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Comparison of Documented and Recalled Histories of Exposure to Diagnostic X-rays in Case-Control Studies of Thyroid Cancer

Amy Berrington de Gonzalez[1], Anders Ekbom[2,3], Andrew G. Glass[4], Maria Rosaria Galanti[5], Lars Grimelius[2], Michael J. Allison[4], and Peter D. Inskip[6]

[1] Cancer Research UK Epidemiology Unit, University of Oxford, Oxford, United Kingdom.
[2] Department of Medical Epidemiology, Karolinska Institute, Stockholm, Sweden.
[3] Department of Epidemiology, Harvard School of Public Health, Boston, MA.
[4] Oncology Research, Kaiser Permanente Medical Care Program, Portland, OR.
[5] Centre for Tobacco Prevention, Stockholm, Sweden.
[6] Radiation Epidemiology Branch, Division of Cancer Epidemiology and Genetics, Department of Health and Human Services, National Cancer Institute, Bethesda, MD.

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Most information concerning possible cancer risks attributable to lifetime exposure to diagnostic x-rays comes from studies in which x-ray history was ascertained by interview or questionnaire, but little is known about the accuracy of such information. The authors assessed agreement between medical x-ray histories obtained through interview and by review of medical records from thyroid cancer case-control studies conducted in Sweden (1985–1992; 123 cases and 123 controls) and from members of a prepaid health plan in the United States (1986–1991; 50 cases and 50 controls). In both studies, substantial disagreement was found between the numbers of x-ray examinations reported in the interview and in the medical records. There was an indication of relatively poorer reporting among controls, particularly for certain types of x-ray examinations and for large numbers of such examinations. Estimates of the risk associated with exposure to diagnostic x-rays were similar, regardless of whether interview or medical record data were used, even though ordinal dose classifications based on the two sources differed considerably. In populations with a high frequency of exposure, spurious associations with numbers of x-ray examinations or estimated thyroid dose might arise because of differences in recall. However, in the present data, reporting errors by cases and controls seemed to be largely nondifferential.

interviews; medical records; radiography; recall; thyroid neoplasms

Studies of possible cancer risks attributable to a lifetime history of diagnostic x-rays have, for the most part, used a case-control design and have relied on interviews to assess exposure. Several retrospective cohort studies that investigated the risks associated with specific types of diagnostic x-ray examinations, such as fluoroscopy and spinal examinations, were able to base exposure information on medical records (1–3). However, with rare exceptions (4–7), prospectively recorded data about a lifetime history of diagnostic x-rays either are not available or cannot be collected within the constraints of available resources. Interpretation of results from interview studies hinges on the credibility of recalled histories of exposure to x-rays. Issues include whether cases and controls are equally good at remembering having had x-ray examinations, particularly those that occurred in childhood or the distant past, and whether they can correctly identify specific types of x-ray examinations and report when they occurred. More accurate reporting by cases would tend to inflate estimates of the true association, whereas equally inaccurate reporting by cases and controls would tend to dampen a true association.

Few validation studies have addressed the accuracy of recall of lifetime exposure to diagnostic x-rays. A case-control study of diagnostic x-rays and leukemia (8) found that the number of self-reported exposures to diagnostic x-rays was 74 percent lower than the number found in the medical records. The investigators did not assess whether the magnitude of the discrepancy differed between cases and controls.

Reprint requests to Dr. Peter D. Inskip, Radiation Epidemiology Branch, National Cancer Institute, Executive Plaza South, Room 7052, Bethesda, MD 20892 (e-mail: inskippe@mail.nih.gov).

TABLE 1. Demographic characteristics of cases and controls from the Swedish study (members of the Uppsala Health Care Region, 1985–1992) and the US study (members of the Kaiser Permanente Northwest Health Plan, 1986–1991)

Variable	Sweden				United States			
	Cases		Controls		Cases		Controls	
	No.	%	No.	%	No.	%	No.	%
Sex								
Male	27	22	27	22	8	16	8	16
Female	96	78	96	78	42	84	42	84
Year of birth								
1900–1909	0	0	0	0	2	4	2	4
1910–1919	6	5	7	6	8	16	9	18
1920–1929	16	13	15	12	10	20	8	16
1930–1939	28	23	28	23	6	12	7	14
1940–1949	32	26	32	26	13	26	13	26
1950–1959	27	22	27	22	7	14	8	16
1960–1969	10	8	10	8	4	8	3	6
1970–1979	4	3	4	3	0	0	0	0
Year of thyroid tumor diagnosis								
1985	21	17	NA*		0	0	NA	
1986	9	7	NA		5	10	NA	
1987	10	8	NA		1	3	NA	
1988	9	7	NA		11	22	NA	
1989	21	17	NA		12	24	NA	
1990	30	24	NA		10	20	NA	
1991	17	14	NA		11	22	NA	
1992	6	5	NA		0	0	NA	
Time in health plan (years)								
Mean	NA		NA		17.4		17.4	
Minimum	NA		NA		5.3		5.2	
Maximum	NA		NA		42.3		42.2	
Total	123	100	123	100	50	100	50	100

* NA, not applicable.

A few studies have also investigated the accuracy of reporting of specific types of diagnostic x-ray examinations. Two studies of prenatal exposure to diagnostic x-rays investigated the accuracy of mothers' reporting of abdominal and chest x-ray examinations received during pregnancy (9, 10). In both studies, at least 30 percent of the reported examinations could not be confirmed because the records had not survived. From the records available, no evidence was found of a difference in the accuracy of reporting between mothers of cases and of controls. A comparison of self-reported history of dental x-ray examinations with dental records indicated that both patients with salivary gland tumors and controls were equally likely to underreport dental x-ray examinations (11).

Characteristics of the health care system in Sweden afforded a rare opportunity to assemble lifetime histories of diagnostic x-ray examinations based on medical records. This opportunity was exploited in a case-control study of thyroid cancer and diagnostic x-rays (5). The study design also incorporated a telephone interview, in which recently diagnosed cases and their matched controls were asked how many times they had had x-ray examinations of specific types and when those examinations occurred. We supplemented the study in Sweden with a parallel study conducted among members of a large, prepaid health plan in the United States. In this paper, we compare x-ray histories based on interviews with those based on medical records for thyroid tumor cases and matched controls from both countries. Our goal was to assess the accuracy of recall by cases and controls and the sensitivity of estimates of the risk of cancer from lifetime diagnostic x-ray exposure to the method of exposure ascertainment used.

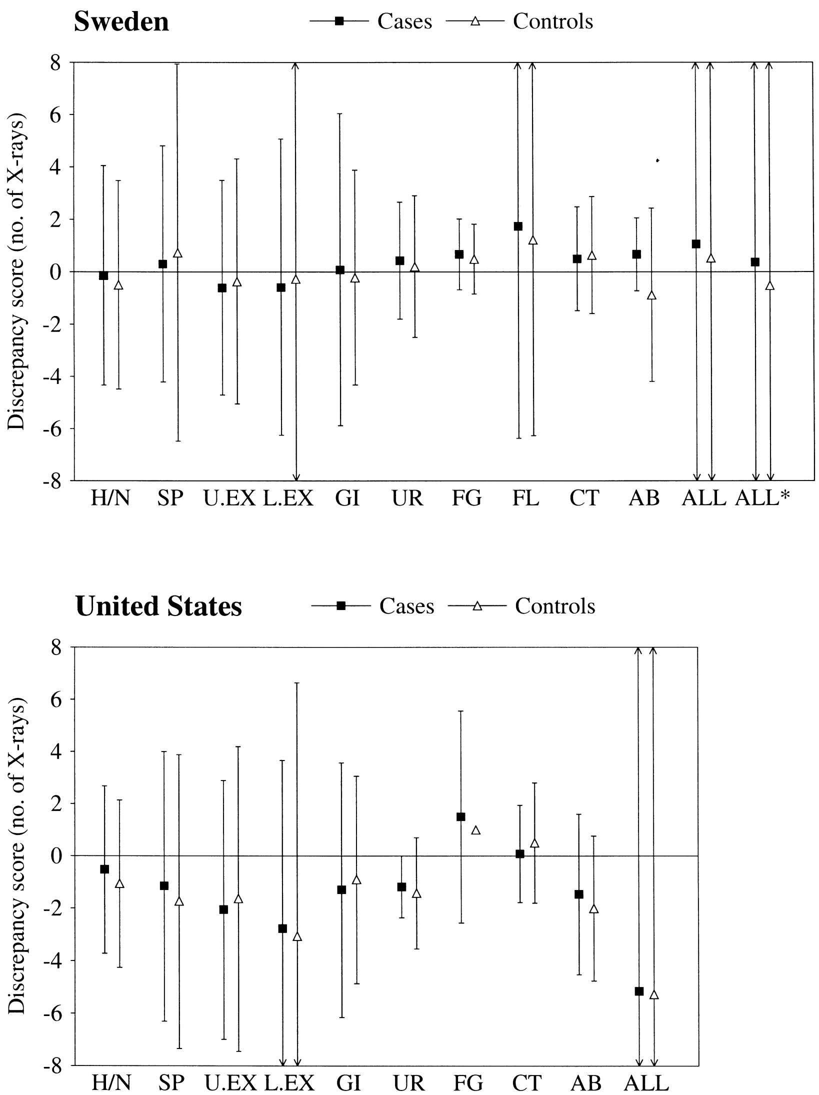

FIGURE 1. Mean discrepancy score (±1.96 × standard deviation), by type of x-ray procedure. Upper-panel: data based on the population of the Uppsala Health Care Region, Sweden, 1985–1992; lower-panel: data for members of the Kaiser Permanente Northwest Health Plan, United States, 1986–1991. Discrepancy score = the number of x-ray examinations reported in the interview minus the number found in medical records. H/N, head/neck; SP, spine; U.EX, upper extremities; L.EX, lower extremities; GI, gastrointestinal tract; UR, urinary tract; FG, female genital tract; FL, chest fluoroscopy; CT, computed tomography scan; AB, abdomen; ALL, all types; ALL*, all types excluding chest fluoroscopy.

MATERIALS AND METHODS

Study populations and identification of cases and controls

Sweden. The study in Sweden was restricted to Swedish citizens residing in the Uppsala Health Care Region who had not lived abroad for more than 5 years since birth. Cases of histologically confirmed papillary and follicular thyroid cancer were identified through the Swedish Cancer Registry for the years 1985–1989 and through the Uppsala Regional Cancer Registry for 1990–1992. A 1:1 sample of age- and sex-matched controls was randomly selected through the national Registry of the Total Population. Controls were required to have been alive and residing in the Uppsala Health Care Region when the matched case was diagnosed. The present analysis was based on the 123 matched pairs for whom interviews were completed. Of the cases, 101 were diagnosed with papillary and 22 with follicular thyroid cancer.

United States. The US study was conducted among members of Kaiser Permanente (Northwest Region) between 1986 and 1991 who had been members for at least 5 years. Kaiser Permanente is a large, prepaid health plan that has been operating since the 1940s. Computerized records of the Kaiser Permanente tumor registry were searched for cases of thyroid cancer or adenoma diagnosed between 1986 and 1991. Controls were identified through computer linkage with a file of all current and former Kaiser Permanente members and were matched to cases on age, sex, year of joining the health plan, and number of years in the health

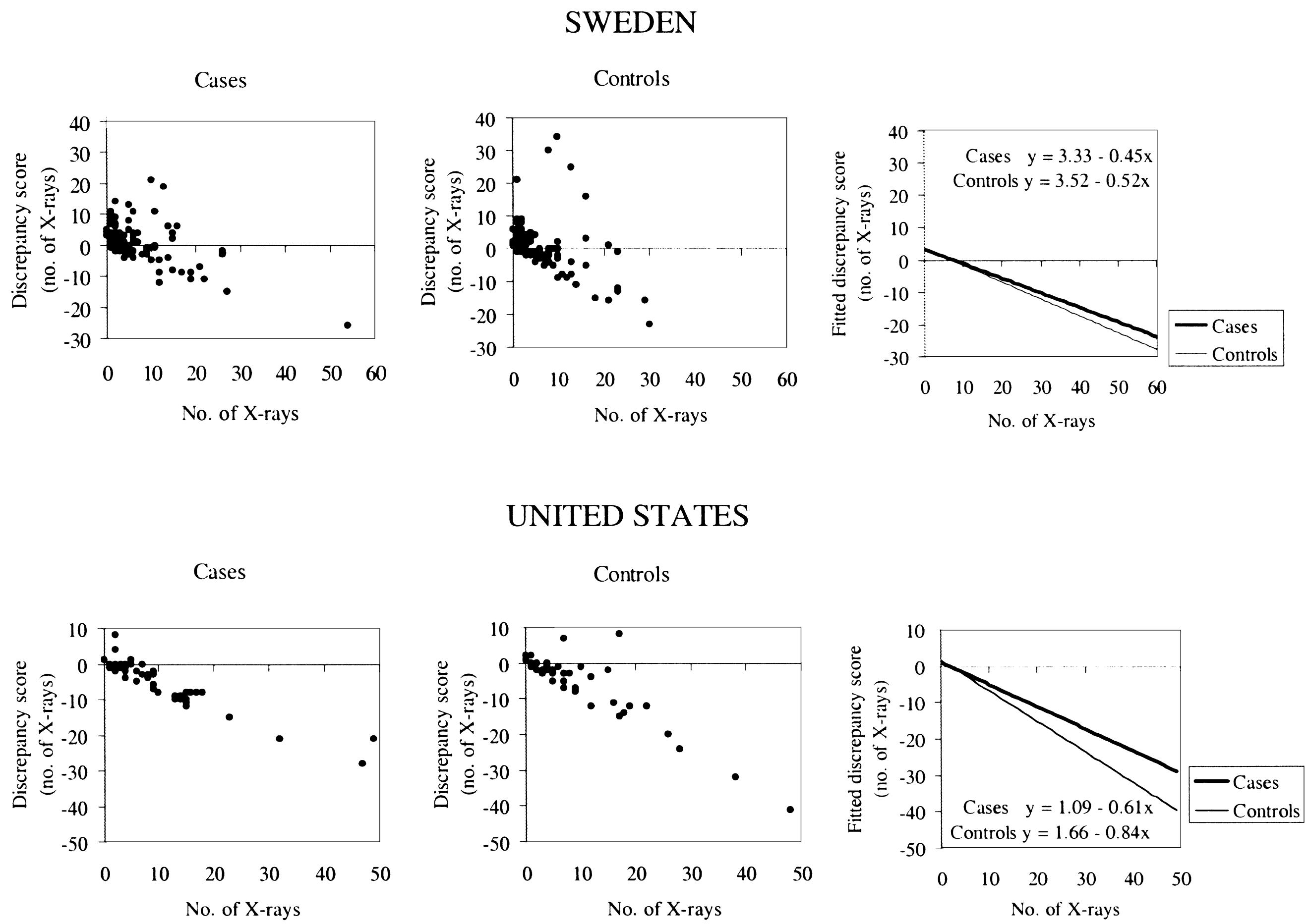

FIGURE 2. Relation between the discrepancy score (the number of x-ray examinations reported in the interview minus the number found in medical records) and the number of x-ray examinations of all types ascertained from medical records. Upper panels: data based on the population of the Uppsala Health Care Region, Sweden, 1985–1992; lower panels: data for members of the Kaiser Permanente Northwest Health Plan, United States, 1986–1991. The panels on the right show the fitted regression lines.

plan. No diagnosis of thyroid cancer or adenoma was noted in their Kaiser Permanente records. A total of 50 thyroid tumor cases (28 papillary carcinomas and 22 adenomas) and 50 matched controls were enrolled.

Ascertainment of x-ray examinations from medical records

Sweden. Costs of health care in Sweden are sufficiently low to permit universal access, and residents seek care at designated institutions. Except under emergency or other unusual circumstances, diagnostic x-ray examinations are performed in departments of radiology at community, county, or regional hospitals. A person's place of residence determines the hospital that he or she visits for usual care. There is a strong financial incentive for people to visit the designated hospital; otherwise, they face considerable out-of-pocket expenses. Nonemergency examinations performed elsewhere are conducted at outpatient clinics operated by county authorities and, very rarely, in private outpatient clinics. Ninety-five percent of all medical diagnostic x-ray examinations in Sweden reportedly were performed at facilities that were part of the public health care system (12). In departments of radiology, x-ray films are sorted by national registration number, a unique personal identifier assigned to all Swedish residents, and are stored indefinitely.

Lifetime residential histories were constructed for all cases and controls. An abstractor, equipped with a roster of all patients who had resided in a particular area, visited hospitals throughout the country and reviewed radiology and other medical records for the applicable time periods of residence. This approach to ascertaining x-ray histories was generally effective and unbiased, although it appears that certain screening examinations, such as mammograms and chest fluoroscopies, which were sometimes performed outside hospitals in mobile clinics, were underascertained (5).

United States. In the Northwest Kaiser Permanente Region, comprehensive medical and dental services are provided at two hospitals, 12 medical offices, and six dental offices. Kaiser Permanente members generally use Kaiser

TABLE 2. Frequencies of different types of x-ray examinations, based on interviews and medical records, for cases and controls from Sweden (members of the Uppsala Health Care Region, 1985–1992)

Examination	Cases (*n* = 123)						Controls (*n* = 123)					
	Interview			Medical record			Interview			Medical record		
	No. of subjects exposed	No. of examinations per exposed subject		No. of subjects exposed	No. of examinations per exposed subject		No. of subjects exposed	No. of examinations per exposed subject		No. of subjects exposed	No. of examinations per exposed subject	
		Mean	Maximum		Mean	Maximum		Mean	Maximum		Mean	Maximum
Orbits and eye sockets	1	1.0	1	0			2	2.0	3	1	1.0	1
Mandible/jaw	5	3.2	10	5	2.0	5	3	1.0	1	4	1.5	3
Nasal bones/sinuses	19	1.2	2	24	1.5	3	9	1.3	3	19	1.7	4
Other facial bones	2	1.0	1	3	1.3	2	0	0.0	0	2	3.0	4
Skull	11	1.2	2	6	1.3	2	9	1.0	1	10	1.0	1
Neck for soft tissues	11	1.7	5	19	1.3	5	3	1.7	2	2	1.0	1
Any head/neck*	40	1.8	10	62	1.7	12	22	1.5	4	47	1.7	7
Full spine	13	1.2	3	5	1.0	1	6	1.7	5	3	1.0	1
Cervical spine	11	1.4	2	14	1.1	2	6	2.2	5	10	1.4	3
Thoracic/dorsal spine	14	1.3	2	2	1.0	1	21	1.6	5	4	1.0	1
Thoracolumbar spine	15	1.5	3	7	1.3	3	14	1.5	5	6	1.2	2
Myelogram	5	1.2	2	1	3.0	3	7	1.4	2	1	2.0	2
Other spine	0			1	2.0	2	0			0		
Any spine/pelvis*	41	1.9	14	36	1.7	7	35	2.5	20	29	2.0	6
Clavicle	2	1.0	1	2	1.5	2	9	1.2	2	2	1.5	2
Shoulder/scapula	9	2.1	6	9	1.4	2	17	1.6	3	9	1.9	4
Humerus/elbow	38	1.3	4	28	3.2	10	41	1.7	7	38	3.0	13
Any arms/hands*	44	1.6	8	32	3.3	13	57	1.9	8	40	3.3	13
Hip/pelvis	15	1.1	2	15	2.3	7	16	2.4	20	10	2.3	4
Femur/knee	47	1.9	11	45	2.5	6	49	2.0	16	44	3.0	16
Any lower extremities*	55	1.9	12	47	3.1	9	57	2.4	30	47	3.3	16
Abdomen	2	1.0	1	8	1.0	1	3	1.0	3	8	1.9	5

Table continues

Permanente physicians and facilities for all of their medical care, except for some emergencies and instances of acute illness. All Kaiser Permanente members receive a unique health care record number when they enroll in the plan.

Kaiser Permanente has had its own radiology department since 1946. As of 1986, detailed computerized records have been kept on every x-ray examination performed by Kaiser Permanente. Details of all x-ray examinations received before 1986 were abstracted manually from the health records. No attempt was made to collect information on x-ray examinations received prior to Kaiser Permanente membership. Although Kaiser Permanente has a dental plan, relatively few cases and controls were members of the dental plan for more than several years; therefore, routine dental x-ray examinations were excluded from this analysis.

Telephone interview

Cases and controls were interviewed by telephone concerning their histories of exposure to medical diagnostic x-rays. The same person, who was not informed ahead of time whether the respondent was a case or a control, interviewed both members of a matched pair. A standard interview form and interviewer script were used. Apart from language translation, the same questionnaire was used for the US and Swedish components of the study. The only difference was that, for the US study, the respondent was asked to focus on diagnostic procedures received only while he or she was a member of the Kaiser Permanente health plan.

The interview began with the construction of a calendar of health-related events during the subject's lifetime, which was intended to aid in recalling conditions for which x-ray examinations might have been conducted and when they occurred. The interview was divided into sections concerning related groups of x-ray examinations. The respondent was asked whether he or she had ever had that procedure and, if so, how many times and in what year(s) or at what age(s). Because chest x-ray examinations and mammograms are very common, the respondents were asked

TABLE 2. Continued

Examination	Cases (*n* = 123)						Controls (*n* = 123)					
	Interview			Medical record			Interview			Medical record		
	No. of subjects exposed	No. of examinations per exposed subject		No. of subjects exposed	No. of examinations per exposed subject		No. of subjects exposed	No. of examinations per exposed subject		No. of subjects exposed	No. of examinations per exposed subject	
		Mean	Maximum		Mean	Maximum		Mean	Maximum		Mean	Maximum
Upper GI† tract series	23	2.6	15	24	2.4	13	20	1.5	4	17	1.8	6
Lower GI tract series	21	1.1	2	15	1.3	5	12	1.1	2	14	1.2	2
Colonoscopy	8	1.3	3	1	1.0	1	10	1.1	2	0		
Cholecystogram	27	1.4	5	21	1.9	6	15	1.1	2	17	1.1	2
Cholangiogram	2	1.5	2	9	1.0	1	3	1.3	2	5	1.8	3
ERCP†	0			2	1.0	1	1	1.0	1	0		
Any GI tract*	48	2.8	15	34	3.8	24	37	2.0	5	28	2.6	12
Intravenous pyelogram	26	1.3	3	14	1.6	4	20	1.9	12	16	2.1	11
Other urinary tract examination	3	1.0	1	1	1.0	1	1	1.0	1	1	1.0	1
Any urinary tract*	27	1.3	4	14	1.6	4	20	2.0	12	17	2.1	11
Pelvimetry	7	1.0	1	3	1.0	1	13	1.0	1	8	1.0	1
Hysterosalpingogram	8	1.1	2	4	1.0	1	6	1.0	1	2	1.0	1
Other pelvis	4	1.0	1	1	1.0	1	1	1.0	1	0		
Any female genital tract*	18	1.1	2	8	1.0	1	20	1.0	1	10	1.0	1
Computed tomography scan	17	1.1	2	6	1.5	3	9	1.4	3	5	1.2	2
MRI† scan	8	1.3	3	0			0			0		
Standard chest‡	68	3.3	53	78	3.7	15	50	2.1	25	60	4.0	39
Mammography	67	3.9	17	8	1.4	2	67	3.2	14	3	1.5	2
Chest fluoroscopy	95	3.1	29	48	2.6	7	94	2.7	36	54	2.4	11
Ribs	12	1.6	6	2	1.0	1	5	1.2	2	2	1.5	2
Any examination*,§	118	7.2	32	119	6.1	54	115	6.7	44	120	5.8	30

* Total in this category.
† GI, gastrointestinal; ERCP, endoscopic retrograde cholangiopancreatography; MRI, magnetic resonance imaging.
‡ No. of standard chest x-ray examinations in the interview data, estimated only crudely (refer to Materials and Methods in the text).
§ Excluding standard chest x-ray examinations.

to report only the estimated frequency of these exposures as a child and as an adult (if applicable).

Data analysis

Two main sets of analyses were undertaken. The first addressed the agreement between x-ray histories obtained from medical records and from interviews. The second concerned the possible effects of differences in accuracy of reporting on the estimated associations between thyroid cancer and x-rays. This analysis was conducted with only the Swedish data because the US study did not collect lifetime exposure histories.

Descriptive statistics were calculated for each of 32 x-ray examination sites or types, based on the interview and medical record data. These procedures were grouped, a priori, into the following categories: head and neck, spine and pelvis, upper extremities, lower extremities, abdomen, gastrointestinal tract, urinary tract and female genital tract, computed tomography scans, and magnetic resonance imaging scans. To compare the interview data with the records for chest x-ray examinations and mammograms, it was necessary to estimate the approximate total number of procedures on the basis of the age-specific frequencies reported in the interview.

The extent of agreement or disagreement between the two sources of information was assessed by calculating the difference (hereafter referred to as the "discrepancy score") between the number of exposures reported in the interview and the number found in the medical records (number per interview minus number per medical records) for each of the "types" of x-ray procedures and for all types combined, for each subject. If we assume that histories based on the medical records are the "gold standard" (i.e., 100 percent correct), a negative discrepancy score would imply underreporting in the interview, and a positive discrepancy score would imply overreporting of that x-ray procedure type. A

TABLE 3. Distribution of discrepancy scores,* according to type of procedure, in the Swedish study (members of the Uppsala Health Care Region, 1985–1992)†

Procedure type	Cases					Controls				
	0–0‡	No.§	Mean	SD	Minimum, maximum	0–0	No.	Mean	SD	Minimum, maximum
Head and neck	59	64	–0.14	2.14	–6, 10	85	38	–0.63	2.03	–7, 3
Spine	69	54	0.30	2.30	–6, 12	78	45	0.67	3.68	–4, 20
Upper extremities	67	56	–0.61	2.09	–7, 2	56	67	–0.40	2.39	–7, 5
Lower extremities	57	66	–0.59	2.89	–8, 9	54	69	–0.29	4.98	–15, 25
GI¶ tract	70	53	0.08	3.04	–14, 7	79	44	0.02	2.09	–9, 3
Urinary tract	93	30	0.43	1.14	–2, 4	97	26	0.15	1.38	–3, 4
Female genital tract	78	18	0.67	0.69	0, 2	75	21	0.48	0.68	–1, 1
Chest fluoroscopy	24	99	1.74	4.14	–4, 29	22	101	1.22	3.82	–10, 32
Computed tomography scans	105	18	0.50	1.04	–3, 1	112	11	0.64	1.29	–1, 3
Abdomen	114	9	-0.67	0.71	–1, 1	113	10	–1.20	1.69	–5, 1
All types	0	123	1.06	5.91	–26, 22	0	123	0.60	7.33	–23, 34
All types (excluding chest fluoroscopies)	8	115	0.37	5.76	–31, 19	4	119	–0.41	6.19	–25, 32

* Discrepancy score = the number of x-ray examinations reported in the interview minus the number of x-ray examinations reported in the medical records.

† Mean, standard deviation (SD), minimum, and maximum pertain to cases or controls for whom either the medical records or the interviews showed at least one procedure.

‡ 0–0, the number of subjects who had no x-ray examinations of that type according to both their medical records and interview.

§ No., number of exposed subjects based on medical records *or* interview.

¶ GI, gastrointestinal.

positive discrepancy score also might arise if x-ray examinations were missed in the medical record review.

The discrepancy score was treated as a continuous variable, and mean values were calculated for cases and controls. These calculations excluded persons for whom there was no mention in the medical records or the interview of the type of examination under consideration. The numbers of such "zero-zero" persons were reported separately. Analysis of covariance was used to test for differences in mean discrepancy score between the cases and controls, with adjustment for the total number of examinations of that type based on medical records. A product term was included to assess whether dependence of the discrepancy score on number of examinations of that type based on medical records differed between cases and controls.

The association between risk of thyroid cancer and exposure to diagnostic x-rays was evaluated separately for the interview and medical record data by using conditional logistic regression. Analysis was performed in terms of numbers of different types of procedures and estimated dose of radiation to the thyroid gland. For the former, examinations were divided into those that delivered relatively higher (>1 mGy), intermediate (0.05–1 mGy), or lower (<0.05 mGy) doses to the thyroid gland based on surveys of average thyroid doses in Sweden (13) and the United States (14). Higher-dose procedures included x-ray examinations of the head, neck, spine, and ribs as well as chest fluoroscopy. Although these surveys did not assign a high average dose to upper gastrointestinal examinations, the thyroid dose received from these procedures is variable and potentially high; therefore, we repeated the analysis by including these procedures in the higher-dose category. Odds ratios were calculated for the numbers of examinations in each relative dose grouping (categories: 0, 1–5, 6–10, and >10 procedures), and a linear test for trend was performed by using category as a continuous variable and excluding examinations performed within 5 years prior to the date of cancer diagnosis (or pseudodiagnosis). Subjects for whom years or numbers of exposures were unknown were excluded from these analyses.

Because radiation exposures to the thyroid gland early in life carry much higher risks than those received later (15), the same methods were applied for exposures received before and after age 21 years. Examinations also were divided by period of exposure (<1960, 1960–1969, and ≥1970) because doses received from diagnostic procedures decreased over time (16). By using dose estimates from the surveys cited above, we calculated a total thyroid dose for each study participant. Odds ratios were estimated for quartiles of dose defined by the distribution among controls, and evidence for a dose-response relation was tested by using dose category as a continuous variable.

The level of agreement between the ordinal dose classification based on medical record and interview data was estimated by using the weighted kappa statistic. Similar analyses were conducted to assess the agreement between the two data sources with respect to assignment of cases and controls into categories for number of x-ray examinations. All analyses were performed by using SAS statistical software (17).

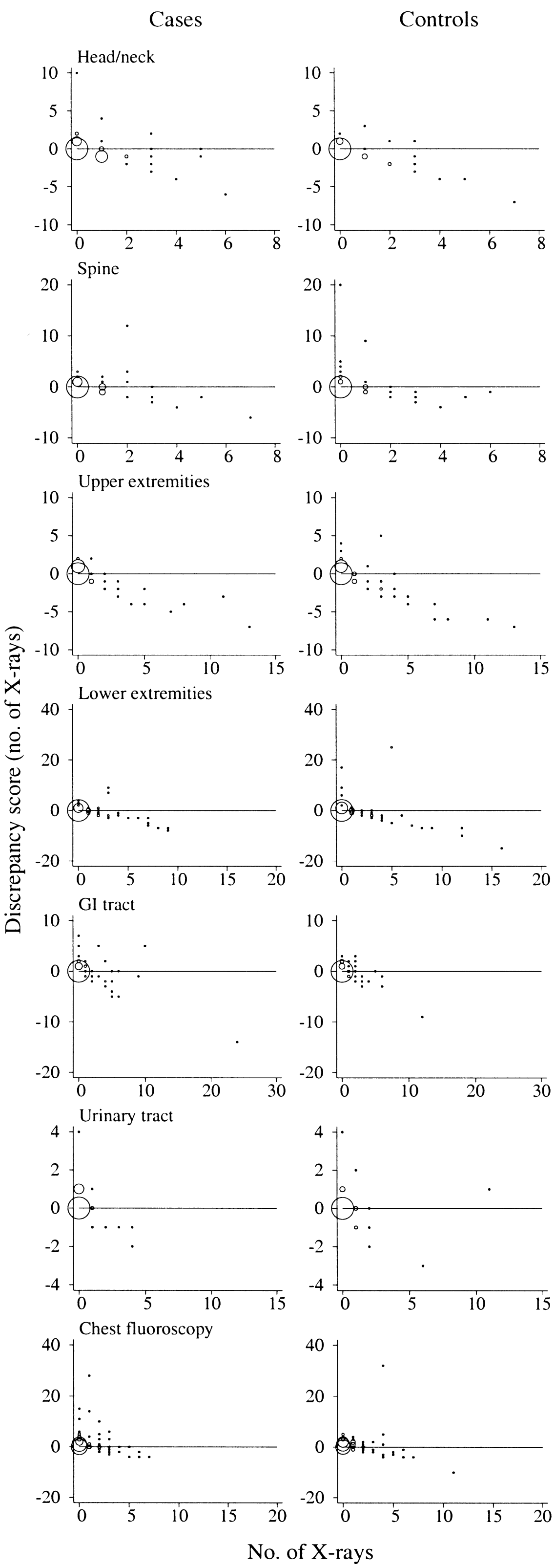

FIGURE 3. Discrepancy score (the number of x-ray examinations reported in the interview minus the number found in medical records) by type of procedure versus the number of x-ray examinations found in medical records. The size of the circle indicates the number of subjects relative to the 0–0 group (large circle). Data are derived from the population of the Uppsala Health Care Region, Sweden, 1985–1992. GI, gastrointestinal.

RESULTS

In Sweden, female cases outnumbered males by nearly four to one (table 1). Mean age at diagnosis of thyroid cancer was 45 years, and the average interval from thyroid cancer diagnosis to interview was 4 years. Cases and controls in the US study had been enrolled in the Kaiser Permanente health plan for an average of 17 years prior to diagnosis (range, 5–42 years). Again, there was a strong female predominance (84 percent). The average age at tumor diagnosis was 52 years, and the average interval from diagnosis to interview was 3 years. Because of the smaller size of the US series, we have presented detailed results for Sweden only, and selected summary results from the two countries are compared and contrasted.

In the Swedish study, for all types of x-ray examinations other than those of the head and neck and the abdomen, the number of cases and controls *ever* exposed was greater according to the interview (table 2). In particular, the number of subjects reporting ever having had chest fluoroscopy was considerably greater than the number ascertained from medical records. Although the mean discrepancy score between interview and medical record counts was between 1 and –1 for most procedure types, the range of the discrepancy scores among persons was quite large, particularly for chest fluoroscopies and x-ray examinations of the spine and lower extremities (table 3 and figure 1, upper panel). When chest fluoroscopies were excluded, the mean discrepancy score was considerably lower and was positive for cases and negative for controls (table 3). The average discrepancy score was negative for x-ray examinations of the head and neck and the abdomen and extremities and was positive for the other types of examinations.

In contrast, in the US study, the number of x-ray examinations based on medical records was greater for all procedure types except female genital tract and computed tomography scans, on average, than the number reported in the interview for both cases and controls (figure 1, lower panel). Chest fluoroscopies were much less common in the United States than in Sweden (three cases and zero controls in the interview reported having had fluoroscopy).

In figure 2, which shows the discrepancy score plotted against counts of x-ray examinations based on the medical records, the horizontal line at discrepancy score 0 represents the hypothetical situation of perfect agreement between the two information sources. The graphs show somewhat different patterns of disagreement in the two countries. For Sweden, points are distributed both above and below the horizontal line. For the United States, the majority of points for cases and controls lie below this line. Significant inverse associations were found between discrepancy score and number of x-ray examinations of all types combined for cases and controls from both countries. Although the slope of the association was always negative, the Y-intercept was always positive; that is, at low examination frequencies (per medical records), interviews yielded higher frequencies of exposure, whereas the reverse was true at high examination frequencies. This finding was particularly so for Sweden; in the United States, the Y-intercept nearly equaled zero (figure 2, lower panel). For both countries, the slope of the line was

TABLE 4. Estimated associations between risk of thyroid cancer and number of x-ray examinations, based on interview data compared with medical records, in the Swedish study (members of the Uppsala Health Care Region, 1985–1992)*,†

Examination	No. of x-ray examinations	Interview data					Medical records				
		Cases (no.)	Controls (no.)	OR	95% CI	*p* for trend	Cases (no.)	Controls (no.)	OR	95% CI	*p* for trend
Higher-dose examinations											
Head, neck, spine, and ribs and chest fluoroscopy	0	28	30	1.0			50	53	1.0		
	1-5	83	86	1.1	0.5, 2.3		65	61	1.0	0.6, 2.0	
	6-10	7	5	1.6	0.4, 5.8		8	8	0.9	0.3, 3.4	
	>10	5	2	2.5	0.4, 17.1	0.3	0	1			0.9
Medium-dose examinations											
Standard chest, shoulders, and upper GI‡ tract	0	44	62	1.0			57	68	1.0		
	1-5	67	55	2.0	1.1, 3.5		50	43	1.7	0.9, 3.1	
	6-10	6	2	4.5	0.8, 24.7		10	9	2.1	0.5, 9.1	
	>10	6	4	2.5	0.5, 11.9	0.01	6	3	3.3	0.6, 16.8	0.05
Low-dose examinations											
Abdomen, pelvis, and upper and lower extremities	0	60	53	1.0			81	76	1.0		
	1-5	58	66	0.7	0.4, 1.2		37	41	0.6	0.3, 1.2	
	6-10	3	2	0.5	0.1, 3.4		2	6	0.2	0.3, 3.4	
	>10	2	2	0.5	0.1, 4.1	0.2	3	0			0.2

* Odds ratios (OR) and 95% confidence intervals (CI) were calculated by using conditional logistic regression and were adjusted for the number of exposures in the other dose categories.

† X-ray examinations conducted within 5 years of thyroid cancer diagnosis/pseudodiagnosis were excluded from this analysis.

‡ GI, gastrointestinal.

more strongly negative for controls than for cases. The case-control difference was not significant for the Swedish data ($p = 0.55$) but was for the US data ($p = 0.0001$).

Patterns for particular types of x-ray examinations in Sweden were similar to those for x-ray examinations of all types combined (figure 3). Discrepancy scores for cases and controls did not differ significantly for any type of examination, with the exception of urinary tract procedures. As the number of urinary tract procedures listed in the medical records increased, the estimated discrepancy score between interview and medical records decreased slightly more rapidly for cases than controls ($p = 0.005$). In the US study, the discrepancy score between interview and medical records decreased more rapidly for controls than cases for x-ray examinations of the lower extremities ($p = 0.0001$) and urinary tract ($p = 0.008$). No clear patterns in discrepancy score were found for x-ray examinations of all types combined, by sex, age at interview or exposure, interval since exposure, or calendar year of exposure in either country (data not shown).

On the basis of either the interview or the medical record data from Sweden, the odds ratio for thyroid cancer did not increase significantly with increasing numbers of higher-dose x-ray procedures (table 4). However, the numbers of cases and controls in each category were quite different, especially in the zero exposure category, and cross-classification revealed poor agreement between assigned categories for both cases (kappa = 0.12) and controls (kappa = 0.12). This difference was partly due to chest fluoroscopies; when these procedures were excluded, the agreement increased (kappa = 0.21 for cases and kappa = 0.41 for controls). For medium-dose examinations, there was a significantly increasing trend in the odds ratios with an increasing number of examinations based on the interview data ($p = 0.01$). A similar trend was evident in the medical record data ($p = 0.05$). However, the level of agreement in the assigned categories was still relatively low, especially for the cases (kappa = 0.16; kappa = 0.40 for the controls). For low-dose examinations, the odds ratios decreased with increasing numbers of examinations reported in both the interview and medical record data, but these trends were not statistically significant. The agreement was fairly poor (kappa = 0.32 for cases and kappa = 0.29 for controls). None of the findings above changed materially if upper gastrointestinal x-ray examinations were categorized as high-dose x-rays (data not shown).

The associations between number of x-ray examinations and thyroid cancer also were compared by age and calendar year of exposure. The numbers of cases and controls reporting high-dose x-ray exposures before age 21 years were higher than the corresponding numbers from medical records (table 5), largely because of chest fluoroscopies. None of these analyses showed a significant association between the odds ratio and the number of exposures. For both sources of exposure information, the odds ratio was nonsignificantly higher for examinations received before 1960 than for those in later years.

TABLE 5. Estimated associations between thyroid cancer and number of higher-dose x-ray examinations, based on interview data and medical records, by age and time period of exposure in the Swedish study (members of the Uppsala Health Care Region, 1985–1992)*,†

Subgroup of high-dose x-ray examinations	Interview data					Medical records				
	Cases (no.)	Controls (no.)	OR	95% CI	*p* for trend	Cases (no.)	Controls (no.)	OR	95% CI	*p* for trend
No. of x-ray examinations at age <21 years										
0	50	56	1.0			103	100	1.0		
1-5	69	66	1.3	0.7, 2.5		19	22	0.8	0.4, 1.6	
≥6	4	1	3.6	0.4, 34.1	0.2	1	1	0.9	0.1, 16.0	0.6
No. of x-ray examinations at age ≥21 years										
0	65	61	1.0			61	64	1.0		
1-5	51	59	0.8	0.4, 1.5		55	53	1.1	0.6, 2.2	
≥6	7	3	2.6	0.6, 11.0	0.9	7	6	1.4	0.3, 5.7	0.7
No. of x-ray examinations before 1960										
0	67	75	1.0			115	119	1.0		
≥1	56	48	1.8	0.8, 3.9	0.1	8	4	2.5	0.6, 9.9	0.2
No. of x-ray examinations in 1960–1969										
0	82	69	1.0			98	90	1.0		
≥1	41	54	0.6	0.3, 1.1	0.1	25	33	0.7	0.3, 1.4	0.3
No. of x-ray examinations in 1970 or later										
0	72	72	1.0			62	66	1.0		
≥1	51	51	1.0	0.6, 1.8	0.9	61	57	1.2	0.6, 2.1	0.6

* Odds ratios (OR) and 95% confidence intervals (CI) were calculated by using conditional logistic regression and were adjusted for the number of examinations in the other dose categories.

† X-ray examinations conducted within 5 years of thyroid cancer diagnosis/pseudodiagnosis were excluded from this analysis.

Although the dose quartiles among controls were slightly higher when estimated by using the interview data, the estimated odds ratios were similar regardless of whether interview or medical record data were used (table 6). However, cross-classification of the subjects according to the dose quartile to which they were assigned on the basis of their medical records and interview data showed poor agreement (kappa = 0.25 for cases and kappa = 0.37 for controls) (table 7).

DISCUSSION

The present study is one of very few to address the accuracy of self-reported histories of lifetime exposure to diagnostic x-rays in case-control studies of cancer. It does so in the context of thyroid cancer, a relatively nonlethal cancer, but one of those most strongly linked to radiation exposure (15, 16). Unlike in previous studies, ascertainment of x-ray examinations by using medical records was entirely independent of the ability of study participants to recall any aspects of their previous medical care. In two earlier validation studies (8, 11), names of health care providers were obtained through interviews, so the medical or dental record review components of these studies were still dependent, to some extent, on respondents' recollections.

A second distinctive feature of the present study is that it was conducted in two different settings: Sweden, which has

TABLE 6. Estimated associations between thyroid cancer and cumulative thyroid radiation dose, based on interview data and medical records, in the Swedish study (members of the Uppsala Health Care Region, 1985–1992)*

Quartile† (mGy)	Interview data					Quartile (mGy)	Medical records				
	Cases (no.)	Controls (no.)	OR‡	95% CI‡	*p* for trend		Cases (no.)	Controls (no.)	OR	95% CI	*p* for trend
0–0.99	26	28	1.0			0	32	35	1.0		
1.00– 2.19	31	34	1.0	0.4, 2.5		0.001–1.19	21	26	1.0	0.4, 2.1	
2.20– 6.88	27	31	0.9	0.4, 2.4		1.20–5.38	29	31	1.1	0.5, 2.4	
>6.88	39	30	1.4	0.6, 3.3	0.3	>5.38	41	31	1.5	0.7, 3.0	0.2

* X-ray examinations within 5 years of thyroid cancer diagnosis/pseudodiagnosis were excluded from this analysis.

† Quartiles were based on the distribution of thyroid doses in the controls.

‡ OR, odds ratio; CI, confidence interval.

TABLE 7. Cross-classification into dose quartiles based on interview data versus medical records for cases and controls in the Swedish study (members of the Uppsala Health Care Region, 1985–1992)*

Interview quartile (mGy)	Medical records quartile (mGy)				
	0	0.001–1.19	1.20– 5.38	>5.38	Total
		Cases			
0–0.99	*12*	9	3	8	32
1.00–2.19	5	*7*	4	5	21
2.20–6.88	3	8	*11*	7	29
>6.88	6	7	9	*19*	41
Total	26	31	27	39	123
		Controls			
0–0.99	*16*	11	5	3	35
1.00–2.19	7	*9*	5	5	26
2.20–6.88	2	9	*14*	6	31
>6.88	3	5	7	*16*	31
Total	28	34	31	30	123

* Weighted kappa = 0.25 for cases and 0.37 for controls.

a government-sponsored, national health care system that includes all residents, and the United States, among members of a large, prepaid health plan. The same questionnaire was used in both countries, but medical record data were collected differently. Each approach had its strengths and weaknesses. Sweden offered the prospect of lifetime ascertainment of medical x-ray examinations, but only after a labor-intensive process involving review of medical records at many hospitals and the lingering possibility of underascertainment of x-ray examinations performed at facilities other than the primary hospital serving participants' residential areas. An advantage of the US study is that the medical records were likely to be more complete, and, for the period of membership, it provided for greatly simplified data collection. A disadvantage is that subjects were asked to report only those exposures they had received while members of the Kaiser Permanente health plan, and this added requirement may have made accurate reporting more difficult. A limitation of both studies is their small size and limited statistical power. Findings should be interpreted with caution, particularly in light of the large number of comparisons made.

Studies in both countries showed substantial lack of agreement between interview and medical records data. In particular, reporting became poorer as the number of x-ray exposures, according to the medical records, increased. There was some evidence that controls' reporting of x-ray examinations in the interview was poorer than cases' as the number of x-ray examinations increased for those of the urinary tract and of the lower extremities as well as for all types of x-ray procedures combined. This finding could create an artifactual dose-response relation in a case-control study and might account for previous reports of positive associations between thyroid cancer and self-reported x-ray examinations of parts of the body remote from the neck (18). Indeed, in an extension to that study, medical records were collected for a proportion of cases and controls, and no evidence of such an association was found (4).

In the present studies, the lack of agreement between interview and medical records data did not translate into large differences in the estimated risks of thyroid cancer from exposure to diagnostic x-rays. In fact, dose-response analyses for Sweden showed similar patterns regardless of which source of exposure information was used. This superficially reassuring finding is undermined by the fact that the two methods often placed subjects in very different ordinal dose categories. With respect to specific types of x-ray examinations, both positive and negative average discrepancy scores were observed, and mean discrepancy scores for cases and controls tended to track together. Of the procedures associated with higher radiation doses to the thyroid gland, there was little evidence of differences in reporting accuracy between cases and controls.

The apparent overreporting of x-ray examinations of all types combined in Sweden, as indicated by positive average discrepancy scores, probably was due in large part to underascertainment of procedures during medical record review. This problem was most pronounced for chest fluoroscopies. These formerly common procedures often were performed in mobile units and would have been missed in our review of hospital records (5). Although the procedure was routine in Sweden, it was much less common in the United States. The likely underascertainment of chest fluoroscopies in our medical record review leaves unresolved the possible carcinogenicity of this exposure, particularly from examinations occurring before 1960. For similar reasons, mammograms also may have been underascertained from medical records, but these procedures are associated with smaller radiation doses to the thyroid gland. There is no reason to believe that underascertainment was differential for cases and controls. In both studies of prenatal x-ray exposure, there was evidence of underascertainment of x-ray examinations; at least 30 percent of the reported x-ray examinations could not be confirmed because the records had been destroyed (9, 10).

In summary, results from the current study suggest that the information from studies that have used self-reported x-ray histories is likely to be inaccurate and *potentially* biased because of differential reporting by cases and controls. Such differential reporting could produce a spurious trend in the risk of cancer with increasing numbers of exposures in studies based on self-reported x-ray exposure histories. However, in the current study, there was greater evidence of nondifferential than differential errors in reporting. The results also highlight the difficulty of collecting accurate lifetime records of diagnostic x-ray exposure histories. The US study was limited because it was not possible to reconstruct lifetime exposure histories. In the Swedish study, where the medical system was more conducive to record collection than in most other countries, there was evidence that records for examinations performed outside of hospitals were underascertained.

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