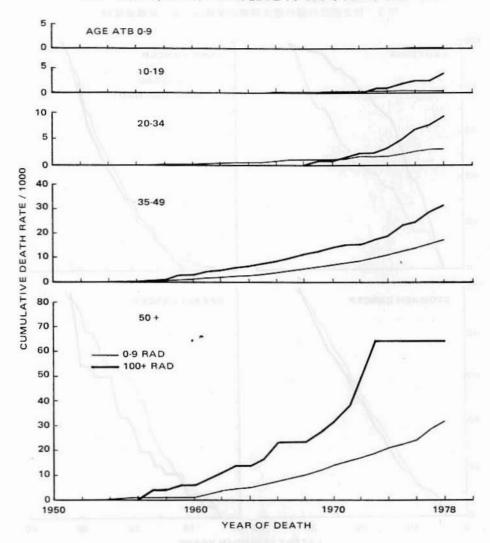
図3 特定部位の癌の潜伏期間の累積百分率，被曝線量別

data, a study was made of cancers of all sites where a dose effect is clear. The distributions of the period until death for cancer deaths are shown as cumulative percentage in Figure 3 for the 100+ rad group and the 0 rad group. The latent period in leukemia is shortened and it depends on dose,[18] and therefore as the proportion of radiation-induced leukemia increased, the average period between exposure and death shortened, but this is not observed for stomach, breast, or lung cancers. Although not shown in this figure, the latent period was not shortened for other solid tumors such as

死亡資料を基にした解析を行った．図3に癌による死亡までの期間の分布を100 rad 以上群及び 0 rad 群について累積百分率で示した．白血病の潜伏期間は短縮しており，その短縮は線量に依存している．[18]したがって放射線誘発白血病の割合が増加するに伴って被曝から死亡までの平均期間は短くなった．しかし，この短縮は胃癌，乳癌あるいは肺癌については認められない．図には示されていないが，食道癌や結腸癌のようなその他の充実性腫瘍でも全年齢あるいは被爆時年齢別の観察でも潜伏期間は短縮

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FIGURE 4 CUMULATIVE DEATH RATE PER 1,000 FOR LUNG CANCER BY AGE ATB, 1950-78

図4　肺癌の1,000人当たりの累積死亡率，被爆時年齢別，1950-78年

esophageal or colon cancers, collectively or by age ATB.

The cumulative mortality rates by year estimated by the life table method and considering competing risks for lung cancer are shown in Figure 4 by age ATB for the high dose group (100+ rad) and the 0-9 rad group. The time at which lung cancer mortality increases apparently differs in the high dose group according to age ATB: radiation-induced lung cancer develops only after the A-bomb survivors attain the age at which this cancer normally develops. This

していない.

図4に肺癌について競合危険度を考慮して生命表の方法で推定した年度別の累積死亡率を高線量群（100 rad 以上）と0-9 rad 群とについて被爆時年齢別に示した．高線量群で肺癌の死亡率が増加する時期は被爆時年齢によって明らかに異なっており，放射線誘発肺癌は，被爆者が好発年齢に達した後に初めて発現する．これは通常40歳以上であり，したがって，

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generally occurs at 40 or more years of age, and thus the period from A-bomb exposure to death (latent period) is longer the younger the age ATB. The same tendency is noted with breast and stomach cancers.

The pattern of the latent period for malignant tumors induced by radiation differs for leukemia and malignant neoplasms other than leukemia. The reasons cannot be readily explained but if an attempt is made to use the two-step mutational theory of carcinogenesis or the theory that two factors, initiator and promoter, are generally necessary in the occurrence of cancer, it might be as follows:

In leukemia, the first and the second mutational steps necessary for radiation to cause transformation in cells may occur simultaneously or very nearly so, or in pre-conditioned individuals, i.e., those who have already undergone the first mutational step prior to exposure may be more numerous normally in human populations. Therefore, leukemia develops earlier the greater the exposure dose, irrespective of age ATB. The evidence for this may be conjectural, but is not necessarily unpersuasive. We recognize a large number of cancer-prone inherited immunodeficiency diseases, and for some of these at least, there is evidence of an increased radiation sensitivity. While this evidence involves an apparent inability to repair radiation-induced DNA damage, it is tempting to speculate that this inability may ultimately culminate in an increased risk of leukemia, for the latter is the most conspicuous malignancy among those common to individuals homozygous for immunodeficiency diseases.[19]

For lung cancer, however, probably only the first mutational step is the result of exposure to radiation and the second and possibly other steps occur only when some other factor acts as a promoter. Cell transformation and proliferation then occur and the cancer develops. In this case, the time when the promoter acts to initiate the second step may be unrelated to the radiation dose, the initiator of the process. Hence, the latent period is unrelated to radiation dose and the cancer develops only when the age at which it is normally prone to develop is attained. Thus, the two different latency patterns can be explained by a two- (multi-) step mutational

原爆被爆から死亡までの期間（潜伏期間）は被爆時年齢が若いほど長い．乳癌及び胃癌についても同様の傾向が認められる．

このように放射線誘発悪性腫瘍の潜伏期間の型は白血病とそれ以外の悪性新生物とで異なる．その理由は簡単に説明できないが，発癌の2段階突然変異説若しくは癌の発生には initiator（起始因子）と promoter（促進因子）という二つの要因が必要であるという説を用いれば次のように説明できる．

白血病においては，放射線が細胞に形質転換（癌化）を起こさせるのに必要な第1段階と第2段階の突然変異は，同時か非常に近い間隔で起こるか，被曝以前に第1段階の突然変異を既に起こした条件の整った者が通常の人間集団に多くいるかもしれない．したがって白血病は被爆時年齢に関係なく被曝線量が多いほど早く発現する．この説の裏付けは推測であるが，必ずしも説得力に欠けるものではない．癌になりやすい遺伝性免疫欠損疾患が多く認められており，少なくともその一部については放射線に対する感受性が高いという所見が得られている．このことは，遺伝性免疫欠損疾患患者の放射線誘発DNA損傷を修復することが不可能であるということを意味している．悪性腫瘍が免疫欠損疾患について同型接合の者に共通して見られる悪性の疾患の中で最も顕著なものであるので，[19] この修復能力の欠損がついには白血病危険度の増加につながると推測することが最も考えやすいと思われる．

しかし，肺癌の場合は放射線被曝によって第1段階の突然変異が起こるのみであり，第2段階以降のものは他の要因が促進因子として作用した場合にのみ起こると考えられる．次に細胞形質転換（癌化）と増殖が起こり，癌が発現する．この場合，促進因子が第2段階の突然変異を起こす時期は，起始因子である放射線量と無関係であるかもしれない．したがって潜伏期間は放射線量とは関係がなく，癌が発現するのは通常の癌好発年齢に達した後となる．このように2（複数）段階突然変異説，すなわち癌の誘発

theory, i.e., an initiator and a promoter are generally necessary in the induction of cancer, but with this alone the different incubation patterns for chronic and acute leukemia cannot be explained.[17] The changes in the immune response of irradiated cells have to be considered also, and in this sense the two-step hypothesis is open to the charge of overly simplifying the mechanism of radiation carcinogenesis, but it can be considered to be a valid working hypothesis to explain the differences in the patterns of latency.

Insofar as breast cancer is concerned, data other than those on A-bomb survivors have been reported recently from a study of this malignancy developing after X-ray therapy for postpartum mastitis[20,21] and from a study of the induction of breast cancer in tuberculosis patients following fluoroscopy of the chest.[20-22] As with A-bomb survivors, no shortening of the latent period due to radiation dose was evident in either instance.

には一般に起始因子と促進因子が必要であると いう説で二つの異なる潜伏期間の説明はできる が，これのみでは慢性白血病と急性白血病の 潜伏期間の型の相違は説明できない.[17] 放射線 を受けた細胞の免疫反応の変化も考慮しなくて はならない．この点で発癌に関する2段階説は 放射線による発癌の機序を過度に簡略視して いるとの非難は避けられないが，潜伏の型の差異 を説明するには有効な仮説であると考えられる．

乳癌に限っていえば，原爆被爆者に関する資料 以外の資料として，分娩後の乳腺炎に対してX線 治療を受けた後に発現した乳癌の調査[20,21] と， 結核患者の胸部透視による乳癌誘発の調査[20-22] が報告されている．原爆被爆者の場合と同様に， これら両調査では放射線量による潜伏期間の 短縮の所見は認められなかった．

TABLE 6 RELATIVE RISK FOR ALL CANCERS EXCEPT LEUKEMIA BY AGE
ATB, 100+ rad vs 0 rad, 1950-78

表6 白血病以外の全部位の癌の相対的危険度，被爆時年齢別，
100rad 以上対 0 rad，1950－78年

Age ATB	Age at death					
	<30	30-39	40-49	50-59	60-69	70+
<10	15.1	5.0	6.8	-	-	-
10-19	1.0	2.5	2.4	8.2	-	-
20-34	-	1.8	1.9	2.0	1.6	-
35-49	-	-	1.2	1.1	1.3	1.4
50+	-	-	-	2.2	1.0	1.4

Because radiation-induced cancer begins to appear after the age is attained at which the cancer is normally prone to develop, it is necessary to investigate the effect of age ATB on the estimation of the risk of radiation-induced cancers either adjusted or specific for age at death.   The relative and absolute risks of all cancers other than leukemia are shown by age ATB in Figure 5, using the data of the present study (age at death has not been considered). The relative risk is high in individuals of younger age ATB, although the absolute risk is higher with older age ATB as would be expected. For age-at-death specific groups the relative risk for all cancers except leukemia (Table 6) is higher the younger the age ATB.   At the same age at

このように放射線誘発癌は通常の癌好発年齢に達した 後に出現し始めるので，放射線誘発癌の危険度推定 に対する被爆時年齢の影響を調べるためには死亡時 年齢を訂正するか，死亡時年齢別に観察する必要が ある．図5に白血病以外のすべての癌の相対的危険度 及び絶対危険度を本調査の資料を用いて被爆時年齢 別に示した（死亡時年齢は考慮していない）．相対的 危険度は被爆時年齢が若い方が高い．しかし絶対危 険度は予測どおりに被爆時年齢が高くなるに従って 高くなる．死亡時年齢別の観察では，白血病以外の 全部位の癌の相対的危険度（表6）は被爆時年齢が

FIGURE 5 ABSOLUTE RISK AND RELATIVE RISK FOR ALL CANCERS EXCEPT LEUKEMIA BY AGE ATB
図5 白血病以外の全部位の癌合計の絶対危険度及び相対的危険度，被爆時年齢別

death, the absolute risk is, like the relative risk, higher the younger the age ATB as shown in Table 7, for all cancers other than leukemia and lung, breast, and stomach cancers. The tendency is similar or becomes much clearer if the value of the highest age ATB in each of the attained age classes (Table 7) is excluded, (i.e., assuming a minimum incubation period of 15 years). Thus, the higher absolute risk of radiation-induced cancers with advancing age ATB (Figure 5) may be a deceptive phenomenon which has occurred because radiation-induced cancers have not increased appreciably in those who were young ATB and have not yet reached the ages at which these cancers develop.

As yet no excess deaths from breast cancer have been observed for ages 35-49 ATB.   This is consistent with results of the previous incidence study 1950-74[15] in which no radiation effect was observed for women aged 40-49 ATB. The excess deaths for the same age ATB cohort for all cancers except leukemia increased with attained ages.   A similar tendency is observed, in general, for cancers of the lung, stomach, and breast (except for ages 35-49 ATB).   Thus, though in the recent BEIR report[8] two different

若いほど高い．表7から明らかなように，死亡時年齢が同じ場合は白血病以外の全部位の癌，肺癌，乳癌及び胃癌の絶対危険度は相対的危険度と同様，被爆時年齢が若いほど高い．各年齢群において被爆時年齢の最も高い値（表7）を除外した場合，すなわち最小潜伏期間を15年と仮定した場合，同様の傾向が一層明白となる．したがって，被爆時年齢と共に放射線誘発癌の絶対危険度が高くなる（図5）のは，放射線誘発癌が被爆時に若年であって，これらの癌の好発年齢にまだ達していない者にはまだそれほど増加していないために認められる偽りの現象である．

被爆時年齢が35～49歳の者には乳癌による死亡の増加は観察されていない．これは，1950～74年についての乳癌発生率調査[15]で被爆時年齢が40～49歳の女性に放射線影響が認められなかったという結果と一致する．被爆時年齢の等しいコホートの白血病以外の全部位の癌の死亡数増加は死亡時年齢と共に増加する．この傾向は一般に肺癌，胃癌及び乳癌にも見られる（被爆時年齢35～49歳を除く）傾向である．

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TABLE 7 ABSOLUTE RISK BY AGE ATB (EXCESS DEATHS/10^6 PYR, 1950-78)

表 7   絶対危険度（増加死亡数／100万人年 rad, 1950−78年），被爆時年齢別

Age ATB	Age at death					
	< 30	30-39	40-49	50-59	60-69	70+
All cancer except leukemia						
<10	1.22	4.35	13.41	-	-	-
10-19	(0.03)*	1.72	4.62	20.69	-	-
20-34	-	(1.35)	1.01	7.97	10.25	-
35-49	-	-	(0.26)	−0.96	2.09	12.67
50+	-	-	-	(17.39)	(0.53)	18.31
Stomach cancer						
<10	0.18	0.40	13.84	-	-	-
10-19	(−0.11)	0.57	0.47	5.05	-	-
20-34	-	(0.10)	1.31	2.06	1.97	-
35-49	-	-	(1.61)	−1.20	−0.08	6.15
50+	-	-	-	(5.06)	(−1.39)	8.82
Breast cancer						
<10	-	−0.02	-	-	-	-
10-19	-	0.80	1.16	-	-	-
20-34	-	(0.17)	−0.18	2.27	4.79	-
35-49	-	-	(−0.66)	−0.08	−0.10	−0.34
50+	-	-	-	(4.66)	(−0.17)	0.38
Lung cancer						
<10	-	−0.01	−0.45	-	-	-
10-19	-	−0.02	0.96	7.48	-	-
20-34	-	-	−0.23	1.73	3.34	-
35-49	-	-	(−0.14)	0.59	1.19	4.72
50+	-	-	-	(−0.13)	(1.84)	0.29

*Value of the highest age ATB of attained age class (see test).

年齢群中の被爆時年齢が最も高い者の値（本文参照）

models (relative risk and absolute risk models) have been used for projection of risk beyond the period of observation, the present data support the relative risk model projection more strongly. The excess deaths from cancers other than leukemia increase with age at death for the same age cohort in proportion to the age-specific death rate from cancers in the population of all Japan and do not show a constant excess value by age at death for the same age cohort. Thus, the effect of age ATB and the attained age has to be considered in estimating the risk of induction of cancer by radiation in man and it is difficult at present to estimate accurately the magnitude of the risk during one's lifetime from the magnitude of the risk observed in A-bomb survivors. Survivors exposed at younger ages are only now beginning to attain cancer ages and their cancer experiences
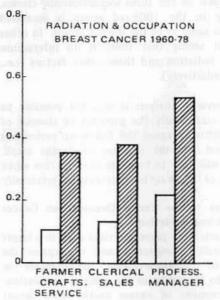
最近の BEIR 報告[8] では危険度の推定に二つの異なる モデル（相対的危険度モデルと絶対危険度モデル）が, 観察期間を越えた危険度の予測に用いられているが, 本報の資料は相対的危険度のモデルの方をより強く 支持する．白血病以外の癌は全国の癌による年齢別 死亡率に比例して死亡時年齢と共に増加し，死亡時 年齢別に一定の増加を示さない．このように放射線に よる癌の誘発危険度を推定するのには被爆時年齢と 対象者の死亡時年齢の両方の影響を考慮しなくては ならない．したがって原爆被爆者で現在までに観察 された危険度の大きさから，その人の生涯を通しての 危険度の大きさを正確に推定することは困難である． 若年で被爆した者はようやく今癌年齢に達し始めた ところであり，その群における癌については将来ある

FIGURE 6 RADIATION AND OTHER CARCINOGENS
図6 放射線と他の発癌要因

will have to be followed for some time into the future.

Relationship Between Radiation and Other Carcinogenic Factors

A-bomb survivors have been exposed not only to radiation but also to other carcinogenic factors. It is essential, therefore, to ascertain whether the effect of radiation interacts with those of other carcinogenic factors, such as smoking. Such investigations may clarify the mechanism of radiation carcinogenesis. Data concerning factors other than radiation have been collected on this fixed population through census, mail survey, and interview since 1960. A prospective analysis has been made using these data. The relationships of radiation to smoking for lung cancer and of radiation and main occupation of household head (a socioeconomic index) for breast cancer are shown in Figure 6.

The age-adjusted lung cancer mortality is higher among heavy smokers than light or nonsmokers in both the 100+ rad group and the 0-9 rad group. Moreover, though there are few cases and the finding is not statistically significant, mortality in the 100+ rad group is increased about the same

程度の期間追跡しなければならない.

放射線と他の発癌要因との関係

原爆被爆者は放射線だけでなく他の発癌要因にもさらされている. したがって, 放射線の影響と喫煙などの他の発癌要因の影響との間に相互作用があるか否かを確認することが重要である. そのような研究によって放射線による発癌の機序が解明されるかもしれない. 1960年以来, 人口調査, 郵送調査及び面接調査によって, この固定集団についての放射線以外の要因に関する資料が収集されている. これらの資料を用いて解析を行った. 図6に肺癌における放射線と喫煙の関係, 乳癌における放射線と世帯主の主な職業〈社会経済的指標〉との関係を示した.

100 rad 以上群と0−9 rad 群とも年齢訂正肺癌死亡率は喫煙量の少ない者あるいは非喫煙者よりも喫煙量の多い者の方が高い. 更に, 症例が少なく統計的に有意な所見ではないが, 100 rad 以上群の死亡率の0−9 rad 群に比べての増加の程度は喫煙量の多い

as that in the 0-9 rad group in heavy and light smokers. In breast cancer also, mortality is higher with higher socioeconomic status in both the 100+ rad group and the 0-9 rad group, and within each of the three socioeconomic classes, mortality in the 100+ rad group is increased about the same as in the 0-9 rad group. In other words, it seems that there is no interaction between radiation and these other factors (i.e., they act additively).

In the present analysis it was not possible to establish statistically the presence or absence of an interaction because the follow-up period has been short and the number of deaths small. A study will have to be made in the future when the years of follow-up have increased substantially.

Estimation of the Excess Deaths from Cancer Among A-bomb Survivors

It is important to place the risks cited in a larger public health perspective and to express the impact of radiation-related malignancies in relation to mortality in the general population. This assessment of excess deaths from cancer has been made, first, for the 79,856 A-bomb survivors who are the subjects of the present analysis and second, for all A-bomb survivors. Clearly, in both instances, the impact, at least in absolute terms, depends upon the population at risk, their exposure dose and years at risk, and the excess deaths per person-year per rad at risk. The average exposure dose among the subjects of this report is 27.2 rad, and the average number of years at risk is 24.27. Thus, the population at risk is 52.7 million PYR (79856 × 27.2 × 24.27). In Table 2, the excess deaths from cancer per million PYR are shown for individual sites of cancer assuming a simple linear dose-response relationship. The excess number of deaths from cancer is merely the population at risk multiplied by the excess deaths from cancer per million PYR; this excess for individual sites of cancer is shown in Table 8. The excess cancer deaths are also given in terms of their proportion of all causes of death and of deaths from individual sites of cancer.

The 90.6 excess deaths from leukemia account for 50.6% of all leukemia deaths in this cohort. For all cancers except leukemia, as a contrast, only 3.5% of the 4,575 such deaths in this cohort are attributable to A-bomb radiation. This proportion, however, varies by site; from 29.0% for multiple myeloma to 2.4% for cancer of the

者と少ない者の両群においてほぼ同様である。乳癌についても100 rad 以上群と 0−9 rad 群の両群において社会経済的状態が良いほど死亡率が高く、三つの社会経済的階層のそれぞれの中では100 rad 以上群の 0−9 rad 群に比べての死亡率の増加の程度はほぼ同じである。つまり、放射線とこれら他の要因の間に相互作用はない(すなわち、両者は相加的に作用する)と考えられる。

本解析では追跡期間が短く、死亡数が少ないため、相互作用の有無を統計的に確定することはできなかった。追跡年数が相当増えた時点で、改めて調査を行う必要がある。

原爆被爆者の癌による死亡増加の推定

本報で示した危険度をより広い公衆衛生の立場で考え、放射線誘発悪性腫瘍の影響を一般集団の死亡率との関係において述べることは重要である。この癌による死亡数増加の評価は最初本解析の対象者である原爆被爆者79,856人について行い、次に被爆者全員について行った。このいずれの場合も、実際の増加死亡実数は対象となる被爆集団、その集団の被曝線量、観察年数、及び観察人年 rad 当たりの死亡数増加に依存することは明らかである。本報の固定集団の対象者の平均被曝線量は27.2 rad であり、平均観察年数は24.27年である。したがって、観察被爆集団は 52,700,000人年(79856×27.2×24.27)となる。一方表2に百万人年 rad 当たりの死亡増加を単純な線形線量反応関係をもとに個々の癌部位別に示してある。癌の増加死亡数(放射線誘発癌による死亡実数)は観察被爆集団に単に100万人年 rad 当たりの癌の死亡数増加を乗じたものであり、個々の癌部位別に表8に示した。またこの放射線誘発癌による増加死亡数を全死因と個々の部位の癌による死亡に対する割合としても示した。

白血病の増加死亡数は90.6でコホートの全白血病死亡の50.6%に当たる。これと比べて白血病以外の全部位の癌合計ではこのコホートの癌死亡4,575人のわずか3.5%が原爆放射線に起因するものである。しかし、この割合は部位によって異なり、多発性骨髄

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TABLE 8 ESTIMATED NUMBER OF EXCESS CANCER DEATHS AND PROPORTION TO ALL CAUSES AND SPECIFIC SITES OF CANCER, 1950-78, EXPOSED, LSS EXTENDED SAMPLE

表 8　癌の増加死亡数の推定数とその全死因及び特定部位の癌死亡に対する割合，1950－78年，寿命調査拡大対象者中の被爆者

Cancer site	Excess Deaths (90% confidence interval)			Upper: % to all causes Lower: % to specific causes			Deaths		
	Cities combined	Hiroshima	Nagasaki	H + N	H	N	H + N	H	N
Leukemia	90.6 (82.7- 98.5)	66.36 (59.78- 73.24)	27.31 (22.58-32.04)	.39 50.3	.36 47.1	.54 70.0	180	141	39
All cancer except leukemia	159.7 (120.7-198.7)	135.22 (102.66-167.77)	27.31 (4.09-50.74)	.68 3.5	.73 3.7	.54 3.0	4576	3659	917
Esophagus	8.4 (1.1- 15.8)	10.64 (4.38- 16.90)	−2.15 (−6.45- 2.15)	.04 5.4	.06 8.4	−.04 −7.2	156	126	30
Stomach	41.6 (17.9- 65.3)	31.61 (10.96- 51.96)	10.32 (−3.23-24.08)	.18 2.4	.17 2.2	.21 3.3	1754	1443	311
Colon	15.8 (8.4- 22.7)	14.09 (8.14- 20.35)	1.94 (−1.72- 5.59)	.07 10.1	.08 10.6	.04 8.1	157	133	24
Other digestive	24.2 (9.5- 38.5)	20.03 (8.76- 31.61)	4.52 (−5.16-13.98)	.10 4.1	.11 4.5	.09 3.0	595	444	151
Lung	32.1 (19.5- 45.3)	25.98 (15.65- 36.31)	7.31 (−.86-15.48)	.14 7.0	.14 7.4	.15 6.9	459	353	106
Breast (Female)	15.4 (8.9- 22.2)	12.88 (7.36- 18.22)	2.83 (−1.23- 7.01)	.13 12.0	.14 12.9	.12 10.1	128	100	28
Urinary tract	7.9 (2.1- 13.7)	4.70 (−.31- 9.70)	2.80 (−.22- 5.81)	.03 7.6	.03 5.2	.06 20.0	104	90	14
Multiple myeloma	5.8 (2.6- 8.4)	2.82 (1.25- 4.70)	2.80 (.65- 4.95)	.02 29.0	.02 23.5	.06 35.0	20	12	8

	Deaths from all causes	Mean dose	Average person-years	No. subjects	Population at risk (10^6 PYR)
H + N	23502 (11740)*	27.2	24.27	79856 (46630)*	52.7×10^6 (30.8×10^6)*
H	18471 (9315)*	21.3	24.27	60482 (35607)*	31.3×10^6 (18.4×10^6)*
N	5031 (2425)*	45.8	24.27	19374 (11023)*	21.5×10^6 (12.3×10^6)*

*For female 女性

TABLE 9 ESTIMATED NUMBER OF EXCESS CANCER DEATHS, 1950-78, AMONG
A TOTAL 283,498 A-BOMB SURVIVORS, ALL JAPAN IN 1950

表 9　1950年の全国被爆者総数283,498人中の癌の増加死亡数の推定数，1950−78年

Cancer site	Excess deaths (90% confidence interval)	Upper: % to all causes Lower: % to specific causes	Estimated deaths
Leukemia	190.6 (174.0-207.2)	0.28 (0.26- 0.31) 49.3 (45.0 -53.5)	387
All cancer except leukemia	335.7 (253.7-417.7)	0.50 (0.37- 0.62) 3.2 (2.4 - 4.0)	10421

Note: Estimated deaths from all causes: 67660

Mean dose	Average person-years	Subjects	Population at risk (10^6 PYR)
H+N 16.1 rad	24.27	283,498	110.8×10^6

stomach. In addition, 0.39% and 0.68% of the 23,499 deaths from all causes in this cohort are attributable to A-bomb radiation for leukemia and all cancers except leukemia, respectively. These estimates are all based on the assumption of a linear increase with dose. The estimated number of excess deaths under the linear-quadratic model differ slightly; 62.2 and 208.5 for leukemia and cancers other than leukemia (corresponding to 34.7% and 4.6% deaths in the cohort, respectively).

The exposed subjects described here are A-bomb survivors who lived either in Hiroshima or Nagasaki cities at the time of the National Census in 1950 which enumerated a total of 283,500 A-bomb survivors throughout Japan. It is of interest therefore to estimate the excess deaths from cancer among all A-bomb survivors. A mean exposure for the latter can be obtained if it is assumed that the T65DR by exposure distance for the A-bomb survivors residing in Hiroshima and Nagasaki cities in 1950, and the distribution by exposure distance of the A-bomb survivors residing elsewhere in Japan in that year do not differ. The mean dose of all survivors based on this assumption is 16.1 rad. If the mortality experience of nonresident survivors in the years since 1950 has been the same as that for residents, then the population at risk is 110.8 million PYR for the 283,498 A-bomb survivors. Given these assumptions, the estimated number of excess deaths is 190.6 for leukemia

腫の29.0%から胃癌の2.4%まである．更に，この コホートにおける全死亡23,499人のうち原爆放射線に よる白血病は0.39%，白血病以外の全部位の癌合計 では0.68%である．これらの推定値はすべて線量と 共に直線的に増加するという仮定に基づいた場合の ものである．線形・二次関数的モデルのもとでの推定 増加死亡数はわずかに異なり，白血病では62.2，白血 病以外の癌が208.5である（本コホートにおいては それぞれ34.7%及び4.6%に相当する）．

本報で解析した被爆者は1950年の国勢調査時（全国 で283,500人の原爆被爆者がいた）に広島市か長崎市 に在住していた原爆被爆者から抽出されている．した がって全国の全被爆者の癌の増加死亡数を推定する ことは興味のあることである．1950年に広島・長崎に 居住していた被爆者の被爆距離別分布と同年に国内 の別の場所に住んでいた被爆者の被爆距離別分布が 異ならないと仮定すれば，全国被爆者の平均被曝線 量が得られる．この仮定に基づいた全被爆者の平均 被曝線量は16.1 radである．1950年以降の両市に 在住していない被爆者の死亡率が両市在住の被爆者 のそれと同じであるとすれば，観察被爆集団は被爆者 283,498人で110,800,000人年となる．このような 仮定のもとでは，表9に示すように白血病の推定増加 死亡数は190.6で白血病以外のすべての癌では335.7

and 335.7 for all cancers except leukemia, as shown in Table 9. The number of deaths among all survivors was estimated using age, sex-specific death rates for 1950, 1965, and 1975 for all Japan and the 1965 life table. The number of deaths thus estimated is 67,660 for all causes, 387 for leukemia, and 10,421 for all cancers except leukemia. The 190.6 excess deaths from leukemia correspond to 0.28% of the total 67,660 deaths, and the 335.7 excess deaths from all cancers except leukemia correspond to 0.50%.

The excess number of cancer deaths thus far estimated is the one experienced during 1950-78 among A-bomb survivors, and not for their whole lives. In the estimation of excess deaths over the whole lifetime of the survivors, a number of assumptions are required which demand detailed justification. We shall develop these arguments elsewhere.

である. 全国被爆者からの死亡数は1950年, 1965年及び1975年の全国の年齢別・性別死亡率と1965年の生命表から推定した. その推定数は全死因による死亡は67,660, 白血病387, 白血病以外のすべての癌10,421である. 白血病の増加死亡数190.6は総死亡67,660人の0.28%に, 白血病以外のすべての癌の335.7はその0.50%に相当する.

現在まで推定された癌による増加死亡数は被爆者の1950～78年の間に生じたものであり, その全生涯にわたる推定死亡数ではない. 被爆者の全生涯にわたる増加死亡数を推定するには詳細な理由付けを必要とする多くの仮定を用いなくてはならない. この問題に関しては別に検討を加えていく予定である.

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1. NUMBER OF SUBJECTS AND MEAN T65DR ESTIMATES, LSS EXTENDED SAMPLE, BY CITY AND TYPE OF RADIATION

1. 拡大寿命調査対象者数及び平均 T 65 DR 推定線量，市及び放射線の種類別

Class		Total	T65DR in rad										
			0	1-9	10-49	50-99	100-199	200-299	300-399	400+*	100+*	10+*	Unknown
						Total							
Subjects		82242	31581	23073	14942	4225	3128	1381	639	887	6035	25202	2386
Mean dose	Total		0	3.4	21.8	70.6	142.4	243.6	345.3	526.4	243.5	83.1	-
	Gamma		0	2.9	18.5	61.4	124.6	214.4	289.4	438.8	208.8	71.3	-
	Neutron		0	0.5	3.3	9.2	17.8	29.2	55.9	87.6	34.7	11.8	-
						Hiroshima							
Subjects		61911	27577	15933	10911	2783	1740	659	369	510	3278	16972	1429
Mean dose	Total		0	3.3	22.0	70.3	138.9	243.6	346.4	524.4	243.3	72.8	-
	Gamma		0	2.6	17.5	56.6	108.4	186.4	254.0	380.3	182.8	55.9	-
	Neutron		0	0.7	4.5	13.7	30.5	57.2	92.4	144.1	60.5	16.9	-
						Nagasaki							
Subjects		20331	4004	7140	4031	1442	1388	722	270	377	2757	8230	957
Mean dose	Total		0	3.6	21.2	71.2	146.9	243.7	343.7	529.2	243.8	104.6	-
	Gamma		0	3.6	21.2	70.7	145.0	239.9	337.7	518.0	239.7	103.1	-
	Neutron		0	0.0	0.0	0.5	1.9	3.8	6.0	11.2	4.1	1.5	-

*Dose estimates in excess of 600 rad have been reduced to 600 (Hiroshima, 428 gamma rad, 172 neutron rad; Nagasaki, 587 gamma rad, 13 neutron rad).

600rad 以上の推定線量は600rad にした．（広島：ガンマ線量428rad，中性子線量172rad，長崎：ガンマ線量587rad，中性子線量13rad）

2. NUMBER OF PERSON-YEARS, LSS EXTENDED SAMPLE BY T65DR, CITY, SEX, AGE ATB, AND TIME PERIOD, 1950-78
2. 拡大寿命調査対象の人年数，T 65 DR 推定線量，市，性，被爆時年齢及び年度別，1950－78年

Class		Total	T65DR in rad									
			NIC	0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Unknown
Total		2622.0	626.9	764.4	561.2	361.8	102.8	76.6	34.4	15.7	21.1	57.0
		(1563.0)	(368.3)	(461.2)	(329.0)	(224.5)	(63.3)	(44.3)	(19.9)	(9.4)	(11.6)	(31.6)
Hiroshima		1962.0	468.3	665.2	385.8	263.6	66.7	41.4	16.1	8.9	12.2	33.8
		(1184.6)	(279.4)	(405.5)	(224.2)	(165.9)	(43.1)	(24.5)	(9.4)	(5.6)	(6.8)	(20.1)
Nagasaki		660.1	158.7	99.2	175.4	98.2	36.2	35.1	18.4	6.8	9.0	23.2
		(378.5)	(88.9)	(55.6)	(104.8)	(58.6)	(20.2)	(19.8)	(10.5)	(3.8)	(4.7)	(11.5)
Age ATB	0-9	568.2	135.3	168.3	128.1	86.2	20.2	11.1	5.5	2.3	3.5	7.6
		(289.6)	(69.0)	(85.4)	(65.9)	(43.2)	(10.3)	(5.9)	(2.8)	(1.2)	(1.8)	(4.1)
	10-19	646.3	157.2	177.1	142.0	76.0	24.4	25.3	11.7	5.1	6.4	21.3
		(365.8)	(87.8)	(101.7)	(73.1)	(45.7)	(15.1)	(15.2)	(7.2)	(3.2)	(3.1)	(13.9)
	20-34	585.1	147.7	166.3	120.5	77.0	24.1	17.5	8.2	4.2	5.4	14.1
		(423.6)	(104.4)	(121.9)	(88.3)	(58.8)	(18.0)	(11.8)	(5.1)	(2.8)	(3.9)	(8.7)
	35-49	583.7	137.1	176.1	118.6	86.0	23.8	17.2	6.7	3.1	4.6	10.4
		(349.7)	(79.1)	(108.0)	(72.3)	(55.7)	(14.2)	(8.9)	(3.8)	(1.8)	(2.3)	(3.6)
	50+	238.8	49.7	76.6	52.0	36.6	10.3	5.6	2.3	1.0	1.3	3.5
		(134.3)	(27.9)	(44.2)	(29.4)	(21.2)	(5.7)	(2.5)	(1.1)	(0.5)	(0.4)	(1.3)
Time Period*	50-54	419.5	76.5	131.5	96.3	62.4	17.7	13.1	5.8	2.7	3.7	9.7
		(242.0)	(41.5)	(77.4)	(55.2)	(37.9)	(10.7)	(7.3)	(3.3)	(1.6)	(1.9)	(5.2)
	55-58	411.9	102.2	118.7	87.1	56.4	16.1	11.8	5.3	2.4	3.3	8.6
		(242.2)	(59.7)	(70.5)	(50.3)	(34.5)	(9.7)	(6.7)	(3.0)	(1.4)	(1.7)	(4.7)
	59-62	394.6	98.2	113.5	83.3	53.8	15.4	11.4	5.1	2.3	3.2	8.3
		(233.8)	(57.7)	(68.0)	(48.5)	(33.2)	(9.4)	(6.5)	(2.9)	(1.4)	(1.7)	(4.6)
	63-66	377.0	94.2	108.5	79.4	51.3	14.6	10.9	4.9	2.2	3.0	8.0
		(225.3)	(55.7)	(65.6)	(46.6)	(31.9)	(9.0)	(6.3)	(2.8)	(1.3)	(1.7)	(4.5)
	67-70	358.8	89.9	103.2	75.5	48.7	13.8	10.4	4.7	2.1	2.9	7.8
		(216.4)	(53.5)	(63.0)	(44.8)	(30.5)	(8.6)	(6.1)	(2.7)	(1.3)	(1.6)	(4.4)
	71-74	339.8	85.2	97.5	71.7	46.0	13.0	9.8	4.4	2.0	2.7	7.4
		(206.8)	(51.2)	(60.0)	(42.9)	(29.0)	(8.2)	(5.8)	(2.6)	(1.2)	(1.5)	(4.3)
	75-78	320.5	80.8	91.5	67.9	43.2	12.2	9.3	4.1	1.9	2.5	7.1
		(196.6)	(49.0)	(56.8)	(40.8)	(27.5)	(7.7)	(5.6)	(2.5)	(1.2)	(1.4)	(4.1)

*Full calendar years except that 1950-54 indicates 1 October 1950 – 31 December 1954.　　　( ) For female.　括弧は女性
年度は完全な暦年．ただし，1950－54年は1950年10月1日から1954年12月31日まで．　　　In thousands.　単位 1000.

3. OBSERVED AND EXPECTED DEATHS FROM LEUKEMIA, BY T65DR, CITY, AGE ATB, AND TIME PERIOD
3. 白血病の観察及び期待死亡数，T 65 DR 推定線量，市，被爆時年齢及び年度別

Class			Total	T65DR in rad								Test P	
				0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total		Obs.	180	46	24	33	11	17	16	12	21	0.0000	0.0000
		Exp.		72.1	51.5	33.5	9.5	6.9	3.0	1.4	2.0		
	Hiroshima	Obs.	141	42	14	28	11	14	9	11	12	0.0000	0.0000
		Exp.		63.8	37.5	25.3	6.5	4.2	1.6	0.8	1.2		
	Nagasaki	Obs.	39	4	10	5	0	3	7	1	9	0.0000	0.0000
		Exp.		8.3	14.0	8.2	3.0	2.7	1.4	0.6	0.7		
Age ATB	0-9	Obs.	30	6	3	4	1	4	4	1	7	0.0000	0.0000
		Exp.		10.8	9.5	6.4	1.5	0.9	0.5	0.2	0.3		
	10-19	Obs.	32	8	3	9	1	4	3	1	3	0.0000	0.0000
		Exp.		12.6	9.8	5.1	1.5	1.6	0.7	0.3	0.4		
	20-34	Obs.	39	9	4	6	3	5	4	5	3	0.0000	0.0000
		Exp.		16.5	10.7	6.8	2.0	1.4	0.7	0.3	0.5		
	35-49	Obs.	57	21	10	8	4	2	3	3	6	0.0000	0.0000
		Exp.		23.1	15.4	11.0	3.2	2.4	0.9	0.4	0.6		
	50+	Obs.	22	2	4	6	2	2	2	2	2	0.0000	0.0000
		Exp.		9.1	6.1	4.3	1.2	0.7	0.3	0.1	0.2		
Time Period	50-54	Obs.	37	7	2	2	3	5	4	3	11	0.0000	0.0000
		Exp.		14.0	10.9	6.9	2.1	1.6	0.8	0.3	0.5		
	55-58	Obs.	32	5	5	8	1	2	6	1	4	0.0000	0.0000
		Exp.		13.2	8.9	5.8	1.7	1.3	0.5	0.2	0.3		
	59-62	Obs.	24	5	1	7	1	4	1	1	4	0.0000	0.0000
		Exp.		9.5	7.0	4.7	1.2	0.8	0.4	0.2	0.3		
	63-66	Obs.	19	3	3	5	2	2	1	3	0	0.0000	0.0000
		Exp.		8.0	5.2	3.6	1.0	0.7	0.3	0.1	0.2		
	67-70	Obs.	18	5	4	2	0	1	2	3	1	0.0000	0.0000
		Exp.		6.6	5.3	3.5	1.1	0.8	0.4	0.2	0.2		
	71-74	Obs.	20	7	7	1	1	2	1	1	0	0.0992	0.0387
		Exp.		8.5	5.7	3.5	0.9	0.7	0.3	0.1	0.2		
	75-78	Obs.	30	14	2	8	3	1	1	0	1	0.1642	0.0711
		Exp.		12.5	8.4	5.6	1.5	1.1	0.5	0.2	0.3		

4. OBSERVED AND EXPECTED DEATHS FROM ALL CANCERS EXCEPT LEUKEMIA, BY CITY, SEX, AGE ATB, AND TIME PERIOD

4. 白血病以外の全部位の癌合計の観察及び期待死亡数，市，性，被爆時年齢及び年度別

Class			Total	T65DR in rad								Test P	
				0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total		Obs.	4576	1770	1224	891	259	205	108	43	76	0.0000	0.0000
		Exp.		1847.8	1272.7	871.6	254.1	177.3	72.5	33.4	46.6		
	Hiroshima	Obs.	3659	1589	896	698	189	136	74	26	51	0.0000	0.0000
		Exp.		1653.4	943.4	680.0	181.0	113.2	39.9	19.3	28.9		
	Nagasaki	Obs.	917	181	328	193	70	69	34	17	25	0.6480	0.0268
		Exp.		194.4	329.3	191.7	73.1	64.1	32.6	14.1	17.7		
	Male	Obs.	2313	925	620	408	129	111	57	20	43	0.0160	0.0001
		Exp.		927.6	646.6	417.9	130.6	103.5	40.3	18.3	28.1		
	Female	Obs.	2263	845	604	483	130	94	51	23	33	0.0000	0.0000
		Exp.		920.1	626.1	453.7	123.5	73.8	32.2	15.1	18.5		
Age ATB	0-9	Obs.	48	15	15	4	1	3	8	0	2	0.0000	0.0000
		Exp.		20.1	14.0	9.4	2.2	1.2	0.6	0.2	0.3		
	10-19	Obs.	221	66	65	32	11	16	11	11	9	0.0000	0.0000
		Exp.		81.0	68.2	35.8	11.9	12.7	5.9	2.4	3.1		
	20-34	Obs.	631	228	160	124	35	35	29	6	14	0.0001	0.0000
		Exp.		247.1	179.6	113.4	36.1	27.0	13.0	6.5	8.2		
	35-49	Obs.	2066	779	559	426	124	85	37	20	36	0.0414	0.0010
		Exp.		828.5	564.5	399.6	114.9	86.5	33.2	15.6	23.2		
	50+	Obs.	1610	682	425	305	88	66	23	6	15	0.2555	0.0797
		Exp.		671.1	446.4	313.5	89.0	49.9	19.7	8.7	11.8		
Time Period	50-54	Obs.	440	181	109	87	25	19	8	4	7	0.5894	0.0215
		Exp.		178.6	123.5	85.4	23.7	15.6	6.0	2.8	4.2		
	55-58	Obs.	519	218	151	93	24	16	8	3	6	0.9021	0.5369
		Exp.		208.8	146.0	101.4	28.6	18.6	7.4	3.4	4.8		
	59-62	Obs.	620	223	181	124	34	36	5	8	9	0.0029	0.0078
		Exp.		256.7	169.0	118.4	35.0	22.4	8.7	4.1	5.7		
	63-66	Obs.	681	266	179	136	46	20	18	2	14	0.0080	0.0063
		Exp.		279.8	185.9	130.1	37.7	25.5	10.5	4.7	6.8		
	67-70	Obs.	718	270	191	150	41	26	23	5	12	0.0345	0.0079
		Exp.		288.8	198.0	136.2	40.4	29.1	12.4	5.4	7.6		
	71-74	Obs.	774	306	199	147	41	45	17	7	12	0.1511	0.0061
		Exp.		307.8	217.2	146.8	43.2	31.6	13.4	6.0	8.0		
	75-78	Obs.	824	306	214	154	48	43	29	14	16	0.0000	0.0000
		Exp.		329.0	231.7	154.0	45.5	34.6	14.2	6.6	8.4		

5. OBSERVED AND EXPECTED DEATHS FROM STOMACH CANCER, BY T65DR, CITY, SEX, AGE ATB, AND TIME PERIOD

5. 胃癌の観察及び期待死亡数，T65DR推定線量，市，性，被爆時年齢及び年度別

Class		Total	T65DR in rad								Test P	
			0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total	Obs.	1754	708	473	340	91	64	32	17	29	0.1203	0.0021
	Exp.		718.0	484.3	331.8	96.2	67.0	26.7	12.2	17.6		
Hiroshima	Obs.	1443	647	356	272	71	47	22	11	17	0.3414	0.0057
	Exp.		651.4	373.6	266.9	71.2	45.2	15.7	7.5	11.5		
Nagasaki	Obs.	311	61	117	68	20	17	10	6	12	0.2412	0.1062
	Exp.		66.6	110.8	64.9	25.0	21.8	11.0	4.8	6.1		
Male	Obs.	997	407	281	177	46	42	17	7	20	0.3628	0.0703
	Exp.		405.5	276.9	180.4	55.2	43.4	16.4	7.5	11.7		
Female	Obs.	757	301	192	163	45	22	15	10	9	0.0841	0.0032
	Exp.		312.5	207.4	151.5	41.0	23.6	10.3	4.8	5.9		
Age ATB 0-9	Obs.	21	10	6	2	0	0	2	0	1	0.0073	0.0121
	Exp.		8.5	6.2	4.2	1.0	0.5	0.3	0.1	0.2		
10-19	Obs.	65	17	24	9	3	5	1	3	3	0.0395	0.0042
	Exp.		22.9	20.7	10.4	3.6	3.9	1.8	0.7	1.0		
20-34	Obs.	211	79	54	45	9	7	11	3	3	0.0394	0.0567
	Exp.		84.1	59.8	37.6	11.8	8.8	4.2	2.1	2.7		
35-49	Obs.	779	305	210	158	45	29	10	9	13	0.5409	0.0978
	Exp.		316.2	211.8	148.7	42.7	32.9	12.2	5.7	8.8		
50+	Obs.	678	297	179	126	34	23	8	2	9	0.6242	0.2076
	Exp.		286.2	185.8	131.0	37.2	21.0	8.2	3.6	5.0		
Time Period 50-54	Obs.	183	80	42	28	15	11	2	2	3	0.1598	0.0502
	Exp.		74.8	51.3	35.0	9.8	6.7	2.5	1.2	1.8		
55-58	Obs.	241	93	75	49	12	5	2	2	3	0.7924	0.6229
	Exp.		98.2	67.3	46.4	13.2	8.7	3.4	1.6	2.3		
59-62	Obs.	257	107	66	48	15	13	3	3	2	0.8623	0.2296
	Exp.		109.1	68.8	48.5	14.2	9.0	3.5	1.6	2.3		
63-66	Obs.	265	107	68	55	14	9	4	1	7	0.3017	0.0551
	Exp.		110.1	71.6	50.1	14.7	10.1	4.1	1.8	2.7		
67-70	Obs.	274	111	77	54	8	9	7	2	6	0.2629	0.0820
	Exp.		112.6	74.6	51.7	15.1	10.8	4.5	1.9	2.8		
71-74	Obs.	273	119	69	51	12	9	6	3	4	0.7909	0.2037
	Exp.		110.6	76.1	51.5	14.9	10.8	4.4	2.0	2.7		
75-78	Obs.	261	91	76	55	15	8	8	4	4	0.2840	0.0388
	Exp.		103.2	74.2	48.9	14.4	11.1	4.5	2.0	2.7		

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6. OBSERVED AND EXPECTED DEATHS FROM LUNG CANCER, BY T65DR, CITY, SEX, AGE ATB, AND TIME PERIOD

6. 肺癌の観察及び期待死亡数，T65DR推定線量，市，性，被爆時年齢及び年度別

| Class | | | | Total | \multicolumn{9}{c}{T65DR in rad} | | Test P | |
					0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total		Obs.	459		156	125	88	27	35	12	8	8	0.0003	0.0000
		Exp.			182.4	127.9	86.8	26.3	19.2	7.7	3.6	5.1		
	Hiroshima	Obs.	353		133	86	75	21	21	6	5	6	0.0009	0.0000
		Exp.			159.0	91.2	65.3	17.3	11.5	3.9	1.8	2.9		
	Nagasaki	Obs.	106		23	39	13	6	14	6	3	2	0.1070	0.0684
		Exp.			23.4	36.7	21.5	8.9	7.7	3.8	1.8	2.1		
	Male	Obs.	276		101	74	48	16	21	7	2	7	0.2159	0.0075
		Exp.			108.2	77.3	50.1	16.2	13.2	5.1	2.4	3.6		
	Female	Obs.	183		55	51	40	11	14	5	6	1	0.0000	0.0001
		Exp.			74.2	50.7	36.7	10.1	6.0	2.6	1.2	1.5		
Age ATB	0-9	Obs.	2		1	1	0	0	0	0	0	0	0.9961	0.6401
		Exp.			0.9	0.5	0.4	0.1	0.0	0.0	0.0	0.0		
	10-19	Obs.	15		2	4	2	1	2	1	1	2	0.0010	0.0000
		Exp.			5.4	4.7	2.4	0.8	0.9	0.4	0.2	0.2		
	20-34	Obs.	51		19	12	8	1	6	3	1	1	0.1208	0.0300
		Exp.			19.4	14.7	9.2	3.0	2.3	1.2	0.6	0.7		
	35-49	Obs.	252		93	66	42	21	15	5	6	4	0.0523	0.0062
		Exp.			101.1	68.3	47.4	14.5	11.3	4.3	2.0	3.0		
	50+	Obs.	139		41	42	36	4	12	3	0	1	0.0020	0.0900
		Exp.			55.7	39.7	27.5	7.9	4.6	1.8	0.8	1.1		
Time Period	50-54	Obs.	9		4	2	3	0	0	0	0	0	0.9422	0.7875
		Exp.			3.4	2.6	1.8	0.5	0.3	0.1	0.1	0.1		
	55-58	Obs.	15		5	4	3	0	2	0	0	1	0.1822	0.0342
		Exp.			6.2	4.1	2.9	0.8	0.6	0.2	0.1	0.1		
	59-62	Obs.	53		16	13	11	5	7	0	1	0	0.0158	0.1430
		Exp.			21.8	14.4	9.9	3.1	2.1	0.8	0.4	0.5		
	63-66	Obs.	70		21	20	15	6	3	3	1	1	0.2726	0.0291
		Exp.			29.2	18.9	13.3	3.8	2.6	1.0	0.5	0.7		
	67-70	Obs.	95		31	28	23	4	3	4	1	1	0.4624	0.2102
		Exp.			37.3	26.7	18.1	5.5	4.0	1.6	0.7	1.0		
	71-74	Obs.	96		37	22	19	5	10	0	2	1	0.0810	0.1611
		Exp.			37.1	27.0	18.4	5.7	4.2	1.8	0.8	1.0		
	75-78	Obs.	121		42	36	14	7	10	5	3	4	0.0029	0.0000
		Exp.			47.7	33.9	22.4	7.0	5.5	2.2	1.0	1.3		

7. OBSERVED AND EXPECTED DEATHS FROM BREAST CANCER, BY T65DR, CITY, AGE ATB, AND TIME PERIOD (FEMALE)

7. 乳癌の観察及び期待死亡数，T 65 DR 推定線量，市，性，被爆時年齢及び年度別（女性）.

Class		Total	T65DR in rad								Test P	
			0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total	Obs.	128	44	29	26	8	14	2	0	5	0.0000	0.0001
	Exp.		51.0	35.7	25.1	7.1	4.8	2.1	1.0	1.2		
Hiroshima	Obs.	100	39	22	20	5	8	2	0	4	0.0005	0.0000
	Exp.		45.7	24.8	19.1	5.0	2.8	1.1	0.6	0.8		
Nagasaki	Obs.	28	5	7	6	3	6	0	0	1	0.0870	0.1240
	Exp.		5.3	10.9	6.0	2.0	1.9	1.0	0.4	0.5		
Age ATB 0-9	Obs.	1	0	1	0	0	0	0	0	0	0.9125	0.6060
	Exp.		0.5	0.3	0.2	0.0	0.0	0.0	0.0	0.0		
10-19	Obs.	24	8	0	6	3	4	1	0	2	0.0001	0.0000
	Exp.		9.9	6.4	4.2	1.3	1.2	0.5	0.3	0.3		
20-34	Obs.	35	10	8	6	3	4	1	0	3	0.0068	0.0002
	Exp.		12.6	10.5	6.7	2.1	1.5	0.7	0.4	0.5		
35-49	Obs.	45	16	15	10	1	3	0	0	0	0.6353	0.7413
	Exp.		19.0	11.7	9.3	2.4	1.4	0.6	0.3	0.4		
50+	Obs.	23	10	5	4	1	3	0	0	0	0.1502	0.3169
	Exp.		9.0	6.9	4.7	1.3	0.6	0.3	0.1	0.1		
Time Period 50-54	Obs.	15	4	5	4	0	2	0	0	0	0.5720	0.5073
	Exp.		5.5	4.4	3.1	0.9	0.6	0.3	0.1	0.2		
55-58	Obs.	13	4	4	3	0	2	0	0	0	0.3006	0.3817
	Exp.		5.3	3.6	2.7	0.7	0.4	0.2	0.1	0.1		
59-62	Obs.	19	7	6	5	0	1	0	0	0	0.9509	0.7706
	Exp.		6.9	5.6	4.0	1.1	0.7	0.3	0.2	0.2		
63-66	Obs.	19	9	3	1	3	2	0	0	1	0.0374	0.0169
	Exp.		8.2	4.9	3.7	1.0	0.6	0.3	0.1	0.1		
67-70	Obs.	20	3	3	6	3	2	1	0	2	0.0003	0.0000
	Exp.		7.9	5.5	3.8	1.1	0.9	0.4	0.2	0.2		
71-74	Obs.	17	8	5	2	1	1	0	0	0	0.9801	0.7330
	Exp.		6.8	4.8	3.3	0.9	0.6	0.3	0.1	0.2		
75-78	Obs.	25	9	3	5	1	4	1	0	2	0.0008	0.0000
	Exp.		10.4	6.8	4.6	1.3	1.0	0.4	0.2	0.3		

8. OBSERVED AND EXPECTED DEATHS FROM ESOPHAGUS CANCER, BY T65DR, CITY, AND TIME PERIOD
8. 食道癌の観察及び期待死亡数，T65DR推定線量，市及び年度別

Class			Total	T65DR in rad								Test P	
				0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total		Obs.	156	68	26	36	10	5	8	0	3	0.0013	0.0329
		Exp.		63.1	43.3	29.1	8.7	6.5	2.5	1.1	1.7		
	Hiroshima	Obs.	126	59	19	28	7	3	7	0	3	0.0000	0.0024
		Exp.		56.4	33.1	22.9	6.2	4.3	1.4	0.6	1.1		
	Nagasaki	Obs.	30	9	7	8	3	2	1	0	0	0.8317	0.7918
		Exp.		6.7	10.2	6.2	2.5	2.2	1.1	0.5	0.6		
Time Period 50-54		Obs.	20	10	3	4	1	1	1	0	0	0.7394	0.4015
		Exp.		8.0	5.7	3.9	1.1	0.7	0.3	0.1	0.2		
55-58		Obs.	17	5	5	4	0	0	3	0	0	0.0000	0.0476
		Exp.		6.9	4.8	3.3	0.9	0.6	0.2	0.1	0.2		
59-62		Obs.	15	6	3	2	2	1	0	0	1	0.4030	0.0543
		Exp.		6.3	4.1	2.8	0.9	0.6	0.2	0.1	0.2		
63-66		Obs.	30	14	5	6	3	0	0	0	2	0.0642	0.0761
		Exp.		12.1	8.4	5.7	1.7	1.2	0.5	0.2	0.3		
67-70		Obs.	28	15	3	6	2	0	2	0	0	0.1844	0.6089
		Exp.		10.8	7.7	5.1	1.7	1.4	0.6	0.2	0.4		
71-74		Obs.	24	12	·1	6	1	2	2	0	0	0.0746	0.1893
		Exp.		9.8	6.4	4.4	1.4	1.0	0.4	0.2	0.3		
75-78		Obs.	22	6	6	8	1	1	0	0	0	0.5956	0.6805
		Exp.		9.3	6.0	4.1	1.1	0.8	0.3	0.1	0.2		

9. OBSERVED AND EXPECTED DEATHS FROM COLON CANCER, BY T65DR, CITY, AND TIME PERIOD
9. 結腸癌の観察及び期待死亡数，T65DR推定線量，市及び年度別

Class			Total	T65DR in rad								Test P	
				0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total		Obs.	157	63	40	27	8	7	5	1	6	0.0104	0.0001
		Exp.		65.1	43.1	29.9	8.4	5.7	2.3	1.0	1.5		
	Hiroshima	Obs.	133	61	29	22	6	6	3	1	5	0.0076	0.0001
		Exp.		60.2	34.3	24.7	6.5	4.1	1.4	0.7	1.0		
	Nagasaki	Obs.	24	2	11	5	2	1	2	0	1	0.6189	0.1938
		Exp.		4.9	8.8	5.1	1.9	1.6	0.8	0.4	0.4		
Time Period 50-54		Obs.	11	4	4	3	0	0	0	0	0	0.9583	0.7839
		Exp.		4.7	3.0	2.1	0.6	0.4	0.1	0.1	0.1		
55-58		Obs.	10	7	1	1	1	0	0	0	0	0.7560	0.7342
		Exp.		4.3	2.6	1.9	0.5	0.3	0.1	0.1	0.1		
59-62		Obs.	10	3	3	2	1	1	0	0	0	0.9157	0.4704
		Exp.		4.5	2.6	1.8	0.5	0.3	0.1	0.1	0.1		

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9 Continued 続き

Class		Total	T65 DR in rad								Test P	
			0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Time Period 63-66	Obs.	25	11	4	6	1	2	0	0	1	0.4516	0.0781
	Exp.		11.0	6.4	4.9	1.3	0.8	0.3	0.1	0.2		
67-70	Obs.	24	11	6	2	1	0	2	0	2	0.0008	0.0004
	Exp.		9.6	6.7	4.7	1.3	0.9	0.4	0.2	0.2		
71-74	Obs.	37	11	13	9	3	1	0	0	0	0.7909	0.7986
	Exp.		14.8	10.6	7.1	2.0	1.4	0.6	0.2	0.3		
75-78	Obs.	40	16	9	4	1	3	3	1	3	0.0000	0.0000
	Exp.		16.4	11.1	7.4	2.2	1.6	0.6	0.3	0.4		

10. OBSERVED AND EXPECTED DEATHS FROM URINARY TRACT CANCER, BY T65DR, CITY, AND TIME PERIOD

10. 泌尿器癌の観察及び期待死亡数，T65DR 推定線量，市及び年度別

Class		Total	T65DR in rad								Test P	
			0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total	Obs.	104	39	26	18	7	7	4	2	1	0.1427	0.0100
	Exp.		43.8	28.3	19.4	5.6	3.8	1.5	0.7	1.0		
Hiroshima	Obs.	90	38	23	13	5	6	4	1	0	0.0298	0.0647
	Exp.		40.7	23.3	16.6	4.5	2.8	1.0	0.5	0.7		
Nagasaki	Obs.	14	1	3	5	2	1	0	1	1	0.2404	0.0573
	Exp.		3.1	4.9	2.9	1.2	1.0	0.5	0.2	0.3		
Time Period 50-54	Obs.	6	2	2	1	1	0	0	0	0	0.9273	0.6098
	Exp.		2.7	1.6	1.1	0.3	0.2	0.1	0.0	0.1		
55-58	Obs.	8	4	2	1	0	1	0	0	0	0.8687	0.5267
	Exp.		3.3	2.2	1.6	0.4	0.3	0.1	0.0	0.1		
59-62	Obs.	14	6	6	1	0	1	0	0	0	0.7616	0.7068
	Exp.		6.1	3.7	2.6	0.8	0.5	0.2	0.1	0.1		
63-66	Obs.	23	7	7	5	1	1	2	0	0	0.1367	0.1628
	Exp.		9.8	6.2	4.5	1.2	0.7	0.3	0.1	0.2		
67-70	Obs.	14	4	0	3	2	1	2	1	1	0.0005	0.0000
	Exp.		5.5	3.8	2.5	0.9	0.7	0.3	0.1	0.2		
71-74	Obs.	22	11	5	5	0	1	0	0	0	0.9215	0.7898
	Exp.		9.3	5.9	4.1	1.2	0.8	0.3	0.1	0.2		
75-78	Obs.	17	5	4	2	3	2	0	1	0	0.0240	0.0558
	Exp.		7.1	4.7	3.1	0.9	0.7	0.2	0.1	0.2		

11. OBSERVED AND EXPECTED DEATHS FROM MULTIPLE MYELOMA, BY T65DR, CITY, AND TIME PERIOD
11. 多発性骨髄腫の観察及び期待死亡数，T 65 DR 推定線量，市及び年度別

Class			Total	T65DR in rad								Test P	
				0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total		Obs.	20	7	5	2	2	0	2	0	2	0.0031	0.0006
		Exp.		8.2	5.0	3.9	1.2	0.9	0.4	0.2	0.2		
	Hiroshima	Obs.	12	5	4	1	0	0	1	0	1	0.0132	0.0040
		Exp.		5.9	2.7	2.2	0.6	0.3	0.1	0.1	0.1		
	Nagasaki	Obs.	8	2	1	1	2	0	1	0	1	0.1384	0.0164
		Exp.		2.3	2.4	1.6	0.6	0.5	0.3	0.1	0.2		
Time Period 50-54		Obs.	1	0	0	1	0	0	0	0	0	0.7273	0.5259
		Exp.		0.5	0.2	0.2	0.1	0.0	0.0	0.0	0.0		
55-58		Obs.	0										
		Exp.											
59-62		Obs.	3	0	1	1	0	0	0	0	1	0.0003	0.0002
		Exp.		0.9	1.0	0.7	0.2	0.1	0.1	0.0	0.0		
63-66		Obs.	1	0	1	0	0	0	0	0	0	0.7956	0.5957
		Exp.		0.5	0.2	0.2	0.0	0.0	0.0	0.0	0.0		
67-70		Obs.	4	2	1	0	1	0	0	0	0	0.8231	0.6091
		Exp.		1.8	0.9	0.7	0.2	0.2	0.1	0.0	0.1		
71-74		Obs.	3	2	0	0	0	0	0	0	1	0.0003	0.0009
		Exp.		1.3	0.7	0.5	0.2	0.1	0.1	0.0	0.0		
75-78		Obs.	8	3	2	0	1	0	2	0	0	0.0059	0.1140
		Exp.		3.2	1.9	1.6	0.5	0.4	0.2	0.1	0.1		

12. OBSERVED AND EXPECTED DEATHS FROM MALIGNANT LYMPHOMA, BY T65DR, CITY, AND TIME PERIOD
12. 悪性リンパ腫の観察及び期待死亡数，T 65 DR 推定線量，市及び年度別

Class			Total	T65DR in rad								Test P	
				0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total		Obs.	84	39	15	17	5	2	4	1	1	0.5119	0.2891
		Exp.		35.7	20.9	15.3	4.8	3.8	1.7	0.8	1.0		
	Hiroshima	Obs.	58	31	8	11	3	1	3	1	0	0.0713	0.1729
		Exp.		28.2	13.5	10.3	2.7	1.8	0.7	0.3	0.5		
	Nagasaki	Obs.	26	8	7	6	2	1	1	0	1	0.9781	0.5249
		Exp.		7.5	7.4	5.0	2.1	2.0	1.0	0.4	0.5		
Time Period 50-54		Obs.	7	4	1	1	0	0	0	1	0	0.0043	0.1215
		Exp.		3.2	1.7	1.3	0.3	0.2	0.1	0.0	0.1		
55-58		Obs.	6	3	1	2	0	0	0	0	0	0.9486	0.7862
		Exp.		2.2	1.7	1.2	0.4	0.3	0.1	0.1	0.1		
59-62		Obs.	7	3	1	2	0	0	1	0	0	0.2502	0.2435
		Exp.		3.3	1.6	1.3	0.4	0.2	0.1	0.1	0.1		

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Class		Total	T65DR in rad								Test P	
			0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Time Period 63-66	Obs.	13	6	4	1	1	0	1	0	0	0.7636	0.5315
	Exp.		5.6	3.2	2.3	0.7	0.6	0.2	0.1	0.1		
67-70	Obs.	16	9	1	3	1	1	1	0	0	0.7087	0.5224
	Exp.		6.5	3.9	3.0	1.0	0.8	0.4	0.2	0.2		
71-74	Obs.	15	4	3	4	1	1	1	0	1	0.2637	0.0078
	Exp.		6.5	3.8	2.8	0.8	0.6	0.2	0.1	0.2		
75-78	Obs.	20	10	4	4	2	0	0	0	0	0.8673	0.8670
	Exp.		8.5	5.0	3.4	1.2	1.0	0.5	0.2	0.3		

13. OBSERVED AND EXPECTED DEATHS FROM RECTUM CANCER, BY T65DR AND TIME PERIOD

13. 直腸癌の観察及び期待死亡数，T65DR推定線量及び年度別

Class		Total	T65DR in rad								Test P	
			0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total	Obs.	157	63	43	33	10	5	3	0	0	0.8335	0.8849
	Exp.		63.6	43.7	30.0	8.6	6.0	2.4	1.1	1.6		
Time Period 50-54	Obs.	16	10	1	1	0	3	1	0	0	0.0040	0.1065
	Exp.		6.8	4.4	3.0	0.8	0.5	0.2	0.1	0.1		
55-58	Obs.	20	10	3	6	1	0	0	0	0	0.7913	0.8141
	Exp.		8.3	5.5	3.9	1.1	0.7	0.3	0.1	0.2		
59-62	Obs.	17	6	6	5	0	0	0	0	0	0.8574	0.8347
	Exp.		6.8	4.9	3.3	1.0	0.6	0.2	0.1	0.1		
63-66	Obs.	21	9	7	4	1	0	0	0	0	0.9697	0.8750
	Exp.		8.2	5.9	4.2	1.2	0.8	0.3	0.2	0.2		
67-70	Obs.	23	6	9	5	3	0	0	0	0	0.3927	0.7438
	Exp.		10.0	6.1	4.4	1.2	0.8	0.3	0.1	0.2		
71-74	Obs.	30	10	12	4	1	2	1	0	0	0.7940	0.6508
	Exp.		11.6	8.3	5.7	1.8	1.4	0.6	0.3	0.4		
75-78	Obs.	30	12	5	8	4	0	1	0	0	0.3091	0.5870
	Exp.		12.0	8.6	5.7	1.6	1.2	0.5	0.2	0.3		

14. OBSERVED AND EXPECTED DEATHS FROM PANCREAS CANCER, BY T65DR AND TIME PERIOD

14. 膵臓癌の観察及び期待死亡数，T 65 DR 推定線量及び年度別

Class		Total	T65DR in rad								Test P	
			0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total	Obs.	148	59	48	26	4	6	3	1	1	0.7955	0.6747
	Exp.		59.8	41.1	28.3	8.1	5.8	2.3	1.1	1.6		
Time Period 50-54	Obs.	5	1	1	3	0	0	0	0	0	0.5187	0.6341
	Exp.		2.3	1.3	0.9	0.2	0.2	0.1	0.0	0.0		
55-58	Obs.	12	6	4	1	0	0	0	1	0	0.1607	0.5162
	Exp.		4.2	3.5	2.4	0.8	0.5	0.2	0.1	0.2		
59-62	Obs.	21	9	6	5	0	1	0	0	0	0.9496	0.7846
	Exp.		8.9	5.6	3.9	1.2	0.8	0.3	0.1	0.2		
63-66	Obs.	25	11	10	1	1	0	2	0	0	0.0538	0.4437
	Exp.		10.6	6.7	4.8	1.4	0.9	0.3	0.2	0.2		
67-70	Obs.	21	10	7	2	0	2	0	0	0	0.6769	0.7318
	Exp.		8.7	5.7	3.9	1.1	0.8	0.3	0.1	0.2		
71-74	Obs.	30	12	8	5	2	1	1	0	1	0.9170	0.1568
	Exp.		11.8	8.5	5.9	1.6	1.2	0.5	0.2	0.3		
75-78	Obs.	34	10	12	9	1	2	0	0	0	0.7489	0.7911
	Exp.		13.3	9.6	6.5	1.9	1.4	0.6	0.3	0.4		

15. OBSERVED AND EXPECTED DEATHS FROM OTHER UNSPECIFIED DIGESTIVE ORGAN CANCER, BY T65DR, CITY, AND TIME PERIOD

15. その他の消化器癌の観察及び期待死亡数，T 65 DR 推定線量，市及び年度別

Class		Total	T65DR in rad								Test P	
			0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total	Obs.	595	219	163	110	43	26	17	8	9	0.1311	0.0033
	Exp.		232.7	168.8	113.3	34.0	24.5	10.4	4.8	6.5		
Hiroshima	Obs.	444	188	118	75	25	18	9	5	6	0.1270	0.0019
	Exp.		200.3	115.1	82.2	21.8	13.8	4.9	2.4	3.5		
Nagasaki	Obs.	151	31	45	35	18	8	8	3	3	0.4689	0.2190
	Exp.		32.4	53.7	31.1	12.3	10.7	5.5	2.4	3.0		
Time Period 50-54	Obs.	70	32	19	12	2	0	3	1	1	0.2513	0.3348
	Exp.		27.2	20.1	13.7	4.0	2.7	1.1	0.5	0.8		
55-58	Obs.	57	27	17	6	5	1	1	0	0	0.5528	0.8245
	Exp.		22.7	16.3	11.2	3.1	2.1	0.8	0.4	0.5		
59-62	Obs.	86	28	30	12	7	5	0	1	3	0.0734	0.0307
	Exp.		34.5	23.7	16.6	5.1	3.3	1.3	0.6	0.9		

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15 Continued 続き

Class			Total	T65DR in rad								Test P	
				0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Time Period	63-66	Obs.	87	35	25	14	6	1	5	0	1	0.1714	0.3908
		Exp.		33.3	25.0	16.6	5.1	3.7	1.6	0.7	1.0		
	67-70	Obs.	82	24	24	17	10	5	2	0	0	0.1645	0.4948
		Exp.		32.1	22.8	15.5	4.8	3.5	1.6	0.7	0.9		
	71-74	Obs.	89	28	22	17	9	7	2	2	2	0.1810	0.0077
		Exp.		34.1	25.7	16.7	5.1	3.9	1.7	0.8	1.0		
	75-78	Obs.	124	45	26	32	4	7	4	4	2	0.0109	0.0064
		Exp.		49.1	35.1	23.1	6.9	5.2	2.2	1.0	1.3		

16. OBSERVED AND EXPECTED DEATHS FROM CANCER OF UTERUS, BY T65DR, CITY, AND TIME PERIOD

16. 子宮癌の観察及び期待死亡数，T65DR推定線量，市及び年度別

Class			Total	T65DR in rad								Test P	
				0	1-9	10-49	50-99	100-199	200-299	300-399	400+	Homog.	Trend
Total		Obs.	332	114	108	74	13	14	2	2	5	0.0707	0.3169
		Exp.		135.2	91.3	65.9	18.2	11.3	4.9	2.3	2.9		
	Hiroshima	Obs.	270	106	74	62	13	8	2	1	4	0.3377	0.1401
		Exp.		123.4	67.0	52.3	13.9	7.2	2.8	1.4	1.9		
	Nagasaki	Obs.	62	8	34	12	0	6	0	1	1	0.0776	0.7618
		Exp.		11.7	24.3	13.6	4.3	4.0	2.2	0.8	1.1		
Time Period	50-54	Obs.	56	14	17	17	4	2	0	0	2	0.0702	0.0747
		Exp.		22.8	15.5	11.4	3.0	1.7	0.7	0.4	0.5		
	55-58	Obs.	56	25	19	8	0	3	0	0	1	0.3486	0.6380
		Exp.		21.4	16.2	11.6	3.2	1.9	0.8	0.4	0.5		
	59-62	Obs.	41	11	14	10	2	1	0	2	1	0.0099	0.0165
		Exp.		17.5	10.9	8.1	2.2	1.2	0.5	0.2	0.3		
	63-66	Obs.	35	9	13	10	3	0	0	0	0	0.3635	0.8434
		Exp.		14.4	9.4	7.0	1.9	1.2	0.5	0.3	0.3		
	67-70	Obs.	43	16	12	12	2	1	0	0	0	0.8510	0.8694
		Exp.		17.7	11.7	8.4	2.4	1.5	0.7	0.3	0.4		
	71-74	Obs.	56	18	22	11	0	3	1	0	1	0.3688	0.4808
		Exp.		22.2	15.7	10.8	3.1	2.2	1.0	0.4	0.6		
	75-78	Obs.	45	21	11	6	2	4	1	0	0	0.5410	0.4508
		Exp.		19.2	11.9	8.7	2.4	1.5	0.6	0.3	0.4		