MULTIPLE MYELOMA AMONG ATOMIC BOMB SURVIVORS, HIROSHIMA AND NAGASAKI, 1950-76

広島・長崎の被爆者からの多発性骨髄腫, 1950—76年

MICHITO ICHIMARU, M.D.　市丸道人
TORANOSUKE ISHIMARU, M.D., M.P.H.　石丸寅之助
MOTOKO MIKAMI, M.D.　三上素子
MASAKO MATSUNAGA, M.D.　松永マサ子

放影研
RERF

ACKNOWLEDGMENT
謝　辞

RERF TECHNICAL REPORT SERIES
放 影 研 業 績 報 告 書 集

MULTIPLE MYELOMA AMONG ATOMIC BOMB SURVIVORS, HIROSHIMA AND NAGASAKI, 1950-76

広島・長崎の被爆者からの多発性骨髄腫，1950－76年

MICHITO ICHIMARU, M.D.(市丸道人)[1] ; TORANOSUKE ISHIMARU, M.D., M.P.H. (石丸寅之助)[2] ;
MOTOKO MIKAMI, M.D. (三上素子)[3] ; MASAKO MATSUNAGA, M.D. (松永マサ子)[3]

*Atomic Disease Institute, Nagasaki University School of Medicine, and Consultant to RERF Department of Medicine[1];
and RERF Departments of Epidemiology & Statistics[2] and Medicine[3]*

長崎大学医学部付属原爆後障害医療研究施設及び放影研臨床部顧問[1]；放影研疫学統計部[2] 及び臨床部[3]

SUMMARY

The relationship between atomic bomb exposure and the occurrence of multiple myeloma has been evaluated in a fixed cohort of approximately 100,000 A-bomb survivors and nonexposed controls during the period from October 1950 to December 1976. Analysis of these data revealed the standardized relative risk adjusted for city, sex, and age at the time of the bombs (ATB) to be significantly greater in the group of individuals who received 100 rad or more of radiation than in their controls. An excess risk became apparent in the high dose group about 20 years after exposure. The excess risk of multiple myeloma in those persons aged 20-59 ATB is estimated to be approximately 0.24 per million person-years per rad (PYR) in kerma dose and approximately 0.48 per million PYR in bone marrow dose. The interval between radiation exposure and the occurrence of an excess risk for multiple myeloma in the high dose population is considerably longer than that for leukemia. The cases of multiple myeloma observed in the high dose group showed no unusual clinical features.

INTRODUCTION

Based on the ABCC autopsy material during 1948-62, Anderson and Ishida[1] reported that multiple myeloma among A-bomb survivors in Hiroshima was slightly increased in prevalence in the group exposed within 1,400 m in comparison with those beyond that distance, but in the

要 約

1950年10月から1976年12月の間の多発性骨髄腫の発生と原爆被爆との関係を被爆者と非被爆対照者を含む約10万人の固定集団を用い検討した．都市，性，被爆時年齢を標準化した相対危険度は，100rad 以上の放射線を受けた群が対照群に比較し有意に高かった．危険度の増加は高線量群において被爆20年後になって明らかとなった．被爆時年齢20－59歳の群の多発性骨髄腫の増加は，100万対年間1rad 当たり kerma 線量で0.24，骨髄線量で0.48前後と推定された．高線量被爆者からの多発性骨髄腫の増加は，白血病に比較してかなり遅れて発現することが明らかである．高線量群の多発性骨髄腫の臨床所見には特に変わった病像を認めなかった．

緒 言

Anderson 及び石田[1] は，1948－62年までの ABCC 剖検材料を検討し，広島原爆被爆者の多発性骨髄腫の有病率は，爆心地から1,400m 未満で被爆した群が1,400m 以遠で被爆した群よりわずかに高いことを報告したが1,400m 未満被爆群ではわずかに1例を

group within 1,400 m there was only one multiple myeloma case. Ichimaru et al[2,3] reported that there were eight multiple myeloma cases among the Nagasaki A-bomb survivors up to September 1964. They reported that these cases had no unusual clinical features, but they did not study the risk of multiple myeloma by distance. Yamamoto and Wakabayashi[4] reported an absence of evidence of radiation induction of bone tumors including multiple myeloma in A-bomb survivors in Hiroshima and Nagasaki during 1950-65. Nishiyama et al[5] also made a study of malignant lymphoma and multiple myeloma in the same fixed cohort of A-bomb survivors in relation to dose, but they could not demonstrate a significant excess risk of multiple myeloma in the heavily exposed survivors. Thus, there was no evidence of an excess of multiple myeloma among the survivors until 1965, or 20 years after exposure to the A-bombs. Around 10 years have passed since the compilation of these last two reports.[4,5]

The present study analyzes by exposure dose the risk of multiple myeloma occurring during a 26-year period from October 1950 to December 1976 in the fixed sample of the ongoing RERF Life Span Study (LSS).[6]

MATERIALS AND METHODS

The LSS sample totals approximately 100,000 exposed and nonexposed subjects who were residing in Hiroshima or Nagasaki City on 1 October 1950, 5 years after the A-bomb.

The estimated A-bomb radiation dose received by each survivor in this sample has been calculated as the simple sum of the neutron and gamma doses by the T65D system.[7] Dose estimates are not as yet available for 1,725 subjects who were exposed under heavy shielding and complicated conditions. The average bone marrow dose was calculated using the bone marrow dose kerma conversion factors obtained for each group of total dose categories.[8]

The koseki system employed for screening of cases insures virtually complete identification of death and causes of death in this fixed sample and thus the deaths ascribed to multiple myeloma were all screened. Furthermore, almost complete screening of possible multiple myeloma was made under the Leukemia and Related Disorders Detection Program at ABCC and RERF.[9] The detection has also been supported

認めたにすぎなかった. 市丸ら[2,3] は, 1964年9月までに長崎の被爆者に8例の多発性骨髄腫を認めたと報告した. この報告によると, これらの多発性骨髄腫における臨床的特徴には特異なものはなかったが, 多発性骨髄腫の被爆距離別にみた危険率は調査していない. 山本及び若林[4] は1950-65年の間, 広島・長崎の被爆者に多発性骨髄腫を含む骨腫瘍が放射線によって誘発される証拠は認められなかったと報告した. 西山ら[5] も同じ被爆者の固定集団で線量別に悪性リンパ腫及び多発性骨髄腫の調査を行ったが, 高線量被曝群に多発性骨髄腫の危険率の有意な増加はみられなかった. このように1965年, すなわち原爆被爆後20年までに, 被爆者からの多発性骨髄腫が増加しているという証拠はなかった. これら二つの報告[4,5] が発表されて10年余りを経過した.

今回の調査では, 現在実施されている放影研寿命調査[6] の固定対象集団において, 1950年10月から1976年12月までの約26年間における多発性骨髄腫の危険率を被曝線量別に解析した.

材料及び方法

寿命調査対象者は, 1950年, すなわち原爆投下5年後の10月1日現在, 広島若しくは長崎市に在住していた被爆者及び非被爆者合計約10万人である.

各対象者の推定被曝放射線量は, T65D推定線量方式[7] による中性子線量とガンマ線量の単純合計により算出されている. 重遮蔽下や複雑な遮蔽状況の下で被爆した対象者1,725人については, 推定線量が計算されていない. 平均骨髄線量は総線量区分の各群について骨髄線量とkerma換算係数を用いて算出した.[8]

戸籍照合によって, この固定集団における死亡例と死因はほとんど完全に確認し, 多発性骨髄腫を死因とする症例はすべて探知した. 更にABCC-放影研の白血病及び関連疾患探知プログラム[9] によって多発性骨髄腫と思われる症例はほぼ完全にスクリーニングした. この探知機構はABCC-放影研剖検プログラ

TABLE 1 DISTRIBUTION OF A-BOMB SURVIVORS AND CONTROLS IN THE LSS SAMPLE
BY DOSE AND CITY

表 1　寿命調査対象者である被爆者及び対照者の分布；線量及び都市別

| Total | Hiroshima | | Nagasaki | | Total | |
Dose in Rad	No.	%	No.	%	No.	%
Unknown	919	1.2	806	3.2	1725	1.7
100 +	2664	3.6	2480	9.9	5144	5.2
1 – 99	22356	30.1	10713	42.8	33069	33.3
<1	28177	37.9	4687	18.7	32864	33.1
NIC*	20231**	27.2	6350	25.4	26581	26.7
Total	74347	100.0	25036	100.0	99383	100.0

*Not in city ATB.　被爆時市内にいなかった者.
**14,495 subjects were selected in 1951 and 1953.　14,495人は1951年及び1953年に抽出された.

by pathological studies intensively conducted under the ABCC-RERF Autopsy Program.[10] For purported cases of multiple myeloma obtained by screening various data sources, hematologists reviewed the pertinent information available at the community hospitals and clinics to confirm the diagnosis. Clinical evidence of myeloma cells, laboratory tests of immunoglobulins, M-protein, X-ray, and autopsy findings were all used to establish the diagnosis.

Through the foregoing screening procedures, 35 cases of possible multiple myeloma were identified in the LSS sample for the period October 1950-December 1976. The medical records of these cases were reviewed by three hematologists and the diagnosis of multiple myeloma was accepted on the basis of available medical data in 29 instances. Of these latter confirmed cases, 22 had been exposed to the A-bomb and 7 were not in the city (NIC) ATB.

Table 1 shows the distribution of A-bomb survivors in the LSS sample by city and total dose. The sample consists of 99,383 subjects, 74,347 in Hiroshima and 25,036 in Nagasaki; the dose has been calculated for 71,077 or 97.6% of the 72,802 A-bomb survivors. Of the 20,231 Hiroshima NIC subjects 14,495 belong to samples selected in 1951 and 1953[11] and hence their observation period differed from that of the exposed and the other NIC subjects.

RESULTS
The crude incidence rate per 1,000 subjects and crude annual incidence rate per 100,000 population during 1950-76 are shown by dose in

ム[10] で強力に実施されてきた病理学的調査によっても補強されている. 種々の資料源から得られた多発性骨髄腫とされている症例について, 血液学者が地元病医院から入手できる該当情報を検討し, 診断を確認した. 診断の確認には, 骨髄腫細胞の確認, 免疫グロブリン, 血清M蛋白の臨床検査, X線所見, 剖検所見のすべてを用いた.

1950年10月から1976年12月までの期間に, 前述のスクリーニングによって寿命調査対象者から35例の多発性骨髄腫の疑いの症状のあるものが発見された. 3名の血液学者がこれら35例の医学記録を再検討し, 入手できた医学資料を参照し, 29例の多発性骨髄腫の診断を確認した. この29例の確診例のうち, 22例は被爆者であり, 7例が原爆時に市内にいなかった者(市内不在者)であった.

表1に寿命調査群における被爆者の都市及び総線量別分布を示した. 対象者は広島74,347人, 長崎25,036人, 計99,383人であった. 72,802人の被爆者中71,077人(97.6%)については線量が算出されている. 広島の市内不在者である20,231人の対象者のうち14,495人が1951年と1953年[11] に抽出されているため, これらの対象者は他の被爆者や市内不在者と観察期間が異なっている.

結 果
表2に1950ー76年までの対象者1,000人対粗発生率及び人口10万対年間粗発生率を線量別に示した.

3

TABLE 2 CRUDE INCIDENCE RATE PER 1,000 SUBJECTS AND CRUDE ANNUAL INCIDENCE RATE
PER 100,000 POPULATION OF MULTIPLE MYELOMA AMONG A-BOMB SURVIVORS AND CONTROLS,
IN THE LSS SAMPLE BY DOSE, CITY, & SEX, OCTOBER 1950-DECEMBER 1976

表2 寿命調査対象者である被爆者及び対照者における多発性骨髄腫の1,000人対粗発生率及び
人口10万対年間粗発生率；線量，都市及び性別，1950年10月－1976年12月

Item		T65 Total Dose in Rad					
		NIC*	<1	1-99	100+	Unknown	Total
Crude incidence rate per 1,000 subjects				Total			
Subjects		26581**	32864	33069	5144	1725	99383
Incidence rate per 1,000		−(7)	0.21(7)	0.30(10)	0.97(5)	0.00(0)	−(29)
90% confidence limits	Upper	−	0.36	0.46	1.81	1.30	−
	Lower	−	0.12	0.19	0.47	0.00	−
Crude annual incidence rate per 100,000 population				Total			
Person years		587052	745912	751517	117924	38250	2240655
Incidence rate (10^{-5})		1.05		1.33	4.24	0.00	1.29
90% confidence limits	Upper	1.64		2.26	8.90	−	1.77
	Lower	0.63		0.73	1.67	−	0.93
				Hiroshima			
Person years		438326	637034	505204	59638	19994	1660197
Incidence rate (10^{-5})		1.02(11)		1.19(6)	3.35(2)	0.00(0)	1.14(19)
90% confidence limits	Upper	1.69		2.35	10.56	−	1.68
	Lower	0.57		0.52	0.60	−	0.75
				Nagasaki			
Person years		148725	108878	246313	58286	18256	580458
Incidence rate (10^{-5})		1.16(3)		1.62(4)	5.15(3)	0.00(0)	1.72(10)
90% confidence limits	Upper	3.01		3.71	13.30	−	2.92
	Lower	0.32		0.55	1.41	−	0.94
				Male			
Person years		242857	298532	301859	50738	17176	911162
Incidence rate (10^{-5})		0.74(4)		0.99(3)	5.91(3)	0.00(0)	1.10(10)
90% confidence limits	Upper	1.69		2.57	15.27	−	1.86
	Lower	0.25		0.27	1.62	−	0.60
				Female			
Person years		344194	447380	449658	67186	21074	1329493
Incidence rate (10^{-5})		1.26(10)		1.56(7)	2.98(2)	0.00(0)	1.43(19)
90% confidence limits	Upper	2.14		2.92	9.38	−	2.10
	Lower	0.69		0.73	0.53	−	0.94

*Number of cases in parentheses. *Not in city ATB. **14495 subjects were added in 1951 or 1953. Thus, it is not applicable to calculate the incidence rate for NIC subjects during 1950-76.*

（ ）は症例数． ＊被爆時市内にいなかった者． ＊＊1951年若しくは1953年に14,495人の対象者が加わったため，1950－76年まで
の市内不在者の発生率の算出は適用できない．

Table 2. The crude incidence rate in the group exposed to 100 rad or more is 0.97 per 1,000 population which is approximately 4.6 times higher than the rate of 0.21 for the group exposed to less than 1 rad. The rate in those exposed to 1-99 rad is 0.30 per 1,000 population, a rate 1.4 times higher than that in the control group (exposed to less than 1 rad). The 90%

100rad以上の被爆者群の発生率は1,000人対0.97で，1rad未満の被爆者群の発生率0.21の約4.6倍である．1－99radの被爆者群の発生率は1,000人対0.30で，対照群（被曝線量1rad未満）の1.4倍である．各発生率の90％信頼限界をみると，危険率は

TABLE 3 STANDARDIZED RELATIVE RISK OF MULTIPLE MYELOMA AMONG
A-BOMB SURVIVORS, AND CONTROLS IN THE LSS SAMPLE BY DOSE,
HIROSHIMA & NAGASAKI, OCTOBER 1950-DECEMBER 1976

表3　寿命調査対象者である被爆者及び対照者の多発性骨髄腫の標準化相対
危険度；線量別，広島・長崎合計，1950年10月－1976年12月

| | T65 Total Dose in Rad | | | |
	NIC	<1	1-99	100 +
Subjects	26581**	32864	33069	5144
Cases	7	7	10	5
Standardized relative risk* (Mantel and Haenszel's procedure[12])	–	1.0	1.5	4.7

Test of significance for homogeneity of three dose group
(<1, 1-99, 100+)
$\chi^2 = 7.03$,　　df = 2,　　$.01 < P < .05$

Person years	587052	745912	751517	117924
Cases	14		10	5
Standardized relative risk* (Miettinen's procedure[13])	1.0		1.8	5.7

*Adjusted for sex, age ATB, and city. **See note Table 2.
＊性，被爆時年齢及び都市別に標準化.　＊＊表2の注参照.

confidence limits of each rate suggest that the risk is greater in the high dose group than in the control group. The crude annual incidence rate per 100,000 population is 4.2 in those exposed to 100 rad or more, 1.3 in those exposed to 1-99 rad, and 1.1 in the control group, respectively. When the crude annual incidence rate is examined by dose and city, the risk is greater in Nagasaki survivors than in Hiroshima survivors of both the low dose group (1-99 rad) and the high dose group (100 rad or more), although these differences are not statistically significant. For the cities combined, the crude relative risk in the high dose vs the control group is greater in males (8.0-fold) than in females (2.4-fold), but again this difference is not statistically significant.

The standardized relative risks adjusted for sex, age ATB, and city for high (100 rad or more) and low (1-99 rad) dose groups with the control group as the standard are given in Table 3. When the risks in the former groups are compared with the risk of individuals who received less than 1 rad as the standard the standardized relative risk is approximately 4.7 in the high dose group and 1.5 in the low dose group, respectively. This difference is statistically significant ($.01 < P < .05$) by Mantel and Haenszel's procedure.[12] When the standardized relative risk is examined

対照群よりも高線量群の方が高いことが示唆される. 100rad 以上の被曝者群の10万対年間粗発生率は4.2 で，1－99rad 群が1.3，対照群が1.1である．年間粗発生率を線量別，都市別にみると，低線量群（1－99rad ），高線量群（100rad 以上）ともに広島の被爆者よりも長崎の被爆者の方に危険率が高いが，統計的に有意な差は認められなかった．両市合計では，高線量群と対照群を比較した粗相対危険度が女性は2.4倍，男性は8.0倍で男の方が高かったが，この差は統計的に有意ではない.

対照群を基準とした高線量群（100rad 以上）と低線量群（1－99rad ）の性，被爆時年齢，都市を標準化した相対危険度を表3に示した．前者2群の危険率を，1rad 未満の放射線を受けた群の危険率を基準として比較すると，標準化した相対危険度は高線量群で約4.7，低線量群で約1.5である．この差は Mantel 及び Haenszel の方法[12] によると統計的に有意（.01< P <.05 ）である．標準化した相対危険度を市内不在

5

TABLE 4 CRUDE INCIDENCE RATE PER 1,000 POPULATION AND CRUDE ANNUAL
INCIDENCE RATE PER 100,000 POPULATION OF MULTIPLE MYELOMA AMONG
A-BOMB SURVIVORS AND CONTROLS IN THE LSS SAMPLE BY DOSE & AGE ATB,
HIROSHIMA & NAGASAKI, OCTOBER 1950 – DECEMBER 1976

表 4　寿命調査対象者である被爆者及び対照者における多発性骨髄腫の1,000人
対粗発生率及び人口10万対年間粗発生率；線量及び被爆時年齢別，
広島・長崎合計，1950年10月－1976年12月

| | | T65 Total Dose in Rad | | | |
		NIC	<1	1–99	100+
		Age less than 20 ATB			
Subjects		11007*	13001	13647	2254
Person years		271756	332862	350224	57102
Cases		0	1	0	0
Rate	(A)	**	0.08	0.00	0.00
	(B)	0.17		0.00	0.00
		Age 20–39 ATB			
Subjects		7874*	9017	8703	1480
Person years		186857	221710	213362	35788
Cases		1	2	2	2
Rate	(A)	**	0.22	0.23	1.35
	(B)	0.73		0.94	5.59
		Age 40–59 ATB			
Subjects		6257*	8671	8555	1217
Person years		115614	169792	166741	23288
Cases		6	3	8	3
Rate	(A)	**	0.35	0.94	2.47
	(B)	3.15		4.80	12.88
		Age 60+ ATB			
Subjects		1443*	2175	2164	193
Person years		12825	21549	21190	1746
Cases		0	1	0	0
Rate	(A)	**	0.46	0.00	0.00
	(B)	2.91		0.00	0.00

*Rate (A): Crude incidence rate per 1000 population. (B): Crude annual incidence rate per
100,000 population. *Subjects selected in 1950, 1951, & 1953. **Rate was not calculated.*
発生率（A）：1,000人対粗発生率．発生率（B）：10万対年間粗発生率．＊1950年，1951年，1953年
に対象者を抽出．　＊＊発生率の計算は行わなかった．

using the NIC and less than 1 rad groups as the standard and Miettinen's procedure,[13] the risk is approximately 5.7 in the high dose group and 1.8 in the low dose group, respectively.

Table 4 shows the crude incidence rate per 1,000 population (A) and the crude annual incidence rate per 100,000 population (B) by dose and four age ATB groups (0-19, 20-39, 40-59, and 60+). The number of cases becomes small when the data are examined by dividing them into 12 different categories (3 dose groups and

者群及び1 rad 未満の群を基準とし，Miettinen の
方法[13]で算出すると，危険度は高線量群で約5.7，低線
量群で約1.8である．

表 4 に線量別，四つの被爆時年齢群別（0－19歳，
20－39歳，40－59歳，60歳以上）に1,000人対粗発生
率（A）と10万対年間粗発生率（B）を示した．資料を
12の区分（三つの線量群と四つの原爆時年齢群）に

FIGURE 1 CRUDE ANNUAL INCIDENCE RATE PER 100,000 POPULATION OF MULTIPLE
MYELOMA AMONG A-BOMB SURVIVORS AND CONTROLS IN THE LSS SAMPLE BY
DOSE & AGE ATB, HIROSHIMA & NAGASAKI, OCTOBER 1950-DECEMBER 1976
図1　寿命調査対象者である被爆者及び対照者における多発性骨髄腫の人口10万対
年間粗発生率; 線量及び被爆時年齢別, 広島・長崎, 1950年10月—1976年12月
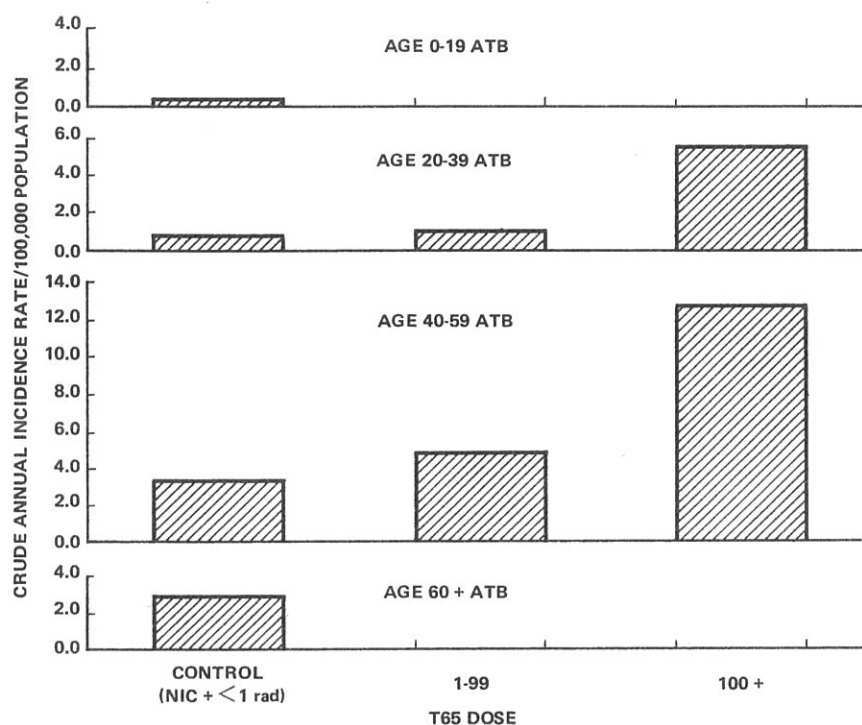
4 age ATB groups). However, the risk increases in the control group with age ATB. When the risk of each age ATB group is examined by dose, the dose effect is evident among those between 20-59 years ATB, and within these ages the absolute excess risk in the high dose group is more evident in the group aged 40-59 ATB than in the group aged 20-39 ATB. Figure 1 shows the crude annual incidence rate per 100,000 population by dose and four age ATB groups.

Table 5 presents the results of goodness of fit tests and regression analysis for a linear dose-response model among those between 20-59 years ATB by kerma and marrow dose. The model fits the data well for both kerma and marrow dose-response and the regression coefficients have suggestive significance ($.05 < P < .10$). The estimated excess risk is approximately 0.24 cases per million PYR in

分けると例数は少なくなるが, 対照群においては危険率は被爆時年齢の増加とともに高くなる. 各被爆時年齢群の危険度を線量別にみると, 被爆時年齢が20—39歳の群において線量の影響が明らかであり, このうち被爆時年齢20—39歳群よりも40—59歳群の方が高線量群における絶対危険度の増加が明らかである. 図1に10万対年間粗発生率を線量別, 四つの被爆時年齢群別に示した.

表5に被爆時年齢20—59歳の群の線型線量反応モデルの適合度検定と回帰分析の結果をkerma線量及び骨髄線量別に示した. このモデルはkerma線量, 骨髄線量ともに線量反応の適合性がよく, 回帰係数は有意差 ($.05 < P < .10$) が示唆された. 危険率の増加は, 100万人年1 rad当たりkerma線量で0.24, 骨髄

TABLE 5 SUMMARY OF LINEAR REGRESSION ANALYSIS FOR DOSE-RESPONSE
OF MULTIPLE MYELOMA AMONG A-BOMB SURVIVORS IN THE LSS SAMPLE,
20-59 ATB BY KERMA AND MARROW TOTAL DOSE, HIROSHIMA & NAGASAKI
OCTOBER 1950-DECEMBER 1976

表5 被爆時年齢20－59歳の寿命調査対象者である被爆者の多発性骨髄腫の
kerma 線量，骨髄総線量別線量反応の線型回帰分析の要約；広島及び長崎，
1950年10月－1976年12月

T65 Total Dose in rad	Subjects	Average total Dose in rad		Multiple Myeloma
		Kerma	Marrow	
Hiroshima				
100-600*	1571	237.7	118.1	2
50-99	1349	70.1	35.6	0
1-49	11037	12.3	6.2	6
<1	15519	0.0	0.0	4
Total	29476	–	–	12
Nagasaki				
100-600*	1126	243.7	133.2	3
50-99	595	70.5	38.8	2
1-49	4277	10.4	5.7	2
<1	2171	0.0	0.0	1
Total	8169	–	–	8

1. Model $P_{ij} = \alpha_i + \beta \cdot D_{ij}$

   P = Probability of incidence 発生の確率値
   i = City 市　　j = Dose category 線量
   D = Average total dose (rad) 平均総線量（rad）

2. Goodness of fit test and regression coefficients 適合度検定及び回帰係数

   Goodness of fit test 適合度検定　　Kerma dose kerma 線量　Marrow dose 骨髄線量
   $\chi^2 = 5.67$　　　　　　$\chi^2 = 5.44$
   d.f. = 5　　　　　　d.f. = 5
   P > .10　　　　　　P > .10

   Regression analysis 回帰分析

   Constant 定数
   - α_1 (Hiroshima)　　3.0985×10^{-4}　　3.1016×10^{-4}
     　　　　　　　　　(1.1395×10^{-4})　(1.1390×10^{-4})
   - α_2 (Nagasaki)　　5.8090×10^{-4}　　5.6457×10^{-4}
     　　　　　　　　　(3.3495×10^{-4})　(3.3147×10^{-4})

   Regression coefficient (β) 回帰係数　0.063×10^{-4}　　0.1250×10^{-4}
   　　　　　　　　　　　　　(0.0369×10^{-4})　(0.0714×10^{-4})

   Test of significance 有意性検定　$.05 < P < .10$　　$.05 < P < .10$
   　　　　　　　　　( ) standard error （）標準誤差

3. Approximate excess risk per 1,000,000 population/year/rad
   100万対年間1 rad 当たりのおおよその危険率

   Kerma dose kerma 線量　0.24 ± 0.14
   Marrow dose 骨髄線量　0.48 ± 0.27

*If the T65 total kerma dose for a survivor was estimated to be 600 rad or more, in Hiroshima the gamma dose was set arbitrarily at 428 rad and the neutron dose at 172 rad; in Nagasaki the gamma dose was set at 587 rad and the neutron dose at 13 rad.

＊被爆者の T65D 推定総 kerma 線量が 600rad 以上と推定されたときは，広島においては任意にガンマ線量を 428rad，中性子線量を 172rad，また，長崎においてはガンマ線量を 587rad，中性子線量を 13rad とした。

8

FIGURE 2 LIFE TABLE ESTIMATES OF CUMULATIVE INCIDENCE OF MULTIPLE MYELOMA
IN THE LSS SAMPLE BY YEAR & EXPOSURE, HIROSHIMA & NAGASAKI, 1950-76
AGE ATB 20-59

図2 寿命調査対象者における多発性骨髄腫の累積発生率の生命表による推定値；暦年及び線量別，広島・長崎合計，1950－76年，被爆時年齢20－59歳
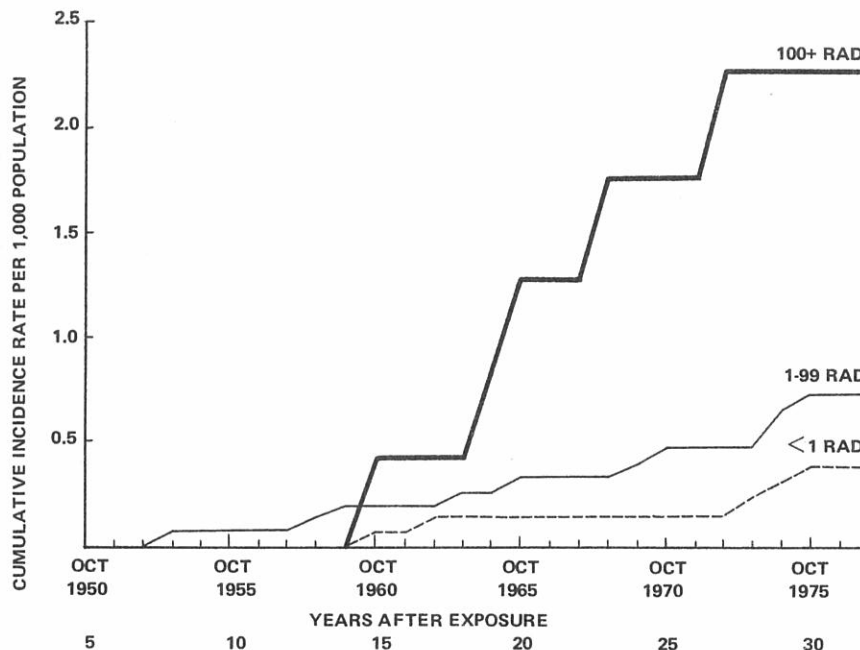
kerma dose and approximately 0.48 cases per million PYR in marrow dose or a risk about 2 times greater for bone marrow dose than kerma dose. When dose-response models having a linear dependence for both gamma rays and neutrons are tested using regression analysis as shown in Table 6, the data fit well. However, the regression coefficient is only suggestively significant for gamma rays and insignificant for neutron doses.

Figure 2 gives the life-table estimates of the cumulative incidence rates of multiple myeloma for those aged 20-59 ATB by the three dose groups of 100 rad or more, 1-99 rad and less than 1 rad for the period 1950-76. Increased risk in the high dose group became apparent from the 20th year after exposure, suggesting that radiation-induced multiple myeloma has a latency period of 20 years or more.

There appears to be no significant difference between the high dose and the control group in the average period from exposure to onset which was 20.3 years in the high dose group, 20.6 years in the low dose group and 22.7 years in

線量で0.48前後と推定された. 危険率はkerma線量に比べ骨髄線量が約2倍である. 表6に示すようにガンマ線，中性子線ともに線型に依存すると仮定した線量反応モデルを回帰分析によって検定するとよい適合度を示す. しかし，回帰係数はガンマ線に対してのみ有意であることが示唆され，中性子線量では有意でなかった.

図2は被爆時年齢20－59歳の群の多発性骨髄腫の1950－76年の累積発生率を100rad以上，1－99rad，1rad未満の三つの線量群別に示した生命表を用いた解析である. 高線量群の危険率の増加は被爆20年後から明らかになっており，放射線誘発性多発性骨髄腫の潜伏期間が約20年以上であることを示唆している.

被爆から発病までの平均期間は，高線量群が20.3年，低線量群が20.6年，対照群が22.7年で，高線量群と対照群の間に有意差はみられなかった. 高線量群の

9

TABLE 6 SUMMARY OF REGRESSION ANALYSIS AND GOODNESS OF FIT TEST OF
A DOSE-RESPONSE MODEL WHICH ASSUMES A LINEAR DEPENDENCE FOR BOTH
GAMMA RAYS AND NEUTRON DOSES FOR MULTIPLE MYELOMA IN THE LSS
SAMPLE SURVIVORS AGED 20-59 ATB, BETWEEN OCTOBER 1950-DECEMBER 1976
表6　被爆時年齢20－59歳の寿命調査対象者の多発性骨髄腫についてガンマ，
中性子の両線量に対して線型依存を示す線量反応モデルを用いて行った
回帰分析及び適合度検定の要約；1950年10月－1976年12月

Dose-response model:

Model: $P_{ij} = \alpha_i + \beta_1 D\gamma_{ij} + \beta_2 Dn_{ij}$

P = Probability of incidence of multiple myeloma
i = Hiroshima and Nagasaki
j = T65 dose category ($<$1, 1-49, 50-99, 100-600)
Dγ = Average gamma dose (rad)
Dn = Average neutron dose (rad)

		Dose in rad	
		Kerma	Marrow
Goodness of fit test	χ^2 [4]	4.00 P$>$.10	4.00 P$>$.10
Constant { Hiroshima		3.2455×10^{-4} (1.1697×10^{-4})	3.2455×10^{-4} (1.1697×10^{-4})
Nagasaki		4.4682×10^{-4} (3.0713×10^{-4})	4.4628×10^{-4} (3.0713×10^{-4})
Regression coefficients	β_1	0.1220×10^{-4} (0.0741×10^{-4})	0.2219×10^{-4} (0.1347×10^{-4})
Test of significance	χ^2 [1]	2.71 .05$<$P$<$.10	2.71 .05$<$P$<$.10
Regression coefficients	β_2	-0.2358×10^{-4} (0.2767×10^{-4})	-0.9665×10^{-4} (1.0954×10^{-4})
Test of significance	χ^2 [1]	0.73 P$>$.10	0.78 P$>$.10

( ) *standard error*　　（）は標準誤差

the control group, respectively. The cases in the high dose group showed no unusual clinical feature in comparison with those of the control group. Amyloidosis was observed in 2 of 4 autopsied cases in the high dose group (50 %) and in 1 of 11 cases where the dose was less than 100 rad (9.1 %); the clinical diagnosis of multiple myeloma could not be confirmed by autopsy in 2 of 6 possible cases (33.3 %). The exposure status and major clinical evidence for the 29 multiple myeloma cases in the present analysis are shown in the Appendix.

症例には対照群と比較して特異な臨床像は見られなかった．高線量群の剖検例4例のうち2例（50%）に，100rad 未満の群11例のうち1例（9.1%）にアミロイドージスが見られた．多発性骨髄腫の疑われた6例のうち2例（33.3%）は剖検によって臨床診断が確定できなかった．今回の調査において解析を行った多発性骨髄腫29例の被爆状態及び主要臨床所見を付録に示した．

DISCUSSION

There are a few studies of the effects of occupational long-term continuous low dose exposure of ionizing radiation in relation to mortality from multiple myeloma.[14-16] Lewis[14] reported that the observed mortality from multiple myeloma among American radiologists was significantly higher than expected. Mancuso et al[15] have reported an excess mortality due to bone marrow cancers, that is, myelomas and myeloid leukemias, among Hanford workers who received radiation exposure during the manufacture of radioactive substances. In 1978, Marks et al[16] examined the cancer mortality among Hanford workers, and reached conclusions somewhat different from those of Mancuso et al.[15] Marks et al[16] observed a significant excess in death for multiple myeloma and carcinoma of the pancreas in the workers after adjusting for age, calendar year of death, length of employment, and occupational categories. However, there was an absence of such correlation for diseases more commonly associated with radiation exposure such as myeloid leukemia. From these studies,[14-16] we thought that the risk of multiple myeloma might increase among A-bomb survivors who had received a significant level of radiation although an increase in mortality from multiple myeloma among A-bomb survivors during 1950-74 had not been reported by Beebe et al.[17]

The present study in A-bomb survivors provides evidence on the relationship of exposure to a single large dose of ionizing radiation composed of both gamma rays and neutrons to the incidence of multiple myeloma. Earlier studies of the incidence of multiple myeloma among A-bomb survivors failed to demonstrate a significantly increased risk.[4,5] These reports covered the incidence of multiple myeloma among survivors up to 1965 or 20 years after exposure. Yamamoto and Wakabayashi[5] have given three reasons for the absence of evidence of radiation induced bone cancer including multiple myeloma among survivors: 1) The dose received by the survivors was not large enough to induce bone tumors including multiple myeloma. 2) An effect, if one exists has not been detected because the number of survivors exposed to an external dose sufficient to induce bone tumors including multiple myeloma is too small. 3) The period 1950-65, 5-20 years after the A-bombs, was too soon for the study of bone tumors including multiple myeloma in survivors.

考 察

職業上の長期継続的な低線量電離放射線被曝の後影響として多発性骨髄腫の死亡率に対する研究は少ない.[14-16] Lewis[14] は米国の放射線科医師に見られる多発性骨髄腫の死亡率は期待値より有意に高かったと報告した. Mancuso ら[15] は放射能物質の生産過程で放射線を受けた Hanford の従業員に骨髄癌,すなわち骨髄腫及び骨髄性白血病の死亡率が増加していることを報告している. Marks ら[16] は1978年 Hanford 従業員の癌死亡率を調査し,Mancuso ら[15] が示した結論と若干異なる結果を報告した. Marks ら[16] が Hanford 従業員の年齢,死亡暦年,雇用期間,職種を訂正してみると多発性骨髄腫と膵臓癌の死亡のみに有意の増加を認めた. しかし,放射線とより関係の深い骨髄性白血病のような疾病との相関関係は認められなかった. 1950-74年の間被爆者の多発性骨髄腫の死亡率は Beebe ら[17] の報告によると増加していないが,前述した三つの調査[14-16] から,有意な線量を受けた被爆者の多発性骨髄腫の危険率は増加するであろうことが想定された.

被爆者に関する今回の調査が,ガンマ線と中性子線から成る電離放射線の1回大量照射と多発性骨髄腫の発生との関係を明らかにする所見を提供した. 被爆者の多発性骨髄腫発生率に関する従来の調査では,その危険率の有意な増加は認められなかった.[4,5] これらの報告は1965年まで,すなわち被爆後20年までの被爆者の多発性骨髄腫の発生率を調べたものである. 山本及び若林[5] は被爆者に多発性骨髄腫等の放射線誘発性骨癌の証拠が確認されなかった理由として次の三つを挙げている. 1)被爆生存者の受けた線量は多発性骨髄腫等の骨腫瘍を誘発するほど高くなかった. 2)多発性骨髄腫等の骨腫瘍を誘発する程の外部照射を受けた被爆生存者の数が少ないため,影響があったとしても探知できない. 3)1950-65年までの期間,すなわち原爆投下後5-20年では被爆者の多発性骨髄腫等の骨腫瘍を探知調査するには時期尚早である.

According to reports of follow-up studies on patients who received radiotherapy for ankylosing spondylitis and tinea capitis, bone tumors can be induced by radiation exposure.[18-20] In these mortality studies of bone tumors, multiple myeloma was not classified as a bone tumor. We consider multiple myeloma to be different from the category of malignant neoplasms of the bone.

In general, the incidence and mortality from multiple myeloma increases with age.[21-23] The distribution of age at onset of the 29 confirmed cases in the present study is shown below:

Age 年齢	Cases 症例数	%
<60	7	24.1
60-69	14	48.3
70 +	8	27.6
Total 計	29	100.0

It appears that multiple myeloma occurs frequently after 60 years of age. The present evidence suggests that multiple myeloma is radiation-related only for exposures experienced during the middle years of life and becomes apparent only 20 years after exposure. However, our analysis has been conducted on a fixed cohort of survivors and controls 5-31 years after exposure. Thus, the whole life-span of the study subjects in the cohort with respect to incidence of multiple myeloma has not been examined. Until the end of 1976, the attrition rate of subjects due to death was about 28% for the entire cohort; deaths among those 60 or more ATB was about 98%, 60% for the 40-59 ATB group, 15% for the 20-39 ATB group, and 5% for those less than 20 ATB, respectively.

It appears that further investigation of this cohort will not result in the detection of many, if any, new cases among individuals 60 or more ATB. It is highly probable that there will be further cases in the 20-39 ATB group and those less than 20 ATB for both the control group and the high dose group after attaining the age of 60 or more which is the susceptible age for multiple myeloma. Though the number of cases is small, comparison of the absolute risk per 1,000 population between the 20-39 and 40-59 age ATB groups shows that the rate in the

強直性脊椎炎や頭部白癬のため放射線治療を受けた患者の追跡調査によると，骨腫瘍は放射線によって誘発される.[18-20] これらの骨腫瘍の死亡調査では，多発性骨髄腫は骨腫瘍として分類されていなかった. 著者らは多発性骨髄腫は骨の悪性新生物の範疇に入らないものと考える.

一般的に多発性骨髄腫の発生率及び死亡率は，年齢とともに増加する.[21-23] 本調査における確診例29例の発病時年齢の分布を以下に示した.

多発性骨髄腫は60歳以後に多く発生するようである. 得られた資料では，多発性骨髄腫は中年期に被曝した場合にのみ放射線と関係があり，被曝後20年経過しないと発現しないことを示唆する. しかしながら，本調査では被爆後5―31年の被爆者及び対照者の固定集団に対して解析を行ったため，集団中の全調査対象者の全生がいについて多発性骨髄腫の発生率を調査していない. 1976年末までの死亡による対象者の減少は集団全体の約28％である. 被爆時年齢60歳以上群の死亡は約98％，40―59歳群は60％，20―39歳群は15％，20歳未満群は5％であった.

この集団について更に調査を行っても，被爆時年齢60歳以上群に新しい症例を多く探知することはできないと考えられる. 対照群，高線量群ともに被爆時年齢20―39歳群と20歳未満群が多発性骨髄腫の罹患年齢である60歳以上に達したとき，更に症例が現れる可能性が強い. 例数は少ないが，被爆時年齢20―30歳群と40―59歳群の1,000人対絶対危険度を比較

controls is 0.22 in the younger and 0.35 in the older subjects (1.6-fold); and, in the 100 rad or more group is 1.35 in the younger and 2.47 in the older subjects (1.8-fold). The cases who were 20-39 ATB became 25-44 in 1950 and 51-70 in 1976, and those who were 40-59 ATB reached 45-64 in 1950 and 71-90 in 1976.

As shown in Table 4, it seems unlikely that there is greater susceptibility among the 40-59 ATB group than the 20-39 ATB group with respect to radiation-related multiple myeloma. It appears that the future increase in absolute excess risk will be greater in the 20-39 ATB group than in the 40-59 ATB group. Thus, our data suggest that the latency period of radiation-related multiple myeloma is longer the younger one's age ATB, except for those whose age ATB was 60 or over. The epidemiological pattern of development, such as latency period and effect of age ATB by exposure dose, of multiple myeloma appears to differ from acute leukemia and chronic granulocytic leukemia among the survivors.[24] The dose-response of multiple myeloma in relation to gamma rays and neutrons using a linear regression analysis suggests the opposite of that seen for chronic granulocytic leukemia among survivors.[25]

Although the incidence of multiple myeloma was significantly elevated among heavily exposed persons, the observed number of cases in the high dose group is small and the clinical findings, properties of immunoglobulin, autopsy and other findings were not unique when compared with the control group. It was noted, however, on comparison of autopsy cases that two of the four individuals with multiple myeloma who received 100 rad or more had amyloidosis. In one of these cases with amyloidosis, Bence Jones protein was demonstrated; in another individual, who had been diagnosed as having aplastic anemia, autopsy revealed a proliferation of myeloma cells. Total proteins prior to death were 5.0 and neither hypergamma-globulinemia nor a myeloma peak was observed. The urinary protein reaction was positive. This case was also suspected to be of the Bence Jones type of myeloma. Therefore, in the high dose group the two cases having amyloidosis are assumed to be cases of myeloma of Bence Jones type. It has been reported that myeloma complicated with amyloidosis is related to Bence Jones protein.[26,27] Elucidation of the relationship between myeloma of Bence Jones type complicated with amyloido-

すると，対照群の危険率は若年群で0.22，高齢者群で0.35（1.6倍）であり，100rad 以上群ではそれぞれ1.35と2.47（1.8倍）である．被爆時年齢20-39歳群は1950年には25-44歳，1976年には51-70歳になり，被爆時年齢40-59歳群は1950年には45-64歳，1976年には71-90歳であった．

表4に示すように，放射線に関連のある多発性骨髄腫については被爆時年齢40-59歳群の方が20-39歳群より感受性が高いとは思われない．今後は被爆時年齢40-59歳群より20-39歳群の方が絶対危険度が高くなると思われる．したがって本調査の資料から，放射線に関連のある多発性骨髄腫の潜伏期間は，被爆時年齢60歳以上群を除いては被爆時年齢が若くなるに従って長くなると考えられる．被曝線量別にみた潜伏期間や被爆時年齢の影響など，多発性骨髄腫の疫学的にみた発現様式は，被爆者の急性白血病や慢性骨髄性白血病とは異なっているように見える．[24] 線型回帰分析によるガンマ線及び中性子線に対する多発性骨髄腫の線量反応は，被爆者の慢性骨髄性白血病の線量反応と逆になっていることが示唆される．[25]

高線量被曝者の多発性骨髄腫発生率は有意に増加しているが，高線量群で観察された例数は少なく，臨床所見，免疫グロブリンの性状，剖検その他による所見は対照群と比較して特異なものではなかった．しかしながら，剖検例を比較すると100rad 以上の線量を受けた者で多発性骨髄腫を有する4例中2例がアミロイドージスを有することが発見された．これらアミロイドージスのうち1例からは Bence Jones 蛋白が見られ，再生不良性貧血と診断された他の1例は，剖検によって骨髄腫細胞の増殖が発見された．死亡直前の総蛋白質は5.0であり過ガンマグロブリン血症や骨髄腫のピークは見られなかった．尿蛋白反応は陽性であった．この症例も Bence Jones 型骨髄腫が疑われる．したがって高線量群では，アミロイドージスを有する2例が Bence Jones 型骨髄腫と考えられる．アミロイドージスを併発する骨髄腫は Bence Jones 蛋白と関係があるとの報告がなされている．[26,27] アミロイドージスを併発する Bence Jones 型骨髄腫と放射線被曝との関係を明らかにするには今後の

13

sis and radiation exposure must await future study.

研究にまたねばならない.

The cases used in this study were identified by retrospective review of records accumulated over the three postwar decades. The older cases in contrast to the more recent ones did not receive full immunological studies. It does not seem probable however that the intensive immunological studies for possible multiple myeloma have a bias by dose, although there has been an improvement in the diagnostic techniques in multiple myeloma over the years.

本調査で用いた症例は，戦後30年間にわたって集積された記録を遡及的に検討することによって確認した. 初期の症例は最近のものと比較して十分な免疫学的検査が行われていない. 多発性骨髄腫と思われる症例に対する効果的な免疫学的検査の実施は線量による偏りはないように思われるが，多発性骨髄腫の診断技術が時代とともに進歩していることはいうまでもない.

The cells constituting myeloma are considered to be malignant tumors of the lymphatic system. However, it is specific that the majority of these cells proliferates in the bone marrow with progress of the disease. They differ somewhat from malignant lymphoma which proliferates in the lymphatic tissues composed primarily of lymph nodes. Myeloma is a disease frequently found in advanced age groups and it is possible that immuno-insufficiency due to aging is related to its development together with A-bomb exposure.

骨髄腫を構成する細胞はリンパ系の悪性腫瘍であると考えられる. しかし，これらの細胞の多くが疾病の進行とともに骨髄の中で増殖するところに特異性があり，主としてリンパ節で構成されているリンパ組織内で増殖する悪性リンパ腫とはやや異なっている. 骨髄腫は高年齢群に多く見られる疾患であり，加齢による免疫不全が原爆放射線被曝とともに本症の発現に関係している可能性がある.

REFERENCES
参考文献

1.   ANDERSON RE, ISHIDA K: Malignant lymphoma in the survivors of the atomic bomb in Hiroshima. Ann Intern Med 61:853-62, 1964 (ABCC TR 2-64)

2.   ICHIMARU M, YASUHI S, OOTSURU S: 12 cases of multiple myeloma in Nagasaki (7 cases from atomic bomb survivors). Nagasaki Igakukai Zasshi-Nagasaki Med J 38:109-13, 1963

3.   ICHIMARU M, YASUHI S, DANNO H, OOTSURU S, KUBO M: Additional two cases of multiple myeloma from atomic bomb survivors. Nagasaki Igakkai Zasshi-Nagasaki Med J 40:608-11, 1965

4.   YAMAMOTO T, WAKABAYASHI T: Bone tumors among the atomic bomb survivors of Hiroshima and Nagasaki. Acta Pathol Jpn 19:201-12, 1969 (ABCC TR 26-68)

5.   NISHIYAMA H, ANDERSON RE, ISHIMARU T, ISHIDA K, II Y, OKABE K: The incidence of malignant lymphoma and multiple myeloma in Hiroshima and Nagasaki atomic bomb survivors, 1945-65. Cancer 32:1301-9, 1973 (ABCC TR 4-71)

6.   BEEBE GW, ISHIDA M, JABLON S: Studies of the mortality of A-bomb survivors, 1. Plan of study and mortality in the medical subsample (Selection 1), 1950-1958, Radiat Res 16:253-80, 1962 (ABCC TR 5-61)

7.   MILTON RC, SHOHOJI T: Tentative 1965 radiation dose estimation for atomic bomb survivors, Hiroshima-Nagasaki. ABCC TR 1-68

8.   JONES TD: Radiation insult to the active bone marrow as predicted by a method of CHORDS. Oak Ridge National Laboratory Report ORNL/TM-5337, 1976

9.   FINCH SC, HRUBEC Z, NEFZGER MD, HOSHINO T, ITOGA T: Detection of leukemia and related disorders, Hiroshima-Nagasaki, Research Plan. ABCC TR 5-65

10.   ABCC-JNIH: ABCC-JNIH pathology studies, Hiroshima-Nagasaki, Research Plan. ABCC TR 12-62

11.   BEEBE GW, USAGAWA M: The major ABCC samples. ABCC TR 12-68

12.   MANTEL N, HAENSZEL W: Statistical aspects of the analysis of data from retrospective studies of disease. J Natl Cancer Inst 22:719-48, 1959

13.   MIETTINEN OL: Standardization of risk ratios. Amer J Epidemiol 96:383-8, 1972

14.   LEWIS EB: Leukemia, multiple myeloma and aplastic anemia in American radiologists. Science 42: 1492-4, 1963

15.   MANCUSO TF, STEWART A, KNEALE G: Radiation exposures of Hanford Workers dying from cancer and other causes. Health Phys 33:369-85, 1977

16.   MARKS S, GILBERT ES, BRITENSTEIN BD: Cancer mortality in Hanford Workers. International Atomic Energy Agency Symposium on the Late Biological Effects of Ionizing Radiation, March 13-17, 1978, Vienna, Austria

17.   BEEBE GW, KATO H, LAND CE: Studies of the mortality of A-bomb survivors. 6. Mortality and radiation dose, 1950-1974. Radiat Res 75:138-201, 1978 (RERF TR 1-77)

18.   COURT BROWN WM, DOLL R: Mortality from cancer and other causes after radiotherapy for ankylosing spondylitis. Br Med J 2:1327-32, 1965

19.   MODAN B, BAIDATZ D, MART H, STEINITZ R, LEVEN SG: Radiation-induced head and neck tumors. Lancet 1:277-9, 1974

20.   SHORE RE, ALBERT RE, PASTERNACK BS: Follow-up study of patients treated by X-ray epilation for tinea capitis. Arch Environ Health 31:21-8, 1976

21.   ISOBE T, OSSERMAN FF: Pathologic condition associated with plasma cell dyscrasias: A study of 806 cases. Ann NY Acad Sci 190:507, 1971

22.   KYLE RA: Multiple myeloma: Review of 869 cases. Mayo Clin Proc 50:29, 1975

23.   厚生省大臣官房統計調査部：昭和50年人口動態統計下巻
      (Health and Welfare Statistics and Information Department, Minister's Secretariat, Ministry of Health and Welfare: Vital Statistics 1975 Japan. Volume 2)

24.   ICHIMARU M, ISHIMARU T, BELSKY JL: Incidence of leukemia in atomic bomb survivors belonging to a fixed cohort in Hiroshima and Nagasaki, 1950-71: Radiation dose, years after exposure, age at exposure, and type of leukemia. J Radiat Res 19:262-82, 1978 (RERF TR 10-76)

25.   ISHIMARU T, OTAKE M, ICHIMARU M: Dose-response relationship of neutrons and gamma rays to leukemia incidence among atomic bomb survivors in Hiroshima and Nagasaki, 1950-71. Radiat Res 77: 377-94, 1979 (RERF TR 14-77)

26.   OSSERMAN EF, TAKATSUKI K, TALAL N: The pathogenesis of amyloidosis. Semin Hematol 1:3-86, 1964

27.   GLENNER GG, TERRY WD, ISERSKY C: Amyloidosis: Its nature and pathogenesis. Semin Hematol 10:65-86, 1973

APPENDIX
CONFIRMED MULTIPLE MYELOMA AMONG A-BOMB SURVIVORS AND CONTROLS IN THE LSS SAMPLE, HIROSHIMA AND NAGASAKI, 1950-76

付　録　　　寿命調査対象者である被爆者及び対照者の多発性骨髄腫確診例；広島・長崎，1950－76年

MF No.	Sex	Age ATB	Dose in rad	Onset Yr. Mo.	Duration** in year	Age at Onset	Major clinical evidence
	M	38	714	71 11	26.7	64	Myeloma cell, IgG ↑
	F	33	563	60 01	14.4	47	Myeloma cell, IgG↑, Bence Jones protein, Amyloidosis
*	F	46	214	68 04	22.7	68	M-protein, Osteoporosis
	M	48	195	63 10	18.2	66	Myeloma cell, Amyloidosis
	M	49	128	65 02	19.5	68	Myeloma cell
	M	45	74	68 12	23.3	68	Myeloma cell, M-protein
	F	42	57	74 07	28.9	70	Myeloma cell, IgA↑, M-protein
	F	52	15	59 06	13.8	65	Myeloma cell, M-protein
	F	33	11	54 02	8.0	41	Myeloma cell, X-ray lesion
	F	41	7	73 10	28.2	69	Myeloma cell, IgG↑
	F	36	4	58 04	12.7	48	Myeloma cell, IgG↑
	M	44	4	70 09	25.1	69	Myeloma cell, IgG↑
	F	40	1	74 11	29.3	69	Myeloma cell
	M	47	1	64 10	19.2	66	Plasmacytoma, Rib fracture
	F	51	1	63 05	17.8	68	Myeloma cell, IgG↑
	F	39	0	74 12	29.3	68	Myeloma cell, M-protein
	M	16	0	71 04	25.7	41	Myeloma cell, IgG↑, M-protein
	F	40	0	62 07	16.9	56	Myeloma cell, IgG↑
	F	69	0	62 10	17.2	86	Myeloma cell, Amyloidosis
	F	58	0	73 02	27.5	85	Myeloma cell, IgG↑, Bone fracture
	F	47	0	73 10	28.2	75	Myeloma cell, M-protein
	F	25	0	59 12	14.3	39	Myeloma cell, IgG↑
	M	—	NIC	68 09	—	73	Myeloma cell, IgG↑, M-protein
	F	—	NIC	75 12	—	74	M-protein, IgG K type
	M	—	NIC	65 04	—	59	Myeloma cell
	F	—	NIC	73 08	—	67	Myeloma cell, IgA↑, Bence Jones protein
	F	—	NIC	62 06	—	61	Myeloma cell, IgG↑
	M	—	NIC	76 04	—	73	Myeloma cell, M-protein
	F	—	NIC	76 01	—	75	Punched out lesion in skull, radius and pelvic bone

*This case was treated as multiple myeloma at Hiroshima Red Cross Hospital for 4 years and the underlying cause of death was multiple myeloma.

＊この症例は広島赤十字病院で 4 年間多発性骨髄腫として治療を受け，原死因が多発性骨髄腫であった．

**Years between exposure and onset

＊＊被爆から発病までの年数．