MORTALITY AND INDOOR RADON DAUGHTER CONCENTRATIONS IN 13 CANADIAN CITIES

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ABSTRACT

A study was carried out to determine if lung cancer and general mortality rates in 13 Canadian cities were significantly correlated with average indoor radon daughter concentrations. The radon daughter measurements were obtained from a study of 10,000 homes chosen in a statistically valid grab sample basis.

Cancer deaths by year of death, sex, age, and cause were retrieved for each of the cities for the period 1957-1976. Age specific and age standardized mortality rates were calculated.

The results showed no evidence of any substantial association between general or lung cancer mortality rates and indoor radon daughter concentrations.

The limitations of this study and the feasibility of a common international program of epidemiology of radon daughter exposure are discussed. A proposal is made for the use of case control studies of lung cancer to assess the relative importance of smoking, occupational and domestic exposure to radon daughters.

INTRODUCTION

The Radiation Protection Bureau of the Department of National Health and Welfare surveyed 9,999 homes in 14 Canadian localities during the summers of 1977 and 1978 (one locality was excluded from this study - see below). These surveys were done according to a random sampling system established by Statistics Canada.[1] The objective of the survey was to sample a wide cross-section of Canadian homes to obtain information on the levels of naturally occurring radon. All studies were done during the summer when students could be hired to do the survey and the field work was considerably easier. The results of this study are presently in press with the Health Physics Journal.[2]

The results showed statistically significant geographical differences. The highest concentration of radon was found to be 75 pCi/l; the highest concentration of radon daughters was 0.233 W.L.

Because of the small size of one city and the lack of adequate data for that area, it was omitted from the study. Thirteen cities were chosen for the present study to determine if cancer mortality rates were significantly correlated with the average indoor concentration of radon daughter products.

METHODS

Cancer deaths by year of death, sex, age and cause were retrieved for each of the 13 study locations for the period 1957 to 1976 from data supplied by the Health Division of Statistics Canada. The study locations were defined by their 1976 boundaries. Populations by sex and age for the census years 1961 and 1971 were obtained for each study location from Statistics Canada publications[3,4]. Age-specific death rates were calculated by determining the average annual number of deaths in each age and sex group during two time periods (1957 to 1965, and 1966 to 1976) and dividing by the mid-year population for the relevant age and sex group. Age-standardized mortality rates (ASMRs) were calculated by the direct method using the 1971 Canadian population as a standard. The standard errors of ASMRs were calculated by the method of Chiang[5].

RESULTS

The geometric mean of the radon daughter concentration varied from .0009 to .0036 W.L. The percentage of homes exceeding .02 W.L. for each city was: St. John's, Nfld. 0.7; Charlottetown 0.9; Halifax 5.2; Fredericton 3.3; St. John, N.B. 2.8; Montreal 1.0; Quebec 2.1; Sherbrooke 6.4; Sudbury 6.9; Thunder Bay 2.2; Toronto 0.9; Calgary 0.2; Vancouver 0.0.

There was a strong correlation between the mean radon concentrations by city and the percentage of homes in which the radon daughter concentrations exceeded 0.02 W.L. In view of the skewed distribution of radon daughter concentrations, the percentage of homes in which radon daughter concentrations exceeded 0.02 W.L. was chosen as the radiation exposure index for correlation with cancer mortality rates.

GENERAL CANCER MORTALITY

Basic population and cancer mortality data from the 13 study locations are presented in Table 1. The reader will note the wide variation in city size with 1971 populations ranging from about 25,000 to almost 3,000,000. Crude mortality rates ranged from 90.8 to 175.1 for the period 1957 to 1965 and from 100.2 to 200.9 for the recent period.

Age-standardized mortality rates (ASMRs) and comparative mortality figures (CMFs) for all cancers combined are presented in Table 2. ASMRs for males generally increased over time while those of females generally declined. However, the changes were only statistically significant for males living in the largest cities. The CMFs represent the relative change in ASMRs across time; the CMF for males in St. John's, Newfoundland indicates that the ASMR during the period 1966 to 1976 was 91% of that during the earlier period.

The correlation between ASMRs for all cancers combined and radon daughter concentrations (RDCs) by city is presented in Figures 1 and 2 and Table 3. There were no statistically significant correlations between RDC and any of the indices of cancer mortality: mortality rates for each of two time periods ($ASMR_1$ = 1957-1965, $ASMR_2$ = 1966-1976, the absolute change in mortality rates over time ($ASMR_2 - ASMR_1$) or the relative change ($ASMR_2 \div ASMR_1$).

LUNG CANCER MORTALITY

ASMRs and CMFs by city for lung cancer are presented in Table 4. ASMRs increased with time in all cities in both males and females. In general, the absolute and relative changes in lung cancer ASMRs were greatest for those cities for which ASMRs were lowest during the first time period. Thus there were strong negative correlations between $ASMR_1$ and CMF ($r = 0.91$ for males, $r = 0.78$ for females).

Correlations between lung cancer mortality indices and RDCs are presented in Table 3 and Figures 3 and 4.

ALL-AGE LUNG CANCER MORTALITY

The results show essentially no correlation in either sex between lung cancer ASMRs in either time period and RDCs by city. This impression is confirmed by the low correlation coefficients presented in Table 4. There were weak positive but statistically insignificant correlations between the indices of time trend for male lung cancer ASMRs and RDCs ($r = 0.26$ for ($ASMR_2$-$ASMR_1$) versus RDC, $r = 0.28$ for CMF versus RDC).

The corresponding correlation coefficients for female lung cancer are also positive but weak (r = 0.25 and 0.10, respectively).

MALE LUNG CANCER MORTALITY, AGES 25 TO 54

Lung cancer ASMRs and CMFs for males aged 25 to 54 were calculated and the correlation between these rates and RDCs were plotted. There was essentially no correlation between any of the mortality indices and RDCs by city.

MALE LUNG CANCER MORTALITY, AGES 55 TO 69

Data similar to those above for males aged 55 to 69 were calculated. There was a weak negative correlation (r = -0.17) between ASMRs for the period 1957 to 1965 and RDCs and a weak positive correlation (r = 0.23) between ASMRs for the recent time period and RDCs. There were also weak positive correlations between the indices of time trend and RDCs (r = 0.30 for ($ASMR_2$-$ASMR_1$) versus RDC, r = 0.26 for CMF versus RDC).

MALE LUNG CANCER MORTALITY, AGES 70 AND OLDER

Results for lung cancer in older males were calculated. There was essentially no correlation between RDC and any of the mortality indices except CMF (r = 0.27).

MALE LUNG CANCER MORTALITY CONTROLLED FOR CITY SIZE

The observed ASMRs for lung cancer (all ages) by city and those expected based on city size were calculated. The CMFs provide an index of lung cancer mortality adjusted for city size. There were weak positive correlations between the CMFs and RDCs by city for both males (r = 0.26) and females (r = 0.37). The latter correlation coefficients are higher than those between lung cancer ASMRs (unadjusted for city size) and RDCs (r = 0.19 for both males and females, see Table 4).

LEUKEMIA

ASMRs and CMFs for leukemia were calculated. There was some tendency for ASMRs for females to decline over time but none of the changes in either sex were statistically significant. Correlations between leukemia mortality indices and RDCs by city were plotted. There was a statistically significant negative correlation between the ASMR for males during the period 1957 to 1965 and RDCs by city (r = -0.59, $p<0.05$) but essentially no correlation during the recent time period (r = -0.06). There were statistically significant positive correlations between RDCs and both indices of time trend (r = 0.56 for ($ASMR_2$-$ASMR_1$) versus RDC, r = 0.62 for CMF versus RDC). Thus there was a statistically significant tendency for male leukemia ASMRs to increase more rapidly over time in cities with higher RDCs compared to cities with lower RDCs. However, no such tendency was observed for female leukemia ASMRs.

DISCUSSION

The study was based on the assumption that the relative differences in household radon daughter concentrations by city have not changed substantially over the past 30 years or more.

The radon daughter surveys were carried out during the summer. The study design was based on the assumption that the relative difference between radon daughter concentrations between the cities were not influenced by seasonal variations.

Data on smoking habits by city would be useful since tobacco smoking is by far the strongest known risk factor for lung cancer in the general population. The absence of such data is a major weakness in the present study.

The mortality rates were based on deaths of persons who were usual residents of the study cities at the time of death. Migration of persons in and out of cities over a period of time will have reduced the chance of observing any correlation between mortality and radon daughter concentrations.

The radon daughter concentrations were relatively low. No matter which model is used to estimate the risk of lung cancer from exposure to radon daughters, the risk will also be minimal. The numbers of excess lung cancer deaths due to such exposures in Canadian cities are probably too low to be detected by the present study.

The size and labour force compositions of the city varied substantially. Lung cancer is known to be associated with city size and certain occupations. Inability to adjust adequately for these variables would tend to obscure any association with radon daughter concentrations.

CONCLUSIONS AND PROPOSAL FOR CASE CONTROL STUDY

In view of the limitations stated above, it is very probable that the present study design could only detect a very strong association between radon daughter concentrations and mortality. The negative results of this study can only be interpreted as indicating in a qualitative manner, that radon daughter concentrations do not have a dominant effect on lung cancer mortality in Canadian cities studied. Although the radon daughter concentrations were generally very low in the three highest risk cities, over 5% of all homes had radon daughter concentrations exceeding 0.02 W.L. Long-term residents in such homes could accumulate relatively high radon daughter exposures during a lifetime. It is suggested, therefore, that a case-control epidemiological study of lung cancer should be performed in one or more of the highest risk cities. This study would be designed to determine if household exposure to radon and radon daughters is a significant risk factor for lung cancer after adjustment for other factors including smoking and occupation.

The cases might consist of residents of the city studied ho had developed or died of lung cancer during the past 10 years; controls could be persons matched for sex, age and smoking habits.

As it is expected that the radon daughter concentrations would not vary significantly over the years in the city studied, all cases and controls (or relatives) would be interviewed to determine the period of residence in various homes which would be surveyed for radon daughters. Lifetime radon daughter exposures would be estimated for each individual and each control. A questionnaire would be designed and administered to surviving cases and controls and relatives of deceased. The questionnaire would include items on smoking habits, lifetime occupations, lifetime places of residence, medical history and family history. It would be desirable to have all interviews conducted by one trained interviewer. This approach of actual measurements of radon daughter concentrations would overcome the major defect of the paper by Axelson et al.[6] based on a case control study of the possible impact of exposure to radon and its daughters in dwellings. It has been well shown in Canada that radon daughter concentrations are not related to the type of dwelling or building materials used but are related to geographical area and the geology of the ground on which the house is actually located.

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TABLE 1

CHARACTERISTICS OF STUDY LOCATIONS

Study Location	Population 1961	Population 1971	Cancer Deaths 1957-1965	Cancer Deaths 1966-1976	Crude Cancer Death Rates[1] 1957-1965	Crude Cancer Death Rates[1] 1966-1976
St. John's, Nfld.	66,418	95,320	964	1,491	161.3	142.2
Charlottetown	21,633	25,245	341	531	175.1	191.2
Halifax	139,477	186,825	1,517	2,915	120.8	141.8
Fredericton	22,916	37,365	303	554	146.9	134.8
Saint John, N.B.	69,001	89,050	1,049	1,968	168.9	206.9
Montreal	2,048,282	2,729,170	27,429	47,700	148.8	158.9
Quebec	385,637	500,975	4,159	7,748	119.8	140.6
Sherbrooke	74,174	101,040	941	1,548	141.0	139.3
Sudbury	95,185	150,265	778	1,656	90.8	100.2
Thunder Bay	90,490	108,400	1,213	1,965	148.9	164.8
Toronto	1,868,821	2,611,875	24,675	41,223	146.7	143.5
Calgary	271,088	403,310	2,893	5,173	118.6	116.6
Vancouver	822,735	1,078,630	12,813	20,367	173.0	171.7

[1] Deaths per 100,000 per year (not adjusted for age).

Note: populations are based on 1976 boundaries.

TABLE 2

GENERAL CANCER MORTALITY

Study Location	Males $ASMR_1$	Males $ASMR_2$	Males CMF	Females $ASMR_1$	Females $ASMR_2$	Females CMF
St. John's, Nfld.	214.0	195.7	91	168.6	127.6	76
Charlottetown	162.3	179.2	110	131.4	123.9	94
Halifax	164.6	189.8	115	127.3	131.7	103
Fredericton	165.2	177.5	107	132.9	110.9	83
Saint John, N.B.	168.2	188.0	112	138.7	131.8	95
Montreal	190.5	211.6	111**	143.5	140.4	98
Quebec	172.1	204.9	119**	126.5	127.8	101
Sherbrooke	173.3	199.0	115	150.3	124.3	83
Sudbury	159.1	186.2	117	96.5	123.5	128
Thunder Bay	172.7	182.4	106	115.9	110.8	96
Toronto	172.6	183.7	106**	122.8	119.5	97
Calgary	147.4	165.6	112*	119.1	115.7	97
Vancouver	155.7	171.2	110**	116.9	115.7	99

* $p<0.05$

** $p<0.01$

Note: 1. $ASMR_1$ = 1957-1965, $ASMR_2$ = 1966-1976

2. CMF = $(ASMR_2 \div ASMR_1) \times 100$

TABLE 3

CORRELATION BETWEEN MORTALITY AND RADON DAUGHTER CONCENTRATION

	Males				Females			
	$ASMR_1$	$ASMR_2$	$ASMR_2 - ASMR_1$	CMF	$ASMR_1$	$ASMR_2$	$ASMR_2 - ASMR_1$	CMF
All Cancer	−0.15	0.24	0.46	0.48	−0.18	0.12	0.26	0.35
Lung Cancer All Ages	0.10	0.19	0.26	0.28	−0.07	0.19	0.25	0.10
25–54	−0.06	−0.07	−0.04	0.11	-	-	-	-
55–69	−0.17	0.23	0.30	0.26	-	-	-	-
70+	0.00	0.09	0.15	0.27	-	-	-	-
Leukemia	−0.59*	−0.06	0.56*	0.62*	0.12	0.21	−0.02	−0.04

* $p<0.05$

Note: 1) the data are Pearson correlation coefficients based on linear regression of mortality indices and RDCs by city.

2) $ASMR_1$=1957-1965, $ASMR_2$=1966-1976, CMF=($ASMR_2 \div ASMR_1$)x100.

TABLE 4

LUNG CANCER MORTALITY RATES (ALL AGES)

Study Location	Males $ASMR_1$	Males $ASMR_2$	Males CMF	Females $ASMR_1$	Females $ASMR_2$	Females CMF
St. John's, Nfld.	25.1	47.0	188*	4.1	4.4	107
Charlottetown	25.4	54.1	213	1.9	7.7	405
Halifax	27.8	49.6	178**	3.8	10.9	287**
Fredericton	18.7	48.1	257*	1.7	5.7	329
Saint John, N.B.	30.2	59.2	196**	4.2	8.7	207
Montreal	38.0	59.6	157**	5.3	9.2	174**
Quebec	26.3	55.3	210**	3.1	7.0	226**
Sherbrooke	19.1	49.9	261**	3.1	8.3	268
Sudbury	39.4	56.8	144	4.7	9.9	211
Thunder Bay	37.7	52.5	139	3.7	7.7	205
Toronto	39.6	52.1	132**	4.5	9.0	200**
Calgary	21.2	39.7	187**	2.9	9.3	321**
Vancouver	34.6	51.6	149**	5.1	10.8	212**

* $p<0.05$

** $p<0.01$

Note: $ASMR_1$=1957-1965, $ASMR_2$=1966-1976, CMF=($ASMR_2 \div ASMR_1$)x100

FIGURE 1

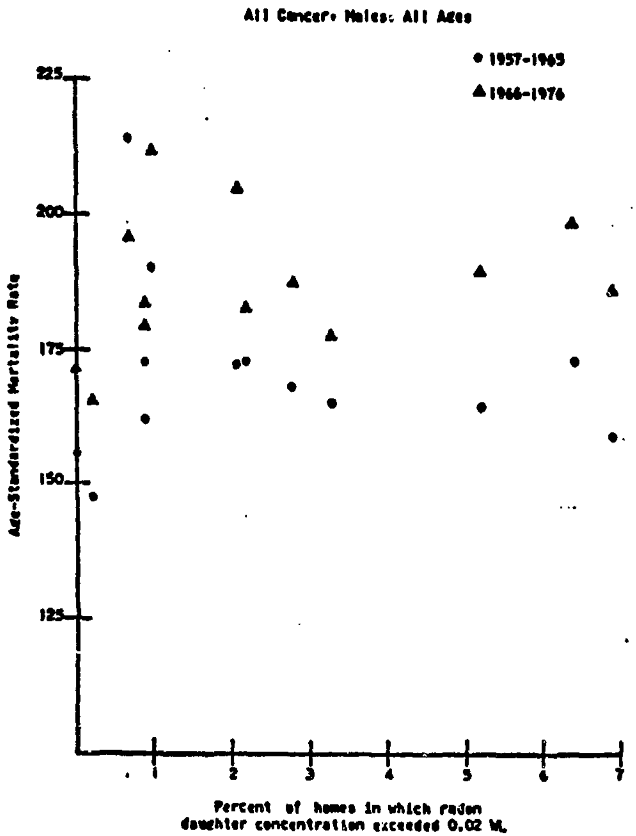

FIGURE 2

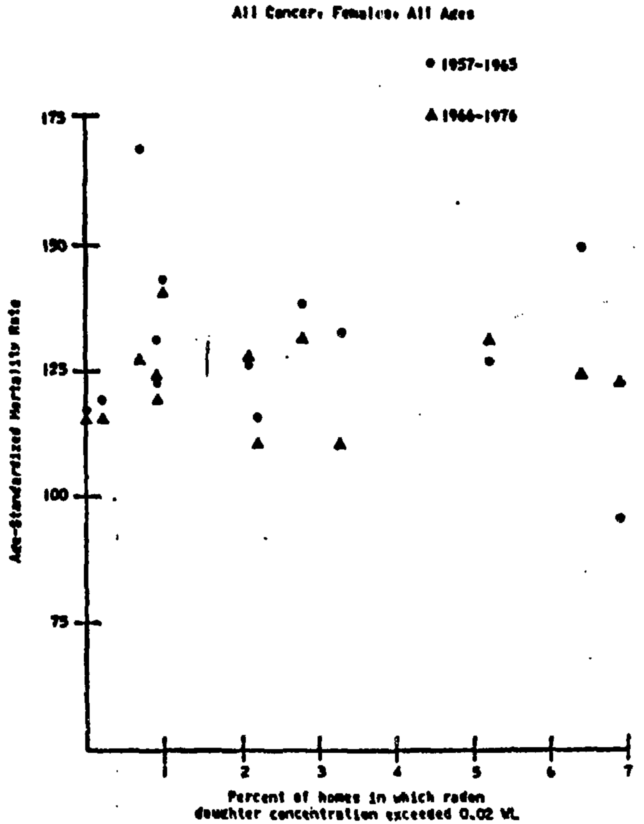

FIGURE 3

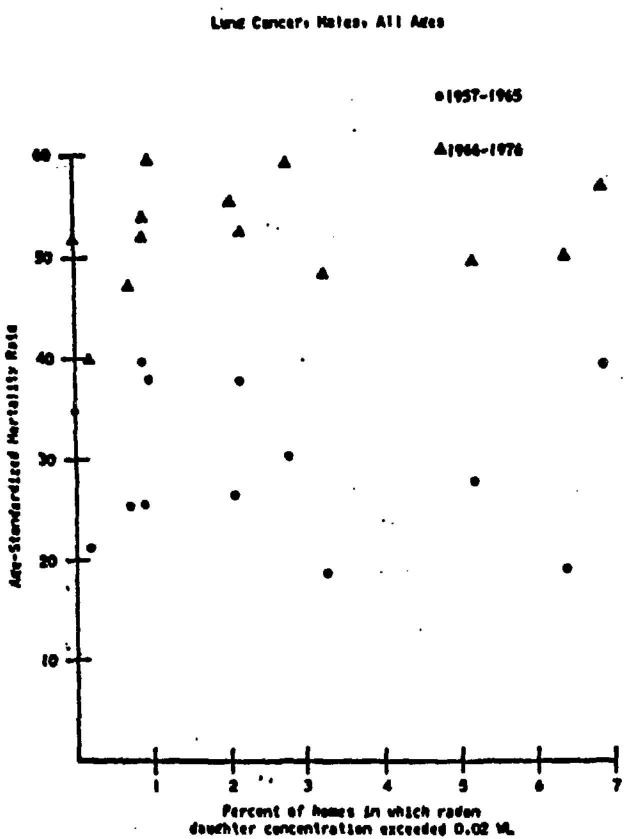

FIGURE 4