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Original Paper

Radon in Devon and Cornwall and Paediatric Malignancies

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Exposure to radon in dwellings may cause cancer including paediatric malignancies. Devon and Cornwall have the highest exposure to radon of the counties of England. However, within these counties there is considerable variation in exposure. Exposure to radon in the 283 postcode sectors of the two counties has been published. The incidence of childhood malignancies between 1976 and 1985 was studied to compare postcode sectors of radon exposures $\geqslant$ 100 Bq/m^3 with sectors $<$ 100 Bq/m^3. No significant difference in the incidence rate of 106.7 per million child years in the high radon postcode sectors and 121.7 in the low ($P = 0.29$) was found. When the incidences of individual tumours were examined, a significantly increased rate of neuroblastoma ($P = 0.02$) and a non-significant increased rate of acute myeloid leukaemia were found in the high exposure postcode sectors. No association between radon exposure and overall rate of childhood malignancy was found.

Key words: radon, incidence, population-based, childhood
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INTRODUCTION

Devon (68 Bq/m^3) and Cornwall (170 Bq/m^3) are the counties with the highest mean levels of radon intensity in England and Wales [1, 2]. Radon levels can be exceptionally high in buildings constructed on granite. An action level of 200 Bq/m^3 was recommended by the National Radiological Protection Board in 1990 and accepted by the Government. In the counties of Devon and Cornwall, 12% (60 000) of houses are estimated to be above this action level [3].

Alpha radiation from natural radon may account for 6% of the cases of lung cancer in the U.K. [4]. It has been suggested that 20–25% of acute myeloid leukaemias (AML), the vast majority being in adults, could be due to radon [5]. Moreover, Henshaw and colleagues suggest that 23–43% of the cases of AML in Cornwall are due to radon [6].

Henshaw and colleagues looked at the average radon levels in a number of countries and correlated them with the incidence of all childhood malignancies. They found a significant correlation [6]. However, a Swedish study, using case–control methods, found no correlation between exposure to radon and childhood cancer [7].

The five main outcrops of granite in Devon and Cornwall only cover approximately a sixth of the area of the counties, and are largely regions of moorland with low population levels [8]. In this paper, a study of the relationship between the incidence of paediatric malignancies and radon exposure in these two counties is reported.

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MATERIALS AND METHODS

The incidence of cancer in the period 1976–1985 for children under 15 years of age in postcode sectors of Devon and Cornwall was determined. Incidence in sectors with high radon levels was compared with that in sectors with low radon.

To achieve this, data was needed on (i) the radon levels in each postcode sector, (ii) the childhood population for each postcode sector, and (iii) the number of cases of cancer in each postcode sector.

An example of a postcode is PL12 3LR, where PL is the postcode area, PL12 is the postcode district, and PL12 3 is the postcode sector. The counties of Devon and Cornwall are covered by the postcode areas PL, EX, TR and TQ, and within these are 283 postcode sectors.

Data on radon levels in the postcode sectors of Devon and Cornwall have been published by the National Radiological Protection Board (NRPB), U.K. [2]. In their study, radon levels in 13% of the 647 328 dwellings in Devon and Cornwall were measured, and from these values the average radon level in each of the postcode sectors was published, each postcode sector comprising on average 2300 dwellings. Figure 1 shows a map of Devon and Cornwall indicating the average radon levels in homes in the 283 postcode sectors.

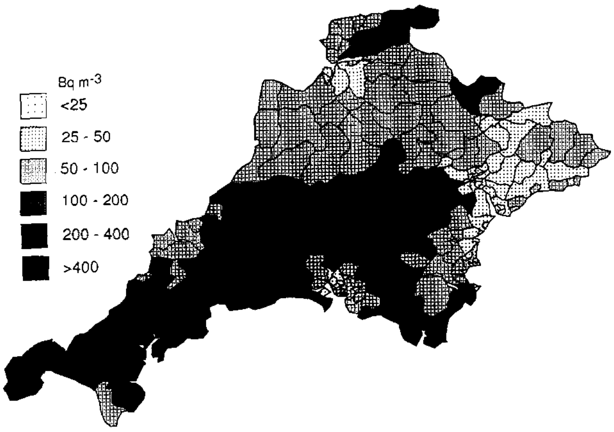

Figure 1. Average radon levels in homes in the 283 postcode sectors of Devon and Cornwall. (Reproduced with kind permission from the National Radiological Protection Board, U.K.).

The childhood population 1976–85, aged under 15 years, for each postcode sector was estimated by taking 15/16th of the child population aged under 16 years in the 1991 census [9]. This source represents the only data available on population by postcode sector, earlier census data being only available by wards and enumeration districts which do not correspond to postcode sectors.

A potential source of error in the analysis of incidence rates is these approximations made in estimating the population base. Analysis of 1981 and 1991 district base population data [10, 11] indicate that the errors in incidence rates from this source will be less than 3%.

Details of newly diagnosed cases of cancer in Devon and Cornwall for the period 1976–1985 among children aged under 15 years were available to the authors from their previous population-based study of childhood cancer in the South-west of England. This study [12] of incidence rates involved pathological review, and divided new cases into the 12 categories as defined by Birch and Marsden [13]. Using the subset of this data covering Devon and Cornwall, with the addition of 18 cases identified since that analysis, 301 cases of cancer were allocated postcodes according to address at the time of diagnosis. Comparison with other well-validated regional registries suggests that ascertainment is virtually complete [14, 15].

Data of the form shown in Table 1 was obtained for each of the 283 postcode sectors and all 12 categories of cancer.

The postcode sectors were then grouped into those having an average radon level ≥ 100 Bq/m^3 and those having an average radon level < 100 Bq/m^3. Using the total child population for each group and the total number of cases in each, the value of overall cancer incidence rate was obtained for the two groups of postcode sectors. The P value (two-tail) for the difference between the two incidence rates was computed using the Poisson model likelihood-ratio test in the EGRET statistical package. Confidence intervals for the incidence rates were found using the Poisson distribution with a continuity correction.

The choice of 100 Bq/m^3 as the dividing point between the two groups was arbitrary and made before the incidence data were viewed.

Similarly, the incidence rates for each of the 12 categories of cancer were found and incidence rates compared. Where an incidence rate was based on 5 or less cases, incidence rates were compared using Fisher's exact test.

Postcode sectors were also grouped into those having an average radon level ≥ 200 Bq/m^3 or < 200 Bq/m^3 for comparison of incidence rates.

RESULTS

The 283 postcode sectors making up Devon and Cornwall contained 113 postcode sectors with average radon level ≥ 100 Bq/m^3 and 170 with average radon level < 100 Bq/m^3. These two groups of postcode sectors were estimated to have population bases of 900 000 child years and 1 680 000 child years, respectively, for children aged under 15 years between 1976 and 1985.

Table 2 shows the number of cases of cancer diagnosed in the children for each of these two groups of postcode sectors in the time period. The same data are represented as incidence rates in Table 3. Confidence limits on the incidence rates are shown, and the P values for the difference between the ≥ 100 and < 100 Bq/m^3 groups of postcode sectors are given.

The overall incidence for all cancers was not significantly different in the two groups ($P = 0.29$). It was lower at 106.7

Table 1. A sample of the data analysed

Postcode sector	Average radon level (Bq/m^3)	Population aged < 16 years in 1991 census	Number of cases of cancer (1976–1985)
PL9 0..	93	499	0
PL9 7..	88	847	1
PL9 8..	88	1357	2
PL9 9..	79	2329	1
PL10 1..	123	592	0
PL11 2..	45	1923	2
PL11 3..	115	451	0

Table 2. Number of cancer cases in postcode sectors with average radon level ≥ 100 and < 100 Bq/m^3. (Diagnosed 1976–1985, aged less than 15 years, living in Devon and Cornwall)

		Postcode sectors with average radon level ≥ 100 Bq/m^3. (Population base 900 000 child years)	Postcode sectors with average radon level < 100 Bq/m^3. (Population base 1 680 000 child years)
All cancer		96	205
I	Leukaemia	35	73
II	Lymphoma	13	17
III	Brain and spinal	17	51
IV	Neuroblastoma	11	6
V	Retinoblastoma	0	3
VI	Kidney	8	15
VII	Liver	1	4
VIII	Bone	2	14
IX	Soft tissue sarcomas	5	12
X	Gonadal and germ cell	1	5
XI	Epithelial	3	4
XII	Others	0	1

Table 3. Cancer incidence in postcode sectors with average radon levels ⩾ 100 Bq/m³ compared with postcode sectors with average radon level < 100 Bq/m³. (Diagnosed between 1976 and 1985, aged less than 15 years, living in Devon and Cornwall)

		Incidence in postcode sectors with average radon level ⩾ 100 Bq/m³ (with 95% CI)	Incidence in postcode sectors with average radon level < 100 Bq/m³ (with 95% CI)	*P* value
All cancer		106.7 (86.4–130.3)	121.7 (105.7–139.6)	0.29
I	Leukaemia	38.9 (27.1–54.1)	43.4 (34.0–54.5)	0.60
	ALL	32.2 (21.6–46.3)	41.0 (31.9–51.9)	0.28
	AML	6.7 (2.4–14.5)	2.4 (0.7–6.1)	0.11
II	Lymphoma	14.4 (7.7–24.7)	10.1 (5.9–16.2)	0.34
III	Brain and spinal	18.9 (11.0–30.3)	30.3 (22.5–39.8)	0.09
IV	Neuroblastoma	12.2 (6.1–21.9)	3.6 (1.3–7.8)	0.02
V	Retinoblastoma	0.0 (0.0–4.1)	1.8 (0.4–5.2)	0.55
VI	Kidney	8.9 (3.8–17.5)	8.9 (5.0–14.7)	0.99
VII	Liver	1.1 (0.0–6.2)	2.4 (0.6–6.1)	0.66
VIII	Bone	2.2 (0.3–8.0)	8.3 (4.5–13.9)	0.08
IX	Soft tissue sarcomas	5.6 (1.8–13.0)	7.1 (3.7–12.5)	0.79
X	Gonadal and germ cell	1.1 (0.0–6.2)	3.0 (1.0–6.9)	0.67
XI	Epithelial	3.3 (0.7–9.8)	2.4 (0.6–6.1)	0.70
XII	Others	0.0 (0.0–4.1)	0.6 (0.0–3.3)	0.99

Incidences are per million child years. The *P* value for the difference between the two incidences is shown (two-tail). ALL, acute lymphoblastic leukaemia. AML, acute myeloid leukaemia.

per million child years in ⩾ 100 Bq/m³ sectors than in the < 100 Bq/m³ sectors where it was 121.7 per million child years.

In the ⩾ 100 Bq/m³ postcode sectors, the incidence rate for neuroblastoma was significantly higher ($P = 0.02$). The rate for AML was higher in the ⩾ 100 Bq/m³ areas ($P = 0.11$) than in the < 100 Bq/m³ sectors, but this was non-significant.

When the postcode sectors of Devon and Cornwall were divided instead into two groups with average radon levels ⩾ 200 and < 200 Bq/m³, the total number of cases of cancer in each group were 21 and 280, respectively giving incidence rates of 70.1 (confidence interval, CI 43.7–107.8) and 122.4 (CI 108.5–137.7) per million child years. With so few cases in the ⩾ 200 Bq/m³ group of postcode sectors, further statistical analysis of incidence rates was not carried out for the different types of cancer.

DISCUSSION

The incidence rate of 106.7 cases per million child years for all cancers in the areas with average radon levels ⩾ 100 Bq/m³ was not significantly different from that of 121.7 cases per million child years in the < 100 Bq/m³ areas. The mean of the radon levels in the ⩾ 100 Bq/m³ postcode sectors was 183 Bq/m³ and that in the < 100 Bq/m³ postcode sectors was 57 Bq/m³. This substantial difference did not lead to a higher incidence of cancer in the children exposed to the high radon levels.

In their study based on international incidences in 14 countries and regions, Henshaw and associates [6] found evidence of a linear increase in childhood cancer incidence with increase in mean radon level. Their model is in close agreement with the incidence of 121.7 cases per million child years for an area with average radon level 57 Bq/m³, but would give an incidence of over 160 cases per million child years in an area with average radon level 183 Bq/m³. This does not fit with our finding of an incidence of 106.7 cases per million child years with a 95% upper confidence limit of 130.3 cases per million child years.

In the Henshaw findings, the significant increase in incidence for all childhood cancers with increasing radon level results from similar significant trends for leukaemia, brain and spinal tumours, and other tumours. The results for Devon and Cornwall do not support this. Decreases rather than increases in incidences were found in the high radon areas for leukaemia, and for brain and spinal tumours, and almost identical incidences (48.9 and 48.1) in the case of all other malignancies.

Higher incidence rates corresponding to the high radon areas in Devon and Cornwall were noted for neuroblastoma and for AML as shown in Table 3. With only 10 cases of AML in total, the difference in incidence rates was non-significant ($P = 0.11$). This result is of interest in the context of earlier correlations between AML incidence and indoor radon concentrations [5]. A plausible pathway by which radon inhalation might expose bone marrow stem cells to biologically effective doses has been suggested by Henshaw and associates [6], but subseqently challenged [16]. An examination of the distribution of adult cases of AML and exposure to radon within the counties of Devon and Cornwall failed to find any positive correlation [17].

The incidence of neuroblastoma is significantly higher in the postcode sectors with greater than 100 Bq/m³ exposure. Environmental hazards have not been thought to play a major role in the aetiology of neuroblastoma [18]. Two studies have reported an association with paternal occupational exposure to electromagnetic fields, although a third study did not confirm this [19–21]. No study has reported a positive correlation between ionising radiation and neuroblastoma. The correlation between radon and neuroblastoma seen here may be simply the result of multiple testing. A further study of the distribution of neuroblastoma in a subsequent time period is therefore being undertaken.

When the postcode sectors were divided into those with greater than 200 Bq/m^3 average radon level and those with less, a remarkably low incidence of cancer in the high radon sectors was found, just 70.1 (CI 43.7–107.8) per million child years. This figure is based on only 21 cases.

A limitation of this study is that radon levels used are averages over postcode sectors as published in 1992, and not the actual exposures of the individual children who developed cancer. The individual child's cumulative exposure will be influenced by the construction of their home, whether the child has moved homes, and similar factors [22]. However, the overall conclusion of this study is that high radon levels have not resulted in high incidences of childhood cancer in Devon and Cornwall.

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