file name newhan

Relations between Exposure Age and Cancer Risk with Special reference to differences between nuclear workers and A-bomb Survivors

by

Alice Stewart

George Kneale

Department of Public Health
and Epidemiology
University of Birmingham
Edgbaston
Birmingham B15 2TT
UK

Tel: 021 414 3367
Fax: 021 414 3630

To: American Journal of Industrial Medicine

22nd March 1994

Abstract

Data relating to cancer deaths and radiation exposures of nuclear workers at Hanford were included in a simple analysis with no controlling factors other than exposure age, death age and date of death. This analysis confirms an earlier finding, namely, that relations between exposure age and cancer risk are totally different for nuclear workers and A-bomb survivors. Non-recognition of this difference by radiation protection committees is probably the result of assuming (wrongly) that A-bomb data are a reliable source of risk estimates for radiation workers and other low dose situations.

Introduction

According to the Radiation Effects Research Foundation, whose risk estimates are based on A-bomb survivors, young adults are more sensitive to carcinogenic effects of radiation than old persons[1,2]. This conclusion has gained widespread acceptance despite the fact that youths are, in general, more resistant to disease than either older or younger persons. Furthermore, according to Kneale *et al*, who have shown that the survivor-based risk estimates of RERF may not be directly applicable to more normal situations, sensitivity to carcinogenic effects of radiation progressively increases with adult age[3,4].

Though there have been several analyses of Hanford data by Kneale and his associates, their risk estimates have been totally ignored by the US committee on Biological Effects of Ionizing Radiation (BEIR) and by other committees whose main concern is the setting of safety standards for radiation workers[5]. The reason for this universal rejection of much needed (worker based) risk estimates is obvious: Gilbert and her associates have repeatedly come to the conclusion that, even for nuclear workers whose cumulative dose exceeded 200 mSv, there was no evidence of any extra cancer deaths either at Hanford, Oak Ridge or Rocky Flats[6,7]. But according to the 1993 analysis by Kneale and Stewart, these negative findings are merely the result of Gilbert *et al* using methods of statistical analysis which made no allowance for exposure age effects[4].

According to BEIR V, exposure age is not of great importance[5]. But, according to Kneale and Stewart, this is a mistaken view caused by failure to recognise that the unusual age distribution of the cancers caused by A-bomb radiation is the result of unrecorded deaths from acute effects of the radiation being concentrated among children and old persons.

Evidence that exposure age is more important than is generally recognised, can be found in the latest Kneale and Stewart publication[4]. But as a result of this complex analysis of Hanford data requiring simultaneous control of many factors, it is not immediately obvious that relations between exposure age and cancer risk are totally different for nuclear workers and A-bomb survivors[4,8]. Hence, the need for a much simpler analysis of Hanford data with no controlling factors other than exposure age, death age and date of death.

Hanford Data

The latest computerised version of Hanford data, already examined by Gilbert *et al*[7] and by Kneale and Stewart[4], describes the mortality experiences of 35,568 badge monitored workers. By 1990, the ascertained deaths of these workers (whose first recorded exposures to radiation were in 1944) included 1863 ascribed to cancer, and a further 191 ascribed to other causes but having cancer as a contributory factor (Table 1).

The results of combining the fatal and non-fatal cancers to form a consecutive series of 2054 'cancer deaths, and classifying each death by calendar year (46 groups) and age (11 groups), are shown in Table 2. To each of the cells in this table with one or more cancer deaths were then added all the workers who were a) still alive at the end of the preceding year, and b) came from the same birth cohorts as the dead workers (Table 3). This produced 334 subcohorts of cases and matched controls, to which were added the seven sets of radiation doses shown in Table 4 in relation to 56 cancer deaths in 1969.

The Need for Certain Dose Restrictions

There is general agreement among epidemiologists that in any survey of cancer effects of radiation, one should allow for long intervals between cancer inductions and cancer deaths by omitting all the radiation received in certain pre-death years or 'lag periods'. For example, in their 1993 analysis of Hanford data, Gilbert *et al* showed the effects of ignoring all the doses received 2 or 10 years before the cancer deaths, but not having any other 'cancer modulating factors'(7). Meanwhile, Kneale and Stewart were using the same data to obtain appropriate estimates of lag periods, and they eventually showed the effects of adding these estimates to other modulating factors(4).

In four of the Kneale and Stewart risk models, where exposure age was one of several cancer modulating factors, the lag period estimates ranged from 14 to 17 years. Therefore, in Table 4, are shown the effects of excluding all doses within 15 years of the cancer deaths and combining this date restriction with four exposure age restrictions (under 35; 35-44; 45-54 and 55+ years). For completeness, the table also shows 1) the inappropriate (lag period) doses; 2) the doses for all the allowable (pre-lag period) exposures, without any age restrictions, and 3) the doses for all exposures with no date or age restrictions.

Results

As a result of the exposure age restrictions being superimposed on a date restriction, only workers who were over 70 years of age when they died had any allowable exposures after 55 years of age. Among the 56 cancer deaths in 1969 there were 15 of these workers, and 37 workers with allowable exposures after 45 years of age (who were over 60 years of age when they died). For the smaller group, the observed dose was 37 mSv and the expected dose was $\frac{894 \times 12}{551} + \frac{1047 \times 3}{357}$ or 28.2 mSv; and for the larger group the observed and expected doses were 150 and 114.4 mSv (Table 5).

Similar calculations for the complete series of 334 subcohorts of cases and matched controls yielded the observed and expected doses in Table 6, where the findings for three follow-up periods are compared. Thus, by the end of 1974 there were 796 cancer deaths, by the end of 1984 there were 1703 of these deaths, and by the end of 1989 there were 2054. For each of these follow-up periods there are seven sets of observed and expected doses, as in Table 5.

In two of the three follow-up periods the total dose for all exposures, with no age or date restrictions, was a fraction smaller than the expected dose. For all exposures 15 or more years before the cancer deaths the observed dose in each period was greater than the expected dose, and for these allowable exposures after 55 years of age, each one of the observed doses was significantly greater than the expected dose. The test of this significance (which yielded a p-value of less than 0.0001) was by Mantel-Haenszel chi-square tests with 1 degree of freedom. Therefore, there was overall significance despite the fact that the dose had been divided into five parts (by lag period and exposure age). The table shows that for allowable exposures after 55 years of age the ratio of the observed to expected dose was 1.34 for the shortest follow-up period; 1.46 for deaths by the end of 1984, and 1.78 for the complete series of 2054 cancer deaths.

Finally, in Table 7 are shown the results of identifying all the cancer cases whose allowable doses after 55 years of age were greater than the expected doses (163 cases), and comparing this 'special series' with the main series in Table 1.

In the main series there were 1863 fatal and 191 nonfatal cancers, and in the special series the corresponding numbers were 130 and 33. Therefore, the proportion of nonfatal cancers was over twice as high for the small series (17.3%) as for the large series (7.0%). This difference, also the fact that prostate tumours accounted for more of the special series (14.7%) than the main series (8.3%), was probably the result of three factors: 1) none of the special cases were under 70 years of age; 2) the workers with prostate tumours were older than the workers with other cancers, and 3) the proportion of nonfatal cancers was exceptionally high for the prostate tumours (22.3%). For the remaining 1884 cancer cases there was little to choose between five diagnostic groups, and the proportion of nonfatal cancers was always higher for the special cases than the main series.

Discussion

There are so many reasons why young adults should be relatively insensitive to all causes of death, including carcinogens, that a totally different impression for one such cause (i.e. radiation) is likely to be an artifact. Thus, for A-bomb survivors this impression could easily be the result of selection, or the effects of unrecorded deaths at high dose levels being concentrated among children and old persons. According to RERF this type of selection bias has been ruled out, since the survivor cohort (assembled in October 1950) had and still has a normal death rate effect of the A-bomb radiation came in the form of extra deaths from myeloid leukaemia(15), and second, that later deaths from aplastic anaemia were the result not of leukaemia but of marrow damage(16).

Since 1965 the only use made of the acute injury data is a study of survivors with and without histories of epilation(17). This has revealed differences between leukaemias and solid tumours. But still needed are a) studies of more serious A-bomb injuries, which include deaths from aplastic anaemia as well as cancer deaths, and b) further studies of nuclear workers by methods of statistical analysis which, like the present analysis of Hanford data, allow for possible effects of exposure age on the radiogenic cancer risk.

Acknowledgements

We are indebted to the TMI Public Health Fund for obtaining the data we have examined and for defraying the full cost of the analysis.

References

1. Kato H & Schull WJ. Studies of the mortality of A-bomb survivors. 7. Mortality, 1950-1878: Part 1. Cancer Mortality. Radiation Research 1982;**90**:395-432.

2. Preston DL, Kato H, Kopecky K & Fujita S. Studies in the mortality of A-bomb survivors. 8. Cancer mortality, 1950-1982. Radiation Research 1987;**111**:151-178.

3. Kneale GW, Mancuso TF & Stewart AM. Hanford Radiation Study III A cohort study of the cancer risks from radiation to workers at Hanford (1944-77 deaths) by the method of regression models in life-tables. Br J Indust Med 1981;**16**:156-166.

4. Kneale GW & Stewart AM. Reanalysis of Hanford data: 1944-1986 deaths. Am J Ind Med 1993;**23**:371-389.

5. BEIR V: "Health Effects of Exposure to Low Levels of Ionizing Radiation." National Academy Press, Washington, D.C. 1990.

6. Gilbert ES, Fry SA, Wiggs LD, Voelz GL, Cragle DL & Petersens GR. Analyses of combined mortality data on workers at the Hanford site, Oak Ridge National Laboratory, and Rocky Flats Nuclear Weapons Plant. Rad Res 1989;**120**:19-35.

7. Gilbert ES, Omohundro E, Buchanan JA & Holter NA. Mortality of workers at the Hanford site: 1945-1986. Health Physics 1993;**64**;no.6:577-590.

8. Stewart AM & Kneale GW. The Hanford data: Issues of age at exposure and dose recording. The PSR Quarterly 1993;**3**;no.3:101-111.

9. Beebe GW, Land CE & Kato H. The hypothesis of radiation-accelerated aging and the mortality of Japanese A-bomb vicitms. <u>in</u> Late Effects of Ionizing Radiation. Vol. 1. Radiation. International Atomic Energy Agency, Vienna, 13-17 March 1978.

10. Stewart AM. Delayed effects of A-bomb radiation: A review of recent mortality rates and risk estimates for five-year survivors. J Epidemiol & Comm Hlth 1982;**36**;(2):80-86.

11. Stewart AM & Kneale GW. A-bomb radiation and evidence of late effects other than cancer. Health Physics 1990;**58**;(6):729-735.

12. Stewart AM & Kneale GW. A-bomb survivors: Further evidence of late effects of early deaths. Health Physics 1993;**64**:67-472.

13. Gilman EA, Kneale GW, Knox EG & Stewart AM. Pregnancy x-rays and childhood cancers: Effects of exposure age and radiation dose. J Soc Radiol Prot 1988;**8**;1:3-8.

references continued

14. Jablon S, Ishida M & Yamasaki M. Studies of the mortality of A-bomb survivors. 3. Description of the sample and mortality, 1950-1960. Rad Res 1965;**25**;(1):25-52.

15. Sstewart AM. Relative sensitivity of myeloid and lymphatic stem cells to mutational and cell killing effects of ionizing radiation. Leukemia Research 1991;**15**;12:1089-90.

16. Beebe GW, Kato H & Land CE. Mortality experience of atomic bomb survivors, 1950-74. Radiation Effects Research Foundation RERF Technical Report 1977, TR 1-77.

17. Neriishi K, Stram DO, Vaeth M, Mizuno S & Akiba S. The observed relationship between the occurrence of acute radiation sickness and subsequent cancer mortality among A-bomb survivors in Hiroshima and Nagasaki. Radiation Effects Research Foundation RERF 1989 TR 18-59.

for all diseases other than cancer[9]. But, according to Stewart, this too could be an artifact, since high dose survivors might still be at risk of non-specific, anti-selection effects of chronic marrow damage[10].

There have so far been only two tests the Stewart hypothesis (both by Stewart and Kneale). The first test showed that although there was no monotone trend of risk with rising dose for fatal diseases other than cancer, for all causes of death except cancer and cardiovascular diseases, the estimated risk (as a quadratic dose response curve) was significantly U-shaped[11]. The second test showed that, in A-bomb data, the proportion of high dose survivors (over 1000 mSv) is much lower for persons who were under 10 or over 50 years of age in 1945 than for the intervening age groups[12].

These tests only provide indirect evidence of there being late effects of A-bomb radiation other than cancer. But direct evidence of a very different relationship between exposure age and cancer risk in less abnormal circumstances than a nuclear holocaust, is also available. Thus, according to Hanford data, sensitivity to carcinogenic effects of radiation increases progressively with adult age, and according to the Oxford Survey of Childhood Cancers, sensitivity to cancer induction by radiation decreases with age before birth[13].

Further demonstration of late effects of A-bomb radiation other than cancer would necessitate using the records of acute injuries to obtain subgroups of survivors representing relatively strong and relatively weak effects of selection and marrow damage[14]. It would also be necessary to bear in mind two possibilities: first, that cancer promotion effects of marrow damage might be the reason why the first evidence of any cancer tabhan

Table 1

Death ages and other characteristics of 1863 fatal and 191 non-fatal cancers

Specifications		Cancer Cases Fatal	Non-fatal	Total	% Non-fatal
Death Years	1944-54	72	-	72	0.0
	1955-64	202	14	216	7.0
	1965-74	457	51	508	11.2
	1975-84	810	97	907	12.0
	*1985-89	322	29	351	9.0
Death Age in Years	under 35	24	-	24	0.0
	35-44	80	4	84	4.8
	45-54	238	12	250	4.8
	55-64	578	25	603	4.1
	65-74	630	72	702	10.3
	75+	313	78	391	19.9
Types of Cancer	Digestive (150-159)	484	45	529	8.5
	Respiratory (160-163)	581	49	630	7.8
	Genito-urinary (180-189)	242	54	296	18.2
	RES neoplasms (200-209)	198	20	218	9.2
	Other & unspecified	358	23	381	6.0
	Totals	1863	191	2054	9.3

* Incomplete identification of death certificates mainly affecting 1987 to 1989 deaths outside Washington State.

( ) ICD nos.

Table 2

Cancer cases by age at death and year of death (334 subcohorts)

Calendar years	Age in years 25-	30-	35-	40-	45-	50-	55-	60-	65-	70-	75+
1944	-	-	-	-	-	1	-	-	-	-	-
1945	-	1	-	-	-	-	-	1	-	-	-
1946	-	-	-	-	-	-	-	1	-	-	-
1947	-	1	-	-	-	1	-	1	-	-	-
1948	-	1	-	1	1	-	1	1	-	-	-
1949	-	1	-	1	1	-	2	2	-	-	-
1950	-	-	-	1	-	-	1	3	-	-	-
1951	1	1	-	-	1	4	1	1	2	-	-
1952	-	1	-	-	1	2	3	1	1	-	-
1953	-	1	1	2	3	2	3	3	1	-	-
1954	-	-	2	-	1	2	3	1	-	3	-
1955	-	2	-	1	1	2	1	4	1	-	-
1956	-	-	1	1	2	1	2	1	4	1	-
1957	-	-	1	-	2	3	5	2	1	2	-
1958	-	1	1	4	3	2	1	4	4	1	1
1959	-	-	-	-	5	3	3	4	2	2	1
1960	-	-	-	2	1	3	3	4	5	2	2
1961	-	-	4	4	1	1	-	4	5	-	3
1962	-	1	2	-	4	4	6	1	5	4	2
1963	-	-	-	1	1	3	7	10	6	2	1
1964	1	-	-	2	5	1	3	7	5	4	1
1965	-	-	-	2	2	4	4	6	7	8	2
1966	-	-	-	-	1	4	6	3	2	4	6
1967	-	1	3	1	-	7	11	6	7	4	2
1968	-	-	2	4	2	1	7	11	11	3	2
*1969	-	1	2	1	4	3	8	10	12	12	3
1970	-	1	-	-	4	10	12	8	10	4	8
1971	-	-	-	2	1	8	14	13	9	11	9
1972	1	-	-	2	3	4	8	13	10	7	10
1973	-	1	1	3	4	7	6	12	12	8	8
1974	-	-	-	2	2	10	9	9	7	7	16
1975	-	-	2	1	3	4	12	15	13	8	9
1976	-	-	-	2	2	7	6	24	9	16	14
1977	-	3	-	-	1	9	7	17	9	16	16
1978	1	-	1	3	3	6	10	19	16	13	17
1979	-	-	2	3	6	4	7	16	17	15	18
1980	-	-	-	1	2	7	15	14	21	21	21
1981	-	-	1	2	2	3	7	12	29	16	14
1982	-	-	1	-	3	2	19	9	22	16	29
1983	-	-	-	2	4	3	10	11	34	15	24
1984	-	-	-	3	2	4	11	17	25	21	30
1985	-	-	-	-	3	2	12	13	21	19	32
1986	1	-	-	2	5	6	7	11	11	22	37
1987	-	-	-	-	-	3	3	11	9	14	20
1988	1	-	-	-	1	2	4	3	8	10	17
1989	-	-	1	-	-	2	-	4	10	8	16

* see Table 4

Table 3

Controls for 334 subcohorts of cancer cases.

Calendar years	Age in years 25-	30-	35-	40-	45-	50-	55-	60-	65-	70-	75+
1944	-	-	-	-	-	188	-	-	-	-	-
1945	-	1324	-	-	-	-	-	104	-	-	-
1946	-	-	-	-	-	-	-	136	-	-	-
1947	-	1731	-	-	-	593	-	170	-	-	-
1948	-	2030	-	1301	990	-	419	206	-	-	-
1949	-	2107	-	1453	1116	-	476	240	-	-	-
1950	-	-	-	1593	-	-	526	287	-	-	-
1951	2504	2498	-	-	1254	1008	600	330	139	-	-
1952	-	2654	-	-	1463	1050	691	376	165	-	-
1953	-	2781	2656	2283	1596	1171	730	432	196	-	-
1954	-	-	2727	-	1752	1288	801	484	-	78	-
1955	-	3151	-	2644	1947	1244	1049	533	274	-	-
1956	-	-	2977	2822	2127	1432	1071	593	311	128	-
1957	-	-	3061	-	2348	1609	1118	671	341	150	-
1958	-	3019	3164	2945	2500	1747	1238	711	384	176	57
1959	-	-	-	-	2627	1852	1342	787	427	200	79
1960	-	-	-	2981	2734	1986	1265	1022	473	233	93
1961	-	-	3355	3084	2883	2112	-	1020	531	-	122
1962	-	2696	3267	-	2915	2317	1571	1044	600	283	140
1963	-	-	-	3289	2997	2476	1680	1156	610	312	176
1964	1777	-	-	3436	3018	2609	1786	1243	678	348	196
1965	-	-	-	3524	3045	2730	1926	1181	883	379	233
1966	-	-	-	-	3156	2876	2062	1321	877	429	267
1967	-	2169	2966	3443	-	2923	2259	1469	918	463	296
1968	-	-	2793	3385	3386	3015	2417	1585	1017	489	322
*1969	-	2232	2579	3340	3539	3048	2548	1693	1089	551	357
1970	-	2208	-	-	3623	3084	2667	1825	1041	722	408
1971	-	-	-	3206	3625	3211	2818	1937	1156	711	467
1972	1452	-	-	3099	3575	3295	2852	2122	1293	745	510
1973	-	2004	2459	2942	3493	3428	2936	2271	1405	823	529
1974	-	-	-	2823	3479	3613	2986	2416	1505	862	594
1975	-	-	2658	2742	3458	3707	3054	2512	1636	844	760
1976	-	-	-	2772	3475	3732	3216	2652	1749	967	781
1977	-	2697	-	-	3457	3761	3360	2715	1916	1091	825
1978	2740	-	2887	3075	3390	3745	3532	2817	2052	1216	909
1979	-	-	2825	3080	3189	3709	3701	2864	2179	1308	1009
1980	-	-	-	3098	3056	3646	3782	2957	2271	1410	1143
1981	-	-	2846	3000	2999	3571	3763	3109	2423	1502	1254
1982	-	-	2947	-	3013	3472	3713	3228	2483	1637	1403
1983	-	-	-	2868	3042	3341	3638	3371	2578	1761	1554
1984	-	-	-	2801	3049	3144	3606	3526	2634	1877	1686
1985	-	-	-	-	3068	3024	3546	3584	2725	1966	1855
1986	795	-	-	2823	2974	2959	3478	3565	2878	2096	2016
1987	-	-	-	-	-	2966	3379	3534	2983	2168	2221
1988	295	-	-	-	2846	3002	3258	3475	3149	2281	2530
1989	-	-	2656	-	-	3017	-	3473	3306	2400	2840

* see Table 4

Table 4

Radiation doses of 56 cancer cases (1969 deaths) and their matched controls

Lag Period	Exposure Age in Years		Final (Death) Age in Years									
			<35	35-	40-	45-	50-	55-	60-	65-	70-	75+
			Cumulative Dose in mSv of Matched Cases and Controls									
15 Years	under 35	cases	0	0	3	40	3	7	0	0	0	0
		controls	61	2461	11746	16670	10134	4027	0	0	0	0
	35-44	cases	0	0	0	0	0	42	25	13	0	0
		controls	0	0	0	0	6402	11541	6114	1488	0	0
	45-54	cases	0	0	0	0	0	0	28	35	87	0
		controls	0	0	0	0	0	0	3439	4528	1860	436
	55+	cases	0	0	0	0	0	0	0	0	27	10
		controls	0	0	0	0	0	0	0	0	894	1047
	All ages	cases	0	0	3	40	3	49	53	48	114	10
		controls	61	2461	11746	16670	16536	15568	9553	6016	2754	1484
Residual exposures		cases	21	61	9	83	20	157	370	176	27	0
		controls	40317	53441	84095	82984	72553	70932	42357	18958	2566	207
All exposures		cases	21	61	12	123	23	206	423	224	141	10
		controls	40378	55902	95841	99654	89089	86500	51910	24974	5320	1691
Nos. of workers[1]		cases	1	2	1	4	3	8	10	12	12	3
		controls	2232	2579	3340	3539	3048	2548	1693	1089	551	357

(1) see Tables 1 & 2

Table 6

Observed and expected radiation doses for three series of cancer cases

Follow-up Period	Cancer Cases	Lag Period in Years	Exposure Age in Years	Dose in mSv Obs (O)	Exp (E)	Ratio O:E
		15	under 35	642	696	0.92
		15	35-44	1477	1221	1.21
		15	45-54	1121	1028	1.09
1944-1974	796	15	55+	501	374	1.34
		15	All ages	3741	3319	1.13
			Residual exposures	10234	11602	0.88
			All exposures	13975	14921	0.94
		15	Under 35	2929	3305	0.89
		15	35-44	6694	6581	1.02
		15	45-54	6917	7875	0.88
1944-1984	1703	15	55+	4270	2916	1.46
		15	All ages	20810	20677	1.01
			Residual exposures	19631	26546	0.74
			All Exposures	40441	47223	0.86
		15	under 35	4996	4709	1.06
		15	35-44	10803	9409	1.15
		15	45-54	12810	11519	1.11
1944-1989	2054	15	55+	8321	4666	1.78
		15	All ages	36930	30303	1.22
			Residual exposures	22362	28513	0.78
			All exposures	59292	58816	1.01

(1) see footnote to Table 4

Table 5

Observed and expected doses for the 56 cancer cases in Table 4

Lag Period	Exposure Age in Years		<35	35-	40-	45-	50-	55-	60-	65-	70-	75+	Total Dose
			Death Age in Years										
			Cumulative Dose for 56 Cancer Cases in mSv										
15 Years	under 35	obs	0	0	3	40	3	7	-	-	-	-	53
		exp	*0.0*	*1.9*	*3.5*	*18.8*	*10.0*	*12.6*	-	-	-	-	*46.8*
	35-44	obs	-	-	-	-	0	42	25	13	-	-	80
		exp	-	-	-	-	*6.3*	*36.2*	*36.1*	*16.4*	-	-	*95.0*
	45-54	obs	-	-	-	-	-	-	28	35	87	0	150
		exp	-	-	-	-	-	-	*20.3*	*49.9*	*40.5*	*3.7*	*114.4*
	55+	obs	-	-	-	-	-	-	-	-	27	10	37
		exp	-	-	-	-	-	-	-	-	*19.4*	*8.8*	*28.2*
	All ages	obs	0	0	3	40	3	49	53	48	114	10	320
		exp	*0.0*	*1.9*	*3.5*	*18.8*	*16.3*	*48.8*	*56.4*	*66.3*	*59.9*	*12.5*	*284.4*
Residual exposures		obs	21	61	9	83	20	157	370	176	27	0	924
		exp	*18.1*	*41.4*	*25.2*	*93.8*	*71.4*	*222.7*	*250.2*	*208.9*	*55.9*	*1.7*	*989.3*
All exposures		obs	21	61	12	123	23	206	423	224	141	10	1244
		exp	*18.1*	*43.3*	*28.7*	*112.6*	*87.7*	*271.5*	*306.6*	*275.2*	*115.8*	*14.2*	*1273.7*
No. of Cancer Cases			1	2	1	4	3	8	10	12	12	3	56

Table 7

Comparisons Between two Series of Fatal and Non-fatal Cancers

Types of Cancer	Cancers All Cases Nos.	%	Special Cases(1) Nos.	%	% of Special Cancers Fatal	Non-Fatal
Digestive (150-159)	529 (45)	25.8	32 (7)	19.6	5.2	15.6
Respiratory (160-163)	630 (49)	30.7	50 (8)	30.7	7.2	16.3
Prostate (185)	170 (38)	8.3	24 (9)	14.7	11.4	23.7
Other GU (180-189)	126 (16)	6.1	12 (2)	7.4	9.1	12.5
RES neoplasms (200-209)	218 (20)	10.6	16 (2)	9.8	7.1	10.0
Other & unspecified	381 (23)	18.5	29 (5)	17.8	6.7	21.7
Total	2054 (191)	100.0	163 (33)	100.0	7.0	17.3

(1) Cancer cases whose observed dose for exposures after 55 years of age and at least 15 years before death was greater than the expected dose.

( ) Non-fatal cancers or ICD Nos.