Evidence of Excess Bone Cancer in the Vicinity of U.S. and U.K. Nuclear Installations

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Abstract
U.S. Mortality data were examined in counties containing or adjacent to nuclear installations, and in matched comparison counties before and after initiating operations. The data allowed us to look for excess of cancer and in various age groups. RESULTS: We found for bone and joint cancer at ages 10-19 and 2039 that observed mortality exceeded expected based on U.S. data for eight out of nine sets of counties including or adjacent to Department of Energy facilities. The facilities were those involved in nuclear research, fabrication, armaments and reprocessing. When the data for these counties were compared with data for comparable counties not near such installations, bone and joint cancer was significantly more frequently greater in the proximity counties than in the comparison ones. In five of the installations with cancer mortality prior to startup, observed was greater than expected in three in each age group, 10-19 and 20-39, which is about what could be expected. Data for comparable sites in the U.K., are not based on the same age strata, but suggest similar effects in 1976-1980. A similar pattern for 1976-1980 is found for morbidity in the UK. Since radiation can cause bone tumors, the findings have biological validity, and justify a case-referent study of exposures for cases of bone and joint cancer in young persons living near nuclear installations.

Introduction

Great interest was generated following the disclosure in 1986 by British Independent Television of the occurrence of excess morbidity and mortality for childhood leukemia in the vicinity of the British nuclear facility at Sellafield. [1,2,5,13] Subsequent studies have revealed that, such excesses as occurred at Sellafield, were related to children born there, and not to those who immigrated into the community, [6,7] and secondly, there were other locations in the U.K. with excess rates of childhood leukemia in the vicinity of planned and developed nuclear installations. [4,9] Gardner et al. showed that the Sellafield excess occurred principally among children whose fathers were employed at the Sellafield plant and who had elevat ed radiation exposures. [8]

Data from the United States, were based on mortality in counties including or adjacent to a nuclear installation, and comparison counties, before and after activation of the nuclear operations. These data of Jablon et al. [10] failed to show any excess of childhood leukemia, but they included data for many other types of cancer and at various ages, which we have examined. Suggestive associations were observed for bone and joint cancer at ages 10-19 and 20-39, as presented below. Comparisons are made with the US data, and also with that for counties thought to be similar but without proximity to such installations, cchosen by Jablon et al..

Bone and joint cancer has a peak of mortality at age 15-19, (Figure 1). Osteogenic sarcoma has been reported to have been in creased among those exposed to fallout radiation in Utah, [11] and to thorotrast or radium. [12,13,14], Such an association is there fore biologically plausible.

The data were from counties including or adjacent to Department of Energy Nuclear

Facilities, and for comparison counties felt to be otherwise similar, during the periods of time after operations had commenced. For each geographical area, the numbers of cases and the age-adjusted SMR are given, using the U.S. Mortality data as a basis for expectation. In Tables 1 and 2, we divide the observed numbers of cases by the SMR (divided by 100) and obtain the expected numbers. Tables show Observed/Expected where possible. In a few cases, where 0 cases were observed, no SMR is given and expected numbers can in some circumstances be obtained by difference, in which case these numbers are given in parentheses.

Results

Of the 10 possible facilities and two age periods, of 10-19 and 20-39, at least one bone or joint cancer death was reported during the relevant time period and age group in 18, Table 1. In sixteen of these, the Observed exceeds the Expected, that is the SMR is greater than 1.0, the exceptions being one with 36 observed deaths and 36.4 expected, SMR of 0.99 and one with 1 death, with an expected number of 1.9, SMR of 0.54. Even in these two cases, the Obs/Exp ratio is higher in the counties containing the facilities than in the comparison counties.

Figure 2 A shows the data for each site for the 10-19 year olds and Figure 2 B shows data for 20-39 year olds by site. The symbols for each site are in the Appendix. Figure 3 shows the data for the Relative Risk based on the Comparison Counties for each site and both both age groups.

The observed numbers of deaths in the age group 10-19 is 144, 24 deaths(20%) more than expected. For those aged 20-39 the observed number is 118 deaths, about 28 deaths(29%) over the 91.2 deaths expected. In the comparison counties expected cancer exceeds observed in age groups 10-19 and 20-39. Children age 0-9 in the counties with or adjacent to installations have less bone and joint cancer than expected. No excess is found for residents of counties or adjacent to nuclear power installations, shown in the „All Electric Utilities" line at the bottom of Table 1.

We now look at the experience before startup, what there is of it. Only for five installations are any data available, Table 2. There does seem to be some excess in three of the five sets of data for both of the age groups of interest. This is about what would be expected. We find a total of 7 deaths observed, compared to 4.8 expected for those age 10-19 and 6, compared to 4.5 expected for those 20-39. These results are not significant, but the ratios are not much different from the 78/68.8 for 10-19 year olds and 67/50.7 for these same installations after startup.

In the U.K., microfiche prepared by the Office of Population Censuses and Surveys [15] contain data for the age group 0-24. We examine these data for bone cancer for locations in which at least 1/3 of the population of the area live within 10 miles of the installation (Table 3). Data for regional mortality were used to es timate the SMR, and observed and expected mortality figures are tabulated for the time periods of 1959-1965, 1966-1975, and 1976-1980. Excesses are found for the most receent period. Here there are 29 deaths with 18.8 expected, a SMR of 154.3, with a Poisson p = 0.017.

As with the U.S. study, the locations are seven sites involving nuclear weapons, nuclear technology, reprocessing, nuclear reagents, and nuclear fuel.

British data include incidence based on a National Cancer Registry. Incidence data shows 40 incident cases in the set of 7 sites for the period 1976-1980, compared to 31.2 expected; in the comparison areas 28 cases are reported compared to 30.8 expected.

Thus the excess incidence appears to be 28% for the recent time period and the mortality excess 54%. As with the mortality data the earlier incidence data does not show any excess, and for the period of 1961-1980 the excess is not statistically significant.

Discussion

Jablon et al present the distributions of the Relative Risks for a number of sites and types of cancer. None of them have the extreme distribution as does the data for bone and joint cancer at ages 10-39.

The evidence of a possible relationship of parental exposure to childhood leukemia raises the question as to whether other conditions may be associated with parental exposures in nuclear facilities. Bone tumors would be a plausible answer. This possibility was emphasized by the recent review of parental exposures to radiation and childhood cancer in the Oxford Survey of Childhood Cancers study by Sorahan and Roberts. [16] They found that while the relative risk for all childhood cancer of paternal exposure to external radiation in the six months prior to conception was about unity, the risk ratio was 2.87 for radionuclide exposure. ($p< 0.05$)

The U.S. data including as it does many sites and age groups, could readily produce some results with apparently significant increases by purely random processes. However, the data for bone cancer at ages 10-19 and 20-39 are consistent and outside of the remainder of the distribution of observed to expected values for other sites of cancer. The findings at the particular ages and time periods are consistent with the usual views as to latency for solid tumors, on the assumption of a perinatal exposure. Somewhat against the hypothesis of the association being causal in the U.S. is the finding of the very scant data on increased bone and joint cancer at some sites prior to plant operations. To have three sites with observed greater than expected is well within expectation, however, and none of the findings for prior to operations comes near to being statistially significant.

These data are consistent with there being excess risk of bone and joint cancer among populations in the U.S. and probably also in the U.K. living adjacent to active nuclear installations. Whether this may have some relationship to exposure at or from the workplace is yet to be determined. The association is not greater than an overall 50% increase, but unlike the data for childhood leukemia, it seems to occur in the U.S., and at least in recent years in the U.K. as well.

We feel that there is therefore sufficient evidence to justify case-referent studies of osteogenic sarcoma among young persons residing near nuclear installations.

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Figure 1:
Bone Cancer Mortality, U.S., Whites 1950-1969 by age and sex. Per 100,000 population

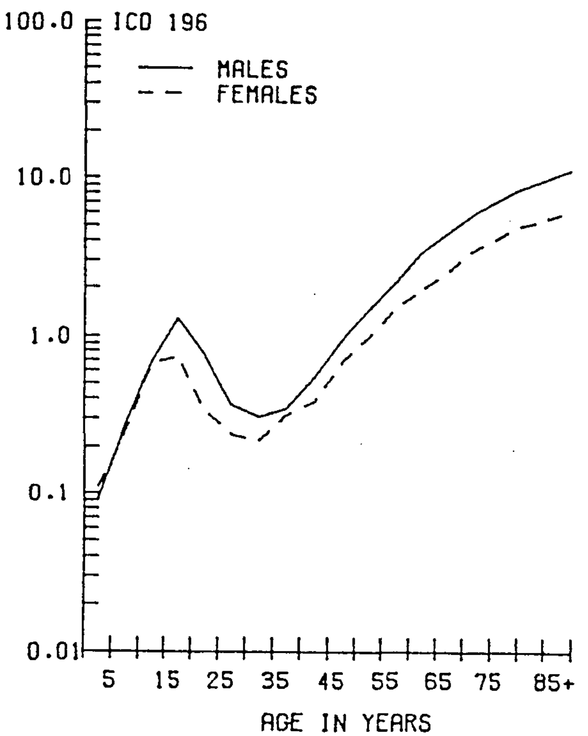
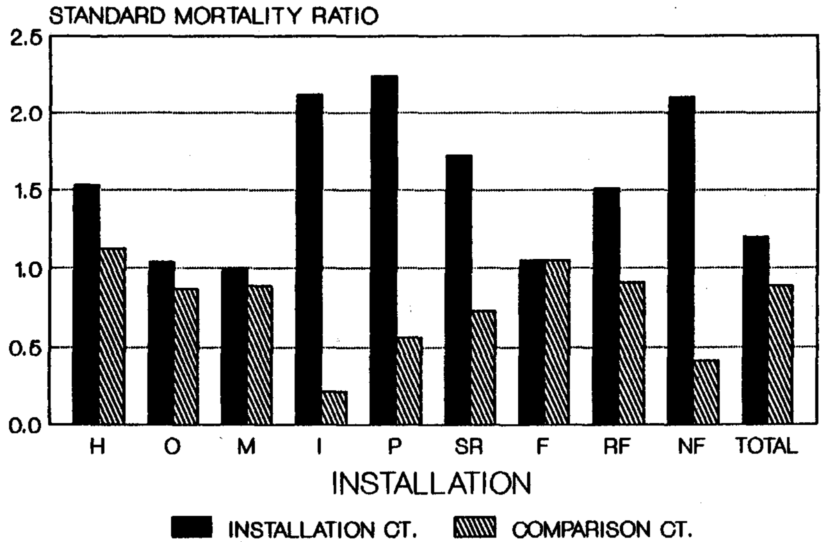
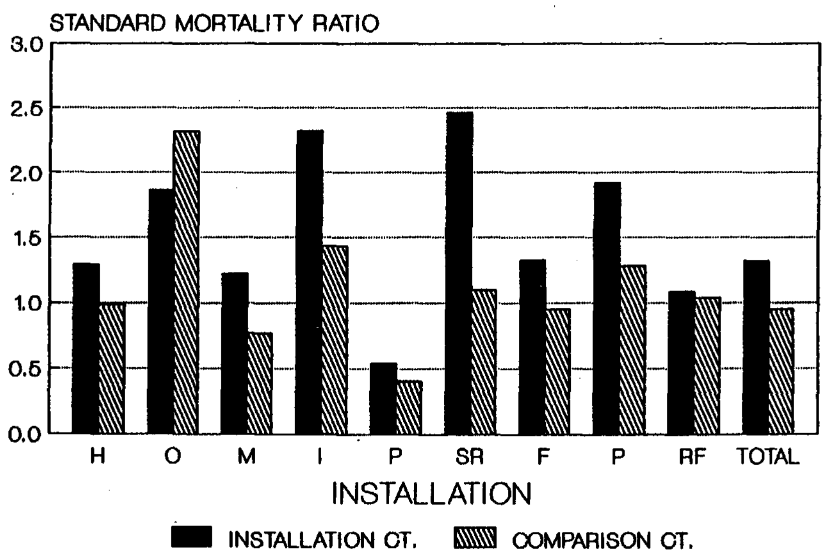


Figure 2a:
Deaths from Bone and Joint Cancer, U.S. Nuclear Installation Counties and Others



SMR for AGE 10-19 YEARS

Figure 2b:
Deaths from Bone and Joint Cancer, U.S. Nuclear Installation Counties and Others



SMR for AGE 20-29 YEARS

Figure 3:
Relative Risks for Bone and Joint Cancer Nuclear Facility Counties and Comparison Counties, after Facility Start-Up, U.S.

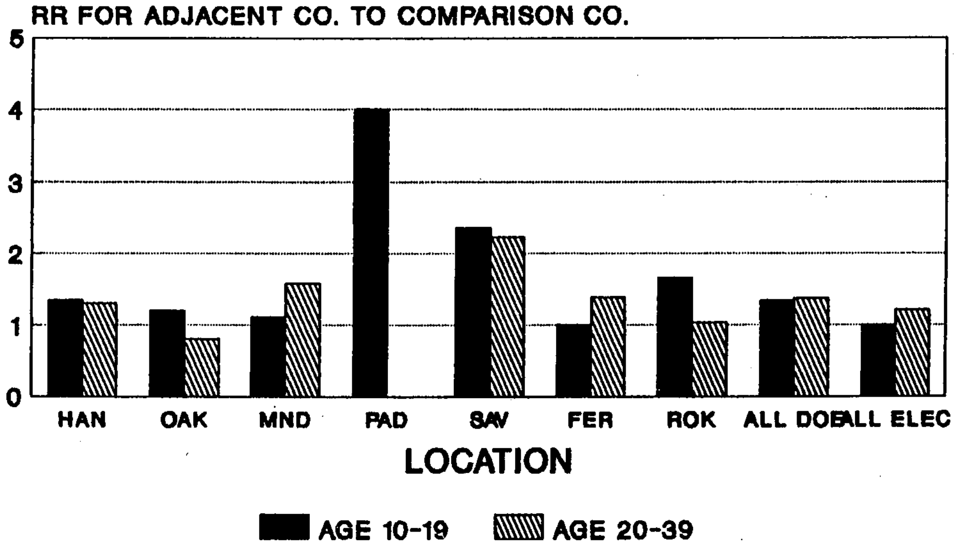


Table 1: Bone and joint cancer at early ages
U.S. counties including or adjacent to nuclear facilities and for comparison counties by facility after startup ovserved and expected numbers based on U.S. data

Observed/Expected

	COUNTIES INCLUDING OR ADJACENT			COMPARISON COUNTIES		
	AGES			AGES		
	0-9	10-19	20-29	0-9	10-19	20-39
HANFORD	3/1.4	13/6.5	6/4.7	7/5.3	31/27.4	19/19.2
OAKRIDGE	1/1.0	5/4.8	6/3.2	1/2.1	10/11.5	19/8.2
MOUND	4/7.3	36/36.4	35/28.7	17/14.2	62/69.7	39/50.7
INEL	0/(0.7)*	5/2.4	3/1.3	1/1.0	1/4.8	4/2.8
PADUCAH	0/(0.7)	6/2.7	1/0.9	1/2.9	9/16.1	5/12.5
SAVANNAH	0/(0.7)	10/5.8	9/3.7	3/2.7	11/15.1	11/10.0
FERNALD	4/8.5	46/43.8	44/33.3	12/9.4	54/51.3	40/42.1
PORTSMOUTH	0/(0.7)	0/(1.1)	1/0.5	0/(0.9)	0/(1.7)	2/1.6
ROCKY FLATS	1/2.4	22/14.6	13/12.0	1/2.0	11/12.1	11/10.6
NFS	0/(0.7)	4/1.9	0/(0.3)	0/(0.9)	2/4.9	3/3.1
ALL DOE	13/23.2	144/120.0	118/90.18	43/41.4	191/214.6	153/161.7
"Positive" (Locations Obs>Exp)	1/10	8/9	8/9	4/8	2/9	5/10
ALL ELECTRIC UTILITIES:	3/1.9	13/14.3	16/15.9	5/4.4	33/34.4	30/35.3

* Expected values in brackets ( ) obtained by subtraction

Table 2: Deaths from bone and joint cancer in U.S. counties including or adjoining nuclear installations and in comparison counties before and after start of operations by age group and with observed (OBS) and expected (EXP) deaths based on U.S. data

	BEFORE STARTUP*		AFTER STARTUP	
AGE	ADJACENT OBS/EXP	COMPARISON OBS/EXP	ADJACENT OBS/EXP	COMPARISON OBS/EXP
0-9	1/1.3	1/2.2	5/12.9	17/17.97
10-19	7/4.8	10/8.3	78/68.8	87/99.5
20-29	6/4.5	7/7.0	67/50.7	70/78.3

* Data includes that from Paducah, Savannah River, Fernald, Rocky Flats, and NFS. None of the other sites had data from before the starting.

Sites with observed cases greater than expected, including sites with 0 observed in the denominator.

10-19	3/5	2/5	5/5	1/5
20-29	3/5	3/5	3/5	2/5

Table 3: Observed and expexted* mortality from bone and joint cancer in local authority areas (LAAs) of the U.K. with at least 1/3 of the population living within 10 miles of nuclear installations, and in comparable areas not near nuclear installations, age 0-24, 1959-65, 1966-1975 and 1976-1980

Observed/Expected

LOCATIONS	AREAS NEAR INSTALLATIONS			AREAS NOT NEAR INSTALLATIONS		
	1959-65	1966-75	1976-80	1959-65	1966-75	1976-80
SELLAFIELD	2/1.2	2/1.0	1/0.7	1/0.8	3/1.0	0
SPRINGFIELDS	1/6.1	5/9.4	3/2.7	8/6.6	12/10.3	2/3.1
CAPENHURST	4/7.1	9/10.1	7/4.6	2/7.4	10/10.5	6/4.6
AMERSHAM	8/7.2	7/10.8	10/6.2	3/6.6	9/11.0	8/6.8
ALDERMASTON	4/3.4	6/5.7	5/3.5	4/3.7	5/5.6	5/3.0
HARWELL	1/1.3	1/2.0	3/1.2	1/1.2	3/2.9	1/1.1
WINFRITH	0	2	0	0	0	2
(We are not able to compute the expected deaths due to the small numbers of observed and frequency of zero deaths. For the whole period 1959-1980, in LAAs near facilities 2 deaths observed and 4.0 expected, compared to 2/4.2 for the comparison areas.)						
TOTAL	20/26.2	30/39.0	29/18.8	19/26.2	42/41.2	22/18.5
(Excluding Winfrith)						

* Expected deaths based on regional data

Appendix
Lists of locations of counties containing or adjancet to facilities and abbreviations used in tables and charts in this article

Table 1:

Hanford	Hanford, Washington (Benton, Franklin and Grant Counties)
Oakridge	Oakridge, Tennessee (Anderson and Roan Counties)
Mound	Mound, Ohio (Butler, Montgomery and Warren Counties)
INEL	Idaho National Engineering Laboratory, Idaho (Bingham, Butte, and Jefferson Counties)
Paducah	Paducah Gas Diffusion Facility, Kentucky (Ballard and McCracken Counties)
Savan. Riv.	Savannah River, South Carolina (Alken and Barwell, in South Carolina, Burke Co., Georgia)
Fernald	Fernald, Ohio (Butler and Hamilton Counties)
Portsmouth	Portsmouth Gas Diffusion Facility, Ohio (Pike County)
Rocky Fl.	Rocky Flats, Colorado (Boulder and Jefferson Counties)
Nucl. F.S.	Nuclear Fuel Services, New York (Cattaragus County)
DOE	Department of Energy. All DOE refers to all of the above facilities

In Table 3, dealing with data from the United Kingdom, the following abbreviations are used:

CAPEN	Capenhurst Facility of British Nuclear Fuels, plc (BNF)
ALDER	Aldermaston, British Ministry of Defense
SELLA	Sellafield Facility of BNFL
SPRING	Springfields Facility of BNFL
HARWEL	Harwell Facility of the U.K. Atomic Energy Authority (UKAEA)
AMERSH	Amersham Facility of Amersham Int. plc
WINFR	Winfrith Facility of UKAEA

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INS Referring to data from the Local Authority Areas in which at least 1/3 of the population lives within 10 miles of the installation

COM Referring to data from the Local Authority Areas in the same region as INS, with similar size, urbanization and social clas (when possible)

SMR Standard Mortality Ratio based on regional data; similarly with incidence (standard morbidity ratio) or SIR, standard incidence ratio