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Cancer in young people in the north of England, 1968–85: analysis by census wards

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Abstract

***Objective*—To determine whether the seeming excess of childhood leukaemia and lymphoma identified in Seascale, Cumbria, UK, remains unusual when put into a wider context.**

***Design*—Analysis of cancer incidence by geographical area.**

***Setting*—The north of England including the Northern and North Western Regional Health Authority regions and the Southport and South Sefton districts of the Mersey Regional Health Authority.**

***Subjects*—Altogether 6686 cases of malignant disease in people under 25 years old.**

***Measurements and main results*—Cases of cancer diagnosed before their 25th birthday between January 1968 and December 1985 identified from three regional cancer registries were allocated to a census ward on the basis of 'usual place of residence'. Population data were derived from the 1971 and 1981 censuses, and the cancer incidence was calculated for each ward. Of the 6686 cases, there were 1035 cases of acute lymphoblastic leukaemia and 361 of non-Hodgkins lymphoma. Wards were ranked by cancer incidence and Poisson probability, using different population bases. Seascale ward is the most highly ranked ward for acute lymphoblastic leukaemia for the time periods 1968–85 or 1968–76. It is not the most highly ranked for non-Hodgkins lymphoma. However, combining acute lymphoblastic leukaemia and non-Hodgkins lymphoma incidence gives an even more extreme position for Seascale. The most extreme Poisson probability for any of the analyses was that for brain tumours in the electoral ward of Ashton St Michael, Tameside (p=0·000009).**

***Conclusion*—The incidence of acute lymphoblastic leukaemia and non-Hodgkins lymphoma in the Seascale ward remains high when put into a wider context. For other cancers there are wards with even more extreme Poisson probability values.**

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The seeming excess of cancer in young people on the Cumbrian coast identified in 1983 by Yorkshire Television in a documentary entitled, *Windscale: the nuclear laundry* led the government to set up an independent inquiry under the chairmanship of Sir Douglas Black. The report of this advisory group[1] concluded that there did seem to be an excess of leukaemia in young people in some villages, particularly Seascale, near to the Sellafield nuclear installation, and that they could find no biological explanation for this when known radiation exposures were taken into consideration. The Black report made a number of recommendations for further study, the results of which have been published. These include a Seascale birth cohort study,[2] a Seascale school cohort study,[3] and a case-control study of leukaemia and lymphoma in west Cumbria.[4] The cohort studies have confirmed an increased risk of leukaemia in those children born in Seascale but not in those who attended school in the district of Seascale but were born elsewhere. The case-control study of leukaemia and lymphoma has pointed to an increased risk for the children of workers employed at the nuclear installation at Sellafield who were exposed to relatively high doses of radiation. In addition recommendation 4 stated:

'The Northern Children's Cancer Registry should be asked to analyse their data using 1961, 1971 and 1981 population census data where appropriate. Also stratification for age at diagnosis and grouping by census ward at birth (as well as at diagnosis) should be undertaken, to determine the contribution these factors make to the incidence of leukaemia at Seascale.'

The data supplied to the Black enquiry from the Northern Region Children's Malignant Disease Registry were those for 1968–82, using 1981 census population data for children diagnosed before their 15th birthday. The purpose of recommendation 4 was to put the apparent excess of leukaemia in Seascale into a wider context and in consultation with the Department of Health and Social Security it was decided to extend further the recommendation to include data from the Manchester Children's Tumor Registry and to obtain information for all young people diagnosed as having cancer before their 25th birthday. It was also agreed to include the Southport and South Sefton districts of the Mersey health region so that the whole of the coastline from the Solway to the Mersey could be included.

Seascale is an electoral ward and by analysing cancer incidence data by electoral ward for the whole of the Northern and North Western Regional Health Authorities plus the two Mersey health districts the relative importance of the apparent excess described in the Black report could be explored.

Methods

CANCER REGISTRATION DATA

Cases of cancer in young people diagnosed between January 1968 and December 1985 were ascertained from existing cancer registries. The

0–14 year old children from the northern region were obtained from the Northern Region Children's Malignant Disease Registry which was established in 1968[5] and for the north west region from the Manchester Children's Tumour Registry, established in 1953.[6] Both registries have a high level of case ascertainment, estimated at greater than 98%, and there is extensive cross checking with other data sources. All cases have central pathological review. The 15–24 year old cases from the northern and north western regions were obtained from the relevant regional cancer registries. The registries contribute their data to the national cancer registration system. Ascertainment is thought to be in the region of 94% for all ages but is likely to be better for younger people.[7] All cases from 0–24 years for the two Mersey districts were ascertained from the Mersey Regional Cancer Registry.

Patients included were all those with malignant disease receiving their first treatment, or having the diagnosis confirmed if no treatment given, before their 25th birthday. Those with benign or borderline intracranial or intraspinal neoplasms were included but carcinoma in situ of the cervix was excluded. The National Health Service was reorganised in 1974 and regional administrative borders changed. The geographical boundaries of this study were therefore taken as those areas common to the pre-1974 Newcastle and Manchester Regional Hospital Boards and the present Northern and North Western Regional Health Authorities plus the Southport and South Sefton districts of the Mersey region (fig 1). The local authority administrative counties included in the study area were Greater Manchester, Tyne and Wear, Cleveland, Cumbria, Durham, Lancashire, and Northumberland. The first three are large metropolitan urban areas with predominantly heavy engineering and chemical industries while the latter four are largely rural. All patients whose 'usual place of residence' at the time of diagnosis was within this area were included. The definition of 'usual place of residence' used was that defined by the Office of Population Censuses and Surveys for regional cancer registries.

All cases were reviewed to confirm eligibility for the study. This included review of hospital notes and pathological material where this had not been previously seen. Checking of neighbouring health authorities' cancer registries was not carried out, so it is possible that some cases on the borders of the region may have been missed if they were incorrectly attributed. All cases registered by the end of 1987 were included in the analysis.

Cases were classified according to the morphology (M) and topography (T) codes of the International Classification of Diseases for Oncology (ICD-0), 1976.[8]

Table I Number of cases by registry, age group (y), and disease category

Diagnosis	Age groups (y) in Newcastle registry 0–14	Age groups (y) in Newcastle registry 15–24	Age groups (y) in Manchester registry 0–14	Age groups (y) in Manchester registry 15–24	Total
Acute lymphoblastic leukaimia	359	81	459	136	1035
Acute myeloid leukemia	66	59	83	103	311
Chronic myeloid leukaemia	7	13	13	24	57
Other leukaemia	4	9	9	15	37
Astrocytoma/glioma	156	108	192	122	578
Medulloblastoma	61	13	88	15	177
Ependymoma	30	14	48	16	108
Craniopharyngioma	19	17	19	12	67
Other brain	25	57	26	44	152
Osteosarcoma	40	40	44	61	185
Ewing's sarcoma	22	26	27	34	109
Other bone	3	11	7	17	38
Non-Hodgkin's lymphoma	76	73	95	117	361
Hodgkin's lymphoma	56	285	72	353	766
Wilms' tumour	71	–	94	14	179
Neuroblastoma	71	4	100	6	181
Ganglioneuroblastoma	5	1	2	–	8
Retinoblastoma	48	–	41	–	89
Rhabdomyosarcoma	54	11	57	20	142
Other soft tissue sarcoma	20	51	21	71	163
Hepatoblastoma	7	3	10	1	21
Germ cell tumours	31	111	63	198	403
Miscellaneous	104	440	191	784	1519
Total	1335	1427	1761	2163	6686

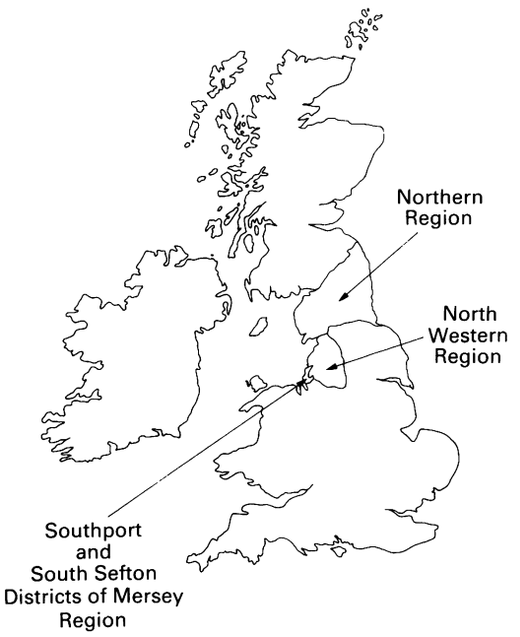

Table II Poisson probability ranking: all cancers, 1981 census population data

Ward name	Numbers P	Numbers C	Statistics Rate*	Statistics Probability
Aged 0–24 y, 1968–85:				
Kendal Fell, South Lakeland, Cumbria	526	7	5·8	·0002610
Central Bolton, Greater Manchester	4698	24	2·2	·0003544
Prudhoe South, Tynedale, Northumberland	1374	11	3·5	·0004430
John O'Gaunt, Lancaster, Lancashire	2347	15	2·8	·0004881
Beswick, Manchester, Greater Manchester	3492	19	2·4	·0006681
Aged 0–14 y, 1968–85:				
Seascale, Copeland, Cumbria	411	6	6·9	·0002804
Easterside, Middlesbrough, Cleveland	1021	8	3·7	·0017235
No 6. Sedgefield, Durham	600	6	4·7	·0019432
Kendall Fell, South Lakeland, Cumbria	267	4	7·1	·0026720
Prudhoe South, Tynedale, Northumberland	676	6	4·2	·0034776
Aged 15–24 y, 1968–85:				
Central, Bolton, Greater Manchester	1914	15	2·6	·0009149
Longhorsley, Castle Morpeth, Northumberland	169	4	7·9	·0018409
No 6, Salford, Greater Manchester	2735	18	2·2	·0020805
Newcastle upon Tyne (Moorside), Newcastle upon Tyne	1479	12	2·7	·0021456
Newcastle upon Tyne (Jesmond), Newcastle upon Tyne	1655	12	2·4	·0051662
Aged 0–24 y, 1977–85:				
John O'Gaunt, Lancaster, Lancashire	2347	12	4·3	·0000330
St Mary's, South Ribble, Lancashire	1755	10	4·8	·0000608
Burnden, Bolton, Greater Manchester	5138	15	2·5	·0015159
Beswick, Manchester, Greater Manchester	3492	11	2·7	·0034839
Caton, Lancaster, Lancashire	1228	6	4·1	·0037404
Aged 0–14 y, 1977–85:				
Yarm, Stockton on Tees, Cleveland	1606	7	4·4	·0013252
Seaton De Laval, Blyth Valley, Northumberland	658	4	6·1	·0045591
Brownhill, Blackburn, Lancashire	1524	6	4·0	·0046886
Burnden, Bolton, Greater Manchester	2711	8	3·0	·0065803
Sandwith, Copeland, Cumbria	744	4	5·4	·0069707
Aged 15–24 y, 1977–85:				
John O'Gaunt, Lancaster, Lancashire	1125	9	4·8	·0001507
St Mary's, South Ribble, Lancashire	717	7	5·8	·0002481
Hulme, Manchester, Greater Manchester	2747	13	2·8	·0009568
Cramlington South East, Blyth Valley, Northumberland	752	6	4·8	·0018822
Walton Le Dale South, South Ribble, Lancashire	1327	8	3·6	·0020690

*Incidence rate ratio; P=population; C=cases

The location of each case at the time of diagnosis was coded by allocating them an Ordnance Survey eight figure grid reference. For the early years of the Manchester Children's Tumour Registry this had already been done directly for a previous study. For the remainder it was achieved by giving each case a postcode and converting this to a grid reference using a computerised matching table supplied by the Post Office (1988 edition). Where there was no clear match, a grid reference was derived by direct inspection of a large scale map of the area. The grid references were then used to allocate each case to the appropriate census ward via a 'point in polygon' procedure.

Table III Poisson probability ranking: all cancers, 1971 census population data

Ward name	*Numbers* P	C	*Statistics* Rate*	Probability
Aged 0–24 y, 1968–85:				
Birch Green, West Lancashire, Lancashire	16	4	118·1	·0000001
Parkside, Blyth Valley, Northumberland	184	6	15·4	·0000035
St Mary's, South Ribble, Lancashire	1305	11	4·0	·0001458
Yarm, Stockton on Tees, Cleveland	1182	10	4·0	·0002789
Shaw, Oldham, Greater Manchester	2174	14	3·0	·0003134
Aged 0–14 y, 1968–85:				
Parkside, Blyth Valley, Northumberland	103	5	27·8	·0000014
Birch Green, West Lancashire, Lancashire	8	2	143·0	·0000970
Yarm, Stockton on Tees, Cleveland	807	8	5·7	·0001125
Shaw, Oldham, Greater Manchester	1381	10	4·1	·0002117
Hemlington, Middlesbrough, Cleveland	22	2	52·0	·0007214
Aged 15–24 y, 1968–85:				
Birch Green, West Lancashire, Lancashire	8	2	77·2	·0003294
St Mary's, South Ribble, Lancashire	397	7	5·4	·0003766
Hulme, Manchester, Greater Manchester	1502	14	2·9	·0005337
Longhorsley, Castle Morpeth, Northumberland	123	4	10·0	·0007626
Walton Le Dale South, South Ribble, Lancashire	777	9	3·6	·0011866
Aged 0–24 y, 1968–76:				
Prudhoe South, Tynedale, Northumberland	1617	8	4·8	·0003417
Hutton, Langbaurgh, Cleveland	855	5	5·7	·0021468
Ormesby, Langbaurgh, Cleveland	1355	6	4·3	·0031711
Slaley & Hexamshire, Tynedale, Northumberland	314	3	9·3	·0044470
Central, Bolton, Greater Manchester	6040	14	2·2	·0049849
Aged 0–14 y, 1968–76:				
Prudhoe South Tynedale, Northumberland	907	5	6·0	·0017182
No 6, Sedgefield Durham	924	5	5·9	·0018614
Norwood, Sefton, Merseyside	2682	8	3·2	·0040087
Easterside, Middlesbrough, Cleveland	2162	7	3·5	·0044806
Ashton St Michael's, Tameside, Greater Manchester	2250	7	3·4	·0055307
Aged 15–24 y, 1968–76:				
Prudhoe South, Tynedale, Northumberland	710	5	4·9	·0039496
Clayton Le Moors, Hyndburn, Lancashire	766	5	4·6	·0054093
Great Moor, Stockport, Greater Manchester	1835	8	3·0	·0057235
Central Bolton, Greater Manchester	2323	9	2·7	·0073331
Cheadle, Stockport, Greater Manchester	1560	7	3·1	·0081389

*Incidence rate ratio

Table IV Poisson probability ranking: acute lymphoblastic leukaemia, 1981 census population data

Ward name	*Numbers* P	C	*Statistics* Rate*	Probability
Aged 0–24 y, 1968–85:				
Seascale, Copeland, Cumbria	750	4	14·0	·0002223
Broughton, South Lakeland, Cumbria	773	3	10·2	·0034311
Whittingham, Alnwick, Northumberland	266	2	19·7	·0048128
Egremont North, Copeland, Cumbria	1941	4	5·4	·0069789
No1, Sedgefield, Durham	2138	4	4·9	·0096901
Aged 0–14 y, 1968–85:				
Seascale, Copeland, Cumbria	411	4	17·5	·0000953
Broughton, South Lakeland, Cumbria	451	3	11·9	·0021909
Whittingham, Alnwick, Northumberland	143	2	25·1	·0030085
Orrell, Sefton, Merseyside	2716	6	4·0	·0046392
No 1. Sedgefield, Durham	1208	4	5·9	·0050165
Aged 15–24 y, 1968–85:				
No 5. Salford, Greater Manchester	2104	3	9·0	·0048437
Great Moor. Stockport, Greater Manchester	2299	3	8·2	·0061767
Derby, Bolton, Greater Manchester	2612	3	7·2	·0087338
No 6. Salford, Greater Manchester	2735	3	6·9	·0098841
No 6. North Tyneside, Tyne and Wear (Percy)	1129	2	11·2	·0142637
Aged 0–24 y, 1977–85:				
Meols, Sefton, Merseyside	3821	4	5·9	·0051221
Gosforth No1. Newcastle upon Tyne, Tyne and Wear	3911	4	5·8	·0055524
No 1. Sedgefield, Durham	2138	3	7·9	·0068348
Broughton, South Lakeland, Cumbria	773	2	14·6	·0085624
Newtown, Stockton on Tees, Cleveland	2538	3	6·7	·0108540
Aged 0–14 y, 1977–85:				
Gosforth No 1. Newcastle upon Tyne, Tyne and Wear	2010	4	7·8	·0018870
Meols, Sefton, Merseyside	2300	4	6·8	·0030536
No 1. Sedgefield, Durham	1208	3	9·8	·0038296
Broughton, South Lakeland, Cumbria	451	2	17·5	·0060789
No 8. North Tyneside, Tyne and Wear (Carville, Hadrian)	1445	3	8·2	·0062704
Aged 15–24 y, 1977–85:				
No 5. Salford Greater Manchester	2104	3	17·6	·0007288
No 6. Salford, Greater Manchester	2735	3	13·5	·0015412
Unsworth, Bury, Greater Manchester	1576	2	15·6	·0075036
Milfield, Berwick upon Tweed, Northumberland	167	1	73·8	·0134516
Longhorsley, Castle Morpeth, Northumberland	169	1	73·0	·0136116

*Incidence rate ratio

REFERENCE POPULATION STATISTICS

The population data used were those derived from the 1971 and 1981 censuses. The data for small areas were obtained from the 1981 census using SASPAC, a software package which is made available to all universities for academic use. For the 1971 census, the data were obtained from a complete set of census tapes purchased by the Economic and Social Research Council's North East Regional Research Laboratory at the University of Newcastle upon Tyne. The age specific population data for the whole study area were identified for both census wards and enumeration districts. The latter is the smallest area for which aggregated population data are available and corresponds to the area covered by one census enumerator. The census wards and enumeration districts as defined for 1971 and 1981 are not geographically identical. Census tracts are areas which are of similar size to wards and designed to be geographically identical in both censuses. Although the mean population of census tracts and wards is similar, however, there is a much larger standard deviation for tracts. A single geographical unit therefore had to be defined for the present study and this was taken as the 1981 census ward rather than the tract. Ward population counts from the 1981 census were obtained directly from SASPAC. The 1971 census data were allocated to 1981 census wards by obtaining population counts for 1971 enumeration districts. The grid reference of the 1971 enumeration district was then used to allocate the population count to the appropriate 1981 census ward using a point in polygon procedure. The enumeration district data were then summated to produce the 1971 population counts within 1981 census ward boundaries. There were 1272 census wards in the study area at the 1981 census. The population aged under 25 years at the 1981 census ranged from 131 to 17 547 per census ward, and for the 1971 census from 0 to 10 625. The total population aged 0–24 years in the study region at the 1981 census was 2 686 983, and at the 1971 census it was 2 915 058.

CANCER RANKING TABLES

The Black report recommended that census wards should be ranked by relative incidence rate and Poisson probability values, and this has been carried out for all major cancer types using different population bases—that is, 1971 or 1981 census and different time periods, either the whole 18 years or the periods 1968–76 and 1977–85. The data were also examined using the age categorisation 0–14 years, 15–24 years, or 0–24 years. As acute lymphoblastic leukaemia and non-Hodgkins lymphoma were the main focus of interest of the Black report, results are presented for these disease categories separately and combined. Also included in this report are 'all cancer' combined and 'all brain tumours', the latter being the largest disease category after acute lym-

phoblastic leukaemia. 'All brain tumours' includes most intracranial tumours although some, for example intracranial germ cell malignancies—are coded elsewhere. The ICD-0 M codes included in the data presented here are acute lymphoblastic leukaemia: 9820–9822 + 9824 + 9850; non-Hodgkins lymphoma: 9590–9642 + 9690–9698; all brain tumours: 9350–9481; and all cancers: 8000–9999.

The cancer incidence in each ward was calculated by conventional methods as the standardised incidence rate and standarised rate ratio relative to the whole regional rate—that is, using the whole study area.

Ethical permission for the study was received from the appropriate authorities in the study areas.

Table V Poisson probability ranking: acute lymphoblastic leukaemia 1971 census population data

Ward name	Numbers P	Numbers C	Statistics Rate*	Statistics Probability
Aged 0–24 y, 1968–85:				
Seascale, Copeland, Cumbria	860	4	13·2	·0002739
Shaw, Oldham, Greater Manchester	2174	5	6·5	·0011574
Egremont North, Copeland, Cumbria	1492	4	7·6	·0020823
Broughton, South Lakeland, Cumbria	820	3	10·4	·0032232
Whittingham, Alnwick, Northumberland	292	2	19·5	·0049237
Aged 0–14 y, 1968–85:				
Seascale, Copeland, Cumbria	605	4	14·3	·0002041
Shaw, Oldham, Greater Manchester	1381	5	7·8	·0005215
Broughton, South Lakeland, Cumbria	525	3	12·4	·0019888
Whittingham, Alnwick, Northumberland	182	2	23·8	·0033475
Birch Green, West Lancashire, Lancashire	8	1	270·4	·0036917
Aged 15–24 y, 1968–85:				
No 5, Salford, Greater Manchester	1647	3	10·6	·0030320
Great Moor, Stockport, Greater Manchester	1835	3	9·5	·0040947
Derby, Bolton, Greater Manchester	2255	3	7·8	·0072069
Castle, Tynedale, Northumberland	100	1	58·4	·0169808
Newton, Stockton on Tees, Cleveland	1222	2	9·6	·0190720
Aged 0–24 y, 1968–76:				
Seascale, Copeland, Cumbria	860	3	18·5	·0006275
Whittingham, Alnwick, Northumberland	292	2	36·4	·0014578
Pendleside, Pendle, Lancashire	393	2	27·0	·0026076
Egremont, North, Copeland, Cumbria	1492	3	10·7	·0029996
Greatmoor. Stockport, Greater Manchester	5261	5	5·0	·0035210
Aged 0–14 y, 1968–76:				
Seascale, Copeland, Cumbria	605	3	19·7	·0005242
Whittingham, Alnwick, Northumberland	182	2	43·7	·0010164
Pendleside, Pendle, Lancashire	257	2	30·9	·0020015
Shaw, Oldham, Greater Manchester	1381	3	8·6	·0053960
No 14. Salford, Greater Manchester	2970	4	5·4	·0071948
Aged 15–24 y, 1968–76:				
Great Moor, Stockport, Greater Manchester	1835	3	19·5	·0005397
Blundell Sands, Sefton, Merseyside	1499	2	15·9	·0072544
Castle, Tynedale, Northumberland	100	1	119·4	·0083422
Hedgeley, Alnwick, Northumberland	127	1	94·0	·0105826
Miles Platting, Manchester, Greater Manchester	2051	2	11·6	·0131737

*Incidence rate ratio

Table VI Poisson probability ranking: non-Hodgkins lymphoma, 1981 census population data

Ward name	Numbers P	Numbers C	Statistics Rate*	Statistics Probability
Aged 0–24 y, 1968–85:				
Besses, Bury, Greater Manchester	3869	4	8·3	·0015385
Kendal Fell, South Lakeland, Cumbria	526	2	30·5	·0020586
Seascale, Copeland, Cumbria	750	2	21·4	·0041085
Penrith South, Eden, Cumbria	783	2	20·5	·0044659
No 23. Sunderland, Tyne and Wear (Houghton No 2)	3488	3	6·9	·0099277
Aged 0–14 y, 1968–85:				
Kendall Fell, South Lakeland, Cumbria	267	2	65·4	·0004582
Seascale, Copeland, Cumbria	411	2	42·5	·0010739
No 23. Sunderland, Tyne and Wear (Houghton No 2)	1944	3	13·5	·0015584
Davenport, Stockport, Greater Manchester	2374	3	11·0	·0027365
Fairfield, Stockton on Tees, Cleveland	976	2	17·9	·0058019
Aged 15–24 y, 1968–85:				
Penrith South, Eden, Cumbria	347	2	35·9	·0014938
Derby, West Lancashire, Lancashire	894	2	13·9	·0093567
Barclay, Burnley, Lancashire	922	2	13·5	·0099226
Beechwood, Middlesbrough, Cleveland	982	2	12·7	·0111849
Grove Hill, Middlesbrough, Cleveland	1044	2	11·9	·0125594
Aged 0–24 y, 1977–85:				
Kendall Fell, South Lakeland, Cumbria	526	2	61·2	·0005229
Seascale, Copeland, Cumbria	750	2	42·9	·0010532
Grove Hill, Middlesbrough, Cleveland	2294	2	14·0	·0092476
Teesville, Langbaurgh, Cleveland	2672	2	12·0	·0123538
No 2. Salford, Greater Manchester	3265	2	9·9	·0180048
Aged 0–14 y, 1977–85:				
Kendall Fell, South Lakeland, Cumbria	267	2	137·9	·0001042
Seascale, Copeland, Cumbria	411	2	89·6	·0002456
Teesville, Langbaurgh, Cleveland	1400	2	26·3	·0027496
Middleton Central, Rochdale, Greater Manchester	2432	2	15·1	·0079956
Arkholme, Lancaster, Lancashire	301	1	61·2	·0162187
Aged 15–24 y, 1977–85:				
Grove Hill, Middlesbrough, Cleveland	1044	2	22·2	·0038206
No 3. Gateshead, Tyne and Wear, Claxton	1212	2	19·1	·0051000
Walton Le Dale South, South Ribble, Lancashire	1327	2	17·5	·0060738
Dunkinfield, Tameside, Greater Manchester	1686	2	13·8	·0096065
Bredbury, Stockport, Greater Manchester	1880	2	12·3	·0118136

*Incidence rate ratio

Results

A total of 6686 cases of cancer in 0–24 year olds were eligible for the analysis. The tumour types and distribution by age and registry of origin are shown in table I. The cases from the two Mersey districts are included in the Manchester registry figures. The standardised incidence rate and standardised rate ratio for all cancers, acute lymphoblastic leukaemia, non-Hodgkin's lymphoma, and all brain tumours showed no significant variation between the seven administrative counties included in the study area. The top five ranked census wards for the analyses described above are shown in tables II–XI. As the census ward of Seascale has been the major focus of previous attention, the cases occurring there are listed in table XII along with the relevant population data.

Discussion

The apparent excess of leukaemia and lymphoma in young people in the village of Seascale was first highlighted by Yorkshire Television, and has subsequently been confirmed by others.[9 10] The proximity to the large nuclear fuel reprocessing plant at Sellafield has led to an enormous focus of attention on the area and attempts to link the apparent increased risk of lymphoid malignancy to radiation discharges or some other factor associated with the plant. The finding of increases in incidence of leukaemia around other nuclear establishments in the UK[11 12] has heightened speculation about a causal relation. The purpose of the present study was not to explore this possibility, which has been considered by others,[4] but to determine whether the incidences of acute lymphoblastic leukaemia and non-Hodgkin's lymphoma in Seascale remain unusual when put into a wider context. The wider context taken for this study when compared with that presented to the Black committee, has been both geographical, to include the north western and part of the Mersey regions as well as the northern health region; temporal, extending the time period to 1985; has increased the age of cases considered to 24 years; and has considered all cancers as well as subtypes. Many reports of the excess of leukaemia around Sellafield have included cases occurring in both the 1950s and 1960s. There were no comprehensive cancer registrations at either a national or local level for this period and it is only by the most intensive scrutiny of a relatively small area that the cases in west Cumbria have been identified. Without similar intensive study to ascertain cases in the rest of the study region it would be scientifically unsound to extend the period of the present study retrospectively to before 1968. Although comprehensive data do exist from 1953 for the north

west region, prospective data collection did not start in the northern region until 1968. Identical case ascertainment methods have been used for the whole study region since 1968, and no additional eligible cases not already recorded in either the Newcastle or Manchester registries have been identified by the investigations of others.

Table VII Poisson probability ranking: non-Hodgkins lymphoma 1971 census population data

	Numbers		Statistics	
Ward name	*P*	*C*	*Rate**	*Probability*
Aged 0–24 y, 1968–85:				
Besses, Bury, Greater Manchester	4259	4	8·2	·0016218
Seascale, Copeland, Cumbria	860	2	20·2	·0045737
Penrith South, Eden, Cumbria	882	2	19·7	·0048026
Kendal Fell, South Lakeland, Cumbria	959	2	18·1	·0056447
No 23. Sunderland, Tyne and Wear (Houghton No 2)	3780	3	6·9	·0098991
Aged 0–14 y, 1968–85:				
Kendal Fell, South Lakeland, Cumbria	530	2	39·7	·0012276
No 23. Sunderland, Tyne and Wear (Hougton No 2)	2358	3	13·4	·0015887
Seascale, Copeland, Cumbria	605	2	34·8	·0015921
Davenport, Stockport, Greater Manchester	2651	3	11·9	·0022114
Fairfield, Stockton on Tees, Cleveland	1385	2	15·2	·0079444
Aged 15–24 y, 1968–85:				
Penrith South Eden, Cumbria	281	2	41·1	·0011457
Barclay, Burnley, Lancashire	706	2	16·4	·0068882
Walton le Dale South, South Ribble, Lancashire	777	2	14·9	·0082760
Derby, West Lancashire, Lancashire	833	2	13·9	·0094513
Beechwood, Middlesbrough, Cleveland	885	2	13·1	·0106051
Aged 0–24 y, 1968–85:				
Besses, Bury, Greater Manchester	4259	3	12·2	·0020526
Faifield, Stockton on Tees, Cleveland	2112	2	16·4	·0068331
No 4. Salford, Greater Manchester	2913	2	11·9	·0126099
Middleton East, Rochdale, Greater Manchester	2982	2	11·6	·0131798
Newcomen, Langbaurgh, Cleveland	3004	2	11·6	·0133639
Aged 0–14 y, 1968–76:				
Fairfield, Stockton on Tees, Cleveland	1385	2	28·9	·0022882
St Matthew's, Preston, Lancashire	2188	2	18·3	·0055610
No 23. Sunderland, Tyne and Wear (Houghton No 2)	2358	2	17·0	·0064226
Davenport, Stockport, Greater Manchester	2651	2	15·1	·0080398
Slaley & Hexhamshire, Tynedale, Northumerland	194	1	103·1	·0096494
Aged 15–24 y, 1968–76:				
Beechwood, Middlesbrough, Cleveland	885	2	28·2	·0023939
Newcomen, Langbaurgh, Cleveland	979	2	25·5	·0029149
No 4. Salford, Greater Manchester	1099	2	22·7	·0036500
Redvales, Bury, Greater Manchester	1712	2	14·6	·0085750
Edgeley, Stockport, Greater Manchester	2231	2	11·2	·0141696

*Incidence rate ratio

Table VIII Poisson probability ranking: all brain tumours 1981 census population data

	Numbers		Statistics	
Ward name	*P*	*C*	*Rate**	*Probability*
Aged 0–24 y, 1968–85:				
Ashton St Michael's, Tameside, Greater Manchester	3889	7	5·8	·0002564
No 9, North Tyneside, Tyne and Wear Howden	3095	5	5·2	·0030602
Alexandra, Oldham, Greater Manchester	5334	6	3·6	·0070020
Northgate North, Darlington, Durham	1386	3	7·0	·0095821
Kendall Fell, South Lakeland, Cumbria	526	2	12·3	·0119076
Aged 0–14 y, 1968–85:				
Ashton St Michael's, Tameside, Greater Manchester	2179	7	8·6	·0000235
Northgate North, Darlington, Durham	723	3	11·1	·0027018
Kendall Fell, South Lakeland, Cumbria	267	2	20·0	·0046752
Reedley, Pendle, Lancashire	935	3	8·6	·0055109
No 1. Salford, Greater Manchester	2064	4	5·2	·0080728
Aged 15–24 y, 1968–85:				
No 9. North Tyneside, Tyne and Wear (Howdon)	1451	4	10·9	·0005633
Pharos, Wyre, Lancashire	497	2	15·9	·0072606
Norden, Hyndburn, Lancashire	497	2	15·9	·0072606
No 14. Gateshead, Tyne and Wear (Felling Central & North)	1572	3	7·5	·0077857
Carleton, Wyre, Lancashire	546	2	14·5	·0086916
Aged 0–24 y, 1977–85:				
Cribden, Rossendale, Lancashire	2007	3	9·6	·0039944
Overton, Hyndburn, Lancashire	2194	3	8·8	·0051077
No 7. Salford, Greater Manchester	2410	3	8·0	·0066047
North Lodge, Chester le Street, Durham	801	2	16·1	·0071150
Brownhill, Blackburn, Lancashire	2567	3	7·5	·0078397
Aged 0–14 y, 1977–85:				
Brownhill, Blackburn, Lancashire	1524	3	11·2	·0026364
North Reddish, Stockport, Greater Manchester	3479	4	6·5	·0036118
Wampool, Allerdale, Cumbria	604	2	18·8	·0052691
No 1. Salford, Greater Manchester	2064	3	8·3	·0061055
Ince, Wigan, Greater Manchester	2141	3	8·0	·0067470
Aged 15–24 y, 1977–85:				
Newburn No 1 (Denton), Newcastle upon Tyne	1721	3	12·3	·0020068
Pharos, Wyre, Lancashire	497	2	28·4	·0023594
Carleton, Wyre, Lancashire	546	2	25·9	·0028346
Normanby, Langbaurgh, Cleveland	699	2	20·2	·0045796
No 4. Sedgefield, Durham	877	2	16·1	·0070901

*Incidence rate ratio

Table XII shows that the occurrence of acute lymphoblastic leukaemia and non-Hodgkin's lymphoma in young people in Seascale is not evenly distributed across time. Most cases of acute lymphoblastic leukaemia are in the first period of the study (1968–76) and most of the non-Hodgkin's lymphoma cases are in the second (1977–85). The age distribution is also uneven. The position of Seascale in the cancer ranking tables will clearly be dependent on both the time period and age range used. This study has shown that Seascale remains the ward most highly ranked by Poisson probability for acute lymphoblastic leukaemia incidence but only for either the whole time period of 1968–85 or the earlier period of 1968–76. Seascale, for obvious reasons (only one case) does not figure among the top ranked wards if the later time period of 1977–85 or only the older age group of 15–24 year olds are considered. For non-Hodgkin's lymphoma Seascale is highly, but not highest, ranked for the time periods and age categories relevant to the occurrence of the cases. Combining acute lymphoblastic leukaemia and non-Hodgkin's lymphoma, the results in Seascale become even more extreme for some of the analyses.

The justification for combining acute lymphoblastic leukaemia and non-Hodgkin's lymphoma is that both are lymphoid malignancies and that in the past there may have been difficulty in distinguishing the two. They may well both originate from a common stem cell and may share common aetiological factors.[13]

In the wider context of other disease types, Seascale is not the most highly ranked and does not have an excess of other cancers. By virtue of the cases of acute lymphoblastic leukaemia and non-Hodgkin's lymphoma, it does appear among the most highly ranked for *all cancers*, but for only one of the analyses was it top ranked. The absolute Poisson probabilities achieved by other disease categories can also be considered. The most extreme Poisson probability for any of the individual disease categories was that seen for all brain tumors in Ashton St Michael's, (p=0·000009) an urban ward in Tameside, Greater Manchester. That of p=0·000001 for Birch Green in table III is almost certainly artefactual. It can therefore be seen that while Seascale remains unusual for acute lymphoblastic leukaemia when particular time periods and age categories are used, it is at least matched by other wards for other diseases and time periods. It is recognised, however, that it is difficult to attatch real significance to the absolute Poisson probability figure because of the problem of multiple significance testing. For a study such as this, the rank position of a ward is probably more important than the absolute Poisson probability value.

It can be concluded therefore that the incidences of acute lymphoblastic leukaemia and non-Hodgkin's lymphoma in Seascale ward remain unusual when put into a wider context. This finding is, however, restricted to an earlier time period and younger age range. There has only been one case of acute lymphoblastic leukaemia in Seascale in the past 20 years. If the time period 1972–89 were considered, the expected number of cases from 0–24 years would be 0·3 and the observed has been 1.

This report has concentrated on the ward of Seascale as has much of the other research in the wake of the Black report. The original allegations in the Yorkshire Television programme were, however, related to a larger geographical area of west Cumbria. The study presented here does not give any suggestion of an increase in the number of highly ranked wards in west Cumbria, apart from Seascale. The whole question of using arbitrary administrative boundaries, however, is one that has engendered considerable research activity over the past few years. Openshaw has devised a Geographical Analysis Machine[14] using a search technique dependent on covering a study area with overlapping circles of various sizes, calculating the rate of disease occurrence in all of the circles and identifying those where the rate is unusual. When used on the same data set as that included in the present study the Geographical Analysis Machine identifies an excess in Seascale but also in other areas distant from Seascale where there seem to be similar or even greater excesses.[14] Other methods developed include those of Besag and Newell,[15] Bithell and Stone,[16] and Cuzick and Edwards.[17]

Table IX Poisson probability ranking: all brain tumours 1971 census population data

Ward name	Numbers P	Numbers C	Statistics Rate*	Statistics Probability
Aged 0–24 y, 1968–85:				
Ashton St Michael's, Tameside, Greater Manchester	3746	7	6·5	·0001252
Carleton, Wyre, Lancashire	963	3	10·9	·0028200
No 9. North Tyneside, Tyne and Wear (Howdon)	3421	5	5·1	·0033108
Birch Green, West Lancashire, Lancashire	16	1	219·0	·0045562
Alexandra, Oldham, Greater Manchester	5625	6	3·7	·0061371
Aged 0–14 y, 1968–85:				
Ashton St Michael's, Tameside, Greater Manchester	2250	7	10·0	·0000088
Birch Green, West Lancashire, Lancashire	8	1	402·3	·0024829
Northgate North, Darlington, Durham	850	3	11·4	·0025228
Reedley, Pendle, Lancashire	926	3	10·4	·0032053
Healey, Rochdale, Greater Manchester	2250	4	5·7	·0057304
Aged 15–24 y, 1968–85:				
No 9. North Tyneside, Tyne and Wear (Howden)	1498	4	9·8	·0008390
No 4. Sedgefield, Durham	185	2	39·6	·0012308
Carleton, Wyre, Lancashire	328	2	22·4	·0037702
Norden, Hyndburn, Lancashire	421	2	17·4	·0061080
No 14, Gateshead, Tyne and Wear (Felling Central & North)	1387	3	7·9	·0068112
Aged 0–24 y, 1968–76:				
Ashton St Michael's, Tameside, Greater Manchester	3746	5	9·4	·0002312
No 4. Wear Valley, Durham	2340	3	9·0	·0048096
Spotland, Rochdale, Greater Manchester	2678	3	7·9	·0069584
Kendal Fell, South Lakeland, Cumbria	959	2	14·6	·0085135
No 5. North Tyneside, Tyne and Wear (Linskill)	3158	3	6·7	·0108526
Aged 0–14 y, 1968–76:				
Ashton St Michael's, Tameside, Greater Manchester	2250	5	13·5	·0000427
Spotland, Rochdale, Greater manchester	1676	3	10·9	·0028498
Kendal Fell, South Lakeland, Cumbria	530	2	22·9	·0035914
Healey, Rochdale, Greater Manchester	2250	3	8·1	·0064309
Broadheath, Trafford, Greater Manchester	2511	3	7·3	·0086607
Aged 15–24 y, 1968–76:				
No 14. Gateshead, Tyne and Wear (Felling Central & North)	1387	3	18·0	·0006798
Norden, Hyndburn, Lancashire	421	2	39·6	·0012354
Brookfield, Middlesbrough, Cleveland	818	2	20·4	·0045190
No 6. South Tyneside, Tyne and Wear (Horsley Hill)	1085	2	15·4	·0077840
No 9. North Tyneside, Tyne and Wear (Howden)	1498	2	11·1	·0143614

*Incidence rate ratio

Table X Poisson probability ranking: acute lymphoblastic leukaemia and non-Hodgkins lymphoma, 1981 census population data

Ward name	Numbers P	Numbers C	Statistics Rate*	Statistics Probability
Aged 0–24 y, 1968–85:				
Seascale, Copeland, Cumbria	750	6	15·8	·0000030
No 1. Sedgefield, Durham	2138	5	4·6	·0050656
John O'Gaunt, Lancaster, Lancashire	2347	5	4·2	·0074138
Broughton, South Lakeland, Cumbria	773	3	7·7	·0074504
Whittingham, Alnwick, Northumberland	266	2	14·9	·0082777
Aged 0–14 y, 1968–85:				
Seascale, Copeland, Cumbria	411	6	21·7	·0000005
No 1. Sedgefield, Durham	1208	5	6·2	·0014992
Broughton, South Lakeland, Cumbria	451	3	9·9	·0036956
Whittingham, Alnwick, Northumberland	143	2	20·8	·0043260
Fairfield, Stockton on Tees, Cleveland	976	4	6·1	·0045785
Aged 15–24 y, 1968–85:				
Longhorsley, Castle Morpeth, Northumerland	169	2	37·2	·0013963
Derby, Bolton, Greater Manchester	2612	5	6·0	·0016686
Grove Hill, Middlesbrough, Cleveland	1044	3	9·0	·0047785
Penrith South, Eden, Cumbria	347	2	18·1	·0056700
No 4. Salford, Greater Manchester	1201	3	7·8	·0070120
Aged 0–24 y, 1977–85:				
Seascale, Copeland, Cumbria	750	3	16·7	·0008427
Gosforth No 1. Newcastle upon Tyne, Tyne and Wear	3911	5	5·3	·0027685
Longhorsley, Castle Morpeth, Northumberland	346	2	24·2	·0032443
Kendal Fell, South Lakeland, Cumbria	526	2	15·9	·0072876
Meols, Sefton Merseyside	3821	4	4·4	·0141806
Aged 0–14 y, 1977–85:				
Seascale, Copeland, Cumbria	411	3	23·7	·0003084
Gosforth No 1, Newcastle upon Tyne, Tyne and Wear	2010	5	8·1	·0004560
Kendal Fell, South Lakeland, Cumbria	267	2	24·3	·0032072
Heaton Moor, Stockport, Greater Manchester	2098	4	6·2	·0043709
Meols, Sefton, Merseyside	2300	4	5·6	·0060137
Aged 15–24 y, 1977–85:				
Longhorsley, Castle Morpeth, Northumberland	169	2	70·7	·0003926
No 20. North Tyneside, Tyne and Wear (Camperdown)	2723	4	8·8	·0012518
No 5. Salford, Greater Manchester	2104	3	8·5	·0056018
Derby, Bolton, Greater Manchester	2612	3	6·9	·0100688
No 6. Salford, Greater Manchester	2735	3	6·6	·0113863

*Incidence rate ratio

The Black report's recommendation 4 included analysis by place of birth as well as by place of diagnosis. To comply with this an attempt was made to obtain the birth certificates for all of the cases who had cancer diagnosed before their 15th birthday. There is increasing evidence that events occurring around the time of conception, pregnancy, or birth may be important in the aetiology of acute lymphoblastic leukaemia[13] and the suggestion was that using only the place of residence at diagnosis would dilute any possible early environmental factor. It was thought unlikely, however, that this would influence the analysis for the older cases. Birth certificates were therefore obtained for 69% of the 0–14 year olds in the present study. Although almost 50% of cases had moved house between birth and diagnosis, most had moved only 5 km or less. The original intention had been to produce ranking tables based on place of birth. This would have been rendered uninterpretable, however, because the registration data included only patients who were diagnosed while living in the study area and would have excluded cases born in the area who moved to another part of the country and developed cancer while living there. The Seascale birth cohort study[2] has shown that this does occur and the only solution is the national birth cohort study of acute lymphoblastic leukaemia and non-Hodgkin's lymphoma using the data held by the Childhood Cancer Research Group in Oxford.

An additional problem encountered in studies of this type is the imbalance between the accuracy of numerator and denominator data. While the cases can be located to a single point in time, the reference population data are only available at two time points, 10 years apart. Any particular case may therefore be allocated to a population which is up to five years out of date. The basic locational unit used in the present study was the enumeration district and more detailed data other than those obtained at the census are not available for such small areas. Inter-census Office of Population Censuses and Surveys estimates are available at a regional and district level, but are not available for smaller areas. It was felt inappropriate to use anything other than fixed, definitive populations and that attempts at extrapolation between the 1971 and 1981 populations for small areas would be fraught with inaccuracies. An average could be taken of the 1971 and 1981 populations for wards as defined in this study but there is no guarantee that this would be any more accurate. Any excess

which survives the analysis using either the 1971 or 1981 data is probably of importance. The most extreme ranking of Birch Green in table III using the 1971 census data, but the whole time period for cancer occurrence with Birch Green's complete absence from the top ranked wards using the 1981 population indicates that large population changes have occurred and the extreme result is spurious.

It can be seen from the ranking tables that the excess in Seascale is apparent using either the 1971 or 1981 census data, suggesting that the excess is robust and not the result of large population changes.

This study has confirmed the apparent excess of lymphoid malignancy is Seascale when put into a wider context as suggested by the Black report. Other even more extreme examples, however, are seen in other wards. Caution is needed in the interpretation of these findings—some may be real and others may be artificial resulting from inadequate population data.

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Table XI Poisson probability ranking: acute lymphoblastic leukaemia and non-Hodgkins lymphoma, 1971 census population data

	Numbers		*Statistics*	
Ward name	*P*	*C*	*Rate**	*Probability*
Aged 0–24 y, 1968–85:				
Seascale, Copeland, Cumbria	860	6	15·0	·0000041
Shaw, Oldham, Greater Manchester	2174	5	4·9	·0038713
No 1. Sedgefield, Durham	2221	2	4·8	·0042324
Egremont North, Copeland, Cumbria	1492	4	5·8	·0056286
Broughton, South Lakeland, Cumbria	820	3	7·8	·0070098
Aged 0–14 y, 1968–85:				
Seascale, Copeland, Cumbria	605	6	17·8	·0000015
No 1. Sedgefield, Durham	1371	5	6·5	·0011558
Shaw, Oldham, Greater Manchester	1381	5	6·5	·0011931
Broughton, South Lakeland, Cumbria	525	3	10·3	·0033590
Birch Green, West Lancashire, Lancashire	8	1	224·3	·0044492
Aged 15–24 y, 1968–85:				
Longhorsley, Castle Morpeth, Northumberland	123	2	47·3	·0008676
Derby, Bolton, Greater Manchester	2255	5	6·5	·0012256
No 20. North Tyneside, Tyne and Wear (Camperdown)	1579	4	7·4	·0023452
Howletch, Easington, Durham	261	2	22·3	·0037858
Pentrith South, Eden, Cumbria	281	2	20·7	·0043683
Aged 0–24 y, 1968–76:				
Seascale, Copeland, Cumbria	605	3	14·2	·0013419
Whittingham, Alnwick, Northumberland	292	2	27·9	·0024522
Pendleside, Pendle, Lancashire	393	2	20·7	·0043697
Alston, Ribble Valley, Lancashire	1431	3	8·5	·0055732
No 4. Salford, Greater Manchester	2913	4	5·6	·0062046
Aged 0–14 y, 1968–76:				
Seascale, Copeland, Cumbria	605	3	16·4	·0008829
Whittingham, Alnwick, Northumberland	182	2	36·4	·0014517
Alston, Ribble Valley, Lancashire	868	3	11·5	·0024584
Prudhoe South, Tynedale, Northumberland	907	3	11·0	·0027806
Pendleside, Pendle, Lancashire	257	2	25·8	·0028516
Aged 15–24 y, 1968–76:				
No 4. Salford, Greater Manchester	1099	3	16·8	·0008365
Great Moor, Stockport, Greater Manchester	1835	3	10·0	·0035630
Beechwood, Middlesbrough, Cleveland	885	2	13·9	·0094440
Newcomen, Langbaurgh, Cleveland	979	2	12·5	·0114409
Castle, Tynedale, Northumberland	100	1	61·4	·0161570

*Incidence ratio rate

Table XII Cases of acute lymphoblastic leukaemia (ALL) and non-Hodgkins lymphoma (NHL) that occurred in Seascale between 1968 and July 1990 and population

Year of diagnosis	*Age at diagnosis (y)*	*Diagnosis*
1968	11	ALL
1968	4	ALL
1971	3	ALL
1979	5	ALL
1983	9	NHL
1984	1	NHL
1988*	23	NHL

	Population of Seascale		
Census year	*Age 0–14 y*	*Age 15–24 y*	*Total*
1971	605	255	860
1981	411	339	750

*Not included in present report.

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