Medical Insurance Claims and Surveillance for Occupational Disease: Analysis of Respiratory, Cardiac, and Cancer Outcomes in Auto Industry Tool Grinding Operations

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To evaluate medical insurance claims for chronic disease investigation, claims from eight automotive machining plants (1984 to 1993) were linked with work histories (1967 to 1993), and associations with respiratory, cardiac, and cancer conditions were investigated, in a case-control design analyzed with logistic regression. The primary focus was tool grinding, but other important processes examined were metalworking, welding, forging, heat treat, engine testing, and diverse-skilled trades work. Considerable variability in claim-derived incidence rates across plants was not explained by age or known exposure differences. Asthma incidence increased in tool grinding (at mean cumulative duration: odds ratio [OR], 3.0; 95% confidence interval [CI], 0.90 to 10.0), as did non-ischemic heart disease (cardiomyopathy, cor pulmonale, rheumatic heart disease, or hypertension; OR, 3.1; 95% CI, 1.26 to 7.6). These trends appeared in models with deficits (OR < 1.0) for those ever exposed to tool grinding because of exposure-response miss-specification, demographic confounding, or removal of high-risk workers from the exposed group. The apparent cancer rates identified from claims greatly exceeded the expected rates from a cancer registry, suggesting that diagnostic, "rule-out," and surveillance functions were contributing. This study supports the epidemiologic use of medical insurance records in surveillance and, possibly, etiologic investigation and identifies issues requiring special attention or resolution. (J Occup Environ Med. *2001;43:335–346*)

Medical insurance records represent a vast repository of morbidity information. Preliminary investigation using insurance records from diverse automotive manufacturing plants identified musculoskeletal disorders associated with categories of recent work.[1,2] The present study examined chronic diseases in eight machining plants of a major automotive manufacturer. Previous studies in machining and grinding operations have identified primarily digestive cancer[3–14] and respiratory excesses.[15–18] Although metalworking was a major process, a detailed retrospective exposure assessment for metalworking fluids was not feasible. Instead, the primary focus was cobalt-related disease among tool grinders because (1) this group was clearly distinguishable within the available work history, and (2) prior hypotheses linked tool grinding with hard-metal disease and cardiomyopathy.[19,20] This choice was further motivated by the belief that these diseases are not reliably attributed to work by the medical profession. Hard-metal disease, which consists of two forms of lung disease (sensitization manifest as bronchial asthma, and an interstitial fibrosis), is believed to be cobalt-induced with a possible role for tungsten carbide.[19,21–24] Several studies have documented hard-metal disease among workers of tool production or grinding enterprises.[21–25] Non-inflammatory cardiomyopathy has been described in cobalt poisoning

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and in a study of mineral laboratory workers.[20] Two studies suggest that misdiagnosis of cobalt-related heart disease may be common.[20,26]

Subjects and Methods

Study Population

Previously, a large database of merged medical insurance and work history information was constructed, with identities encrypted, for the entire United Auto Workers (UAW) workforce of this employer.[1] A concise work history had been appended to each selected paid claim for active and retired employees from July 1984 to December 1987 (a national claim processing network commenced in 1984). A subsequent procedure retrieved claims from the period 1988 to 1993. Claims were selected for a set of 107 medical conditions that could have an occupational origin and for 13 control conditions. These conditions and specifying International Classification of Diseases (9th Revision) diagnostic codes and Current Procedural Terminology (4th Edition) procedure codes were compiled by several consulting physicians. From this database, claims were further selected for a subset of medical conditions in workers from eight automotive machining plants, including two engine plants in Detroit (Michigan), a transmission plant in Kokomo (Indiana), and several parts machining plants (Detroit; Toledo, Ohio; New Castle, Indiana; and Syracuse, New York). Four plants began operations in the 1930s or before, three in the 1950s, and one in 1966. Claims for covered family members were excluded in this study.

All active employees and retirees have a health insurance benefit for which Blue Cross was either one or the only choice, depending on location. Active and retired employees with Blue Cross coverage were not identifiable with the available records, but the employer reported the proportions with Blue Cross insurance in the study plants, which ranged 56% to 100% in 1993 and higher in 1990. Actual coverage included major-medical, laboratory, and drug benefits, with various deductibles, but the details varied between traditional and managed-care options, across locations, and over time. Most of the claims selected were for outpatient procedures.

The medical conditions chosen for this study included non-malignant respiratory diseases (excluding hypersensitivities); asthma and allergic alveolitis; coronary heart disease; other heart diseases; and cancers of the lung, pancreas, prostate, and stomach (Table 1). Bladder cancer was examined, but there were no exposure associations and the results are not presented. Broad categories for heart and respiratory diseases were defined to accommodate misdiagnosis. For controls, the conditions specified were selected infectious, endocrine, peripheral circulatory, digestive, and urinary diseases thought to be unlikely to arise from workplace exposures (Table 2). Workers were not eligible for the control group if they had appeared in a case group for any of the outcomes of interest. Claims had up to three diagnostic and three procedural codes and were classified according to the first code that caused a claim to be selected.

The study population was all UAW workers who were employed for at least 6 months in the period 1967 to 1993 in a study plant and who had a medical insurance (Blue Cross–Blue Shield) claim under that employer's contract for any case or control condition during July 1984 through 1993. Multiple claim–work history records for each worker were consolidated into a single record using FORTRAN programs written for this purpose. The final record specified the medical conditions for which the worker had claims, associated numbers of claims, earliest claim dates, total hospital durations, and costs. Smoking history was unavailable.

Work History

A dictionary of 700 department numbers used from 1967 to 1993 was compiled from employee work histories (a 300-character record consisting of plant and department locations annually since 1967). Using archives of collective bargaining agreements, listings of departments current in 1992, and consultations with knowledgeable plant employees, departments were characterized by name and general process activity. They were then classified as either unexposed or exposed in the following 11 categories, whose selection was motivated by prior hypotheses: (1) tool grinding ("cutter grind")[21-26]; (2) machining or grinding[3-18]; (3) production welding[27,28]; (4) heat treat or forging[5,6] (see also Park RM, Krebs JG: Mortality in an automotive forging plant; unpublished report to UAW/GM National Joint Committee on Health and Safety, October 14, 1992); (5) shipping and receiving[29-31]; (6) testing[31]; (7) laborers; (8) millwrights, maintenance welders, pipefitters, powerhouse[13,32]; (9) tool, die, jig, and fixture[28]; (10) machine repair; and (11) electricians.[13]

Tool grinding was performed exclusively in departments dedicated to that operation. Several of the other process exposures could potentially confound the effects of tool grinding.

Exposure Assessment for Tool Grinding

Workers who perform precision-grinding of machining tools could be exposed to cobalt/tungsten carbide (hard-metal) dusts. Sparse records document toolroom conditions in the two engine plants in which local exhaust was judged to be inadequate, including instances of occluded ducts (Mound Road plant, July 14, 1960). Dust complaints in tool grinding "and adjacent departments" led to these evaluations. At Trenton Engine, one of two breathing zone samples for total dusts at grinding stations was 26 million particles per

TABLE 1
Numbers of Cases and Distribution Across Study Plants, 1984 to 1993

	Detroit Plants				Non-Detroit Plants				
Outcomes*	Mound	Trenton	Universal Division	Axle	Kokomo	Syracuse	New Castle	Toledo	Total
NMRD (excluding hypersensitivities)									
n	601	1,013	165	1,032	499	169	218	125	3,822
%	15.7	26.5	4.3	27.0	13.1	4.4	5.7	3.3	100
Asthma, allergic alveolitis									
n	152	254	54	301	215	70	49	48	1,143
%	13.3	22.2	4.7	26.3	18.8	6.1	4.3	4.2	100
Coronary artery disease									
n	900	1,434	297	1,521	1,087	396	489	274	6,448
%	14.0	23.0	4.6	23.6	16.9	6.1	7.6	4.2	100
Other heart disease									
n	466	792	145	873	510	226	219	138	3,369
%	13.8	23.5	4.3	25.9	15.1	6.7	6.5	4.1	100
Lung cancer									
n	82	188	37	174	111	53	58	29	732
%	11.2	25.7	5.1	23.8	15.1	7.2	7.9	4.0	100
Pancreas cancer									
n	19	58	19	44	2	9	4	5	160
%	11.9	36.3	11.9	27.5	1.3	5.6	2.5	3.1	100
Prostate cancer									
n	81	203	31	191	66	55	68	28	723
%	11.2	28.1	4.3	26.4	9.1	7.6	9.4	3.9	100
Stomach cancer									
n	17	22	2	31	10	7	4	2	95
%	17.9	23.2	2.1	32.6	10.5	7.4	4.2	2.1	100
Employees†									
n	992	1,742	–	802	5,307	1,717	1,046	842	12,448
%	7.9	14.0	–	6.4	42.6	13.8	8.4	6.8	100

* International Classification of Diseases, 9th Revision, diagnostic codes (Current Procedural Terminology, 4th Edition, codes not shown): Nonmalignant respiratory disease (NMRD): 491, 492, 496, 500, 503–506, 516; Asthma/Allergic Alveolitis: 493, 495; Coronary Artery Disease: 410–414; Other Heart Disease: 391–398, 401, 402, 403, 404, 415, 416, 422, 425; Lung Cancer: 162, 231.1; Pancreas Cancer: 157; Prostate Cancer: 185; Stomach Cancer: 151, 230.2.

† Estimated active employees with Blue Cross coverage in 1993 (employer-supplied data).

cubic foot (mppcf; standard: 50 mppcf; August 7, 1963). Measurements taken 3 years later were somewhat lower (5, 5, and 12 mppcf), but improved ventilation was advised in February 7, 1966. None of the early reports identified the nature of the dusts being generated (ie, tool steel vs carbide). Toolroom air concentrations during 1989 to 1994 in several machining plants ranged from 0.4 to 8.9 mg/m^3 for total particulate and, when measured, from 0.002 to 0.120 mg/m^3 for cobalt (current OSHA permissible exposure limit: 0.050 mg/m^3).

Exposure Cumulation Procedures

Dates of onset for chronic medical conditions were not available from claims and could have occurred many years before 1984. To address this ambiguity, the onset for a case was estimated in two ways: (1) *Earliest*: the earliest of the dates of reaching age 65, attaining 25 years of employment, or the first available claim (1984 to 1993); and (2) *1st Claim*: the date of the first available claim. For controls, the same procedures were used, except that the first available claim date was randomly assigned in the period when a worker could have had a claim during 1984 to 1993. Three different exposure cumulation algorithms were specified: (1) *Progressive*: the time in a specific exposure category was summed with a weighting proportional to the time before onset;[33] this cumulative exposure would be more appropriate for progressive diseases, such as some fibroses and, possibly, for some cancers. (2) *Long latency*: the time in an exposure category was summed with a weight of unity for periods greater than 25 years before onset but declining toward zero as onset approached; this cumulative exposure would be appropriate for diseases with long induction periods.[6] (3) *Unweighted duration*: the time in an exposure category was summed over a worker's career until onset.

Study Design and Analysis

A case-control design was selected because the population at risk for a medical claim (workers with Blue Cross) was unknown for most plants. Cases and controls were identified as individuals with one or more claims

TABLE 2
Numbers of Controls and Distribution Across Study Plants, 1984 to 1993

	Detroit Plants				Non-Detroit Plants				
Outcomes*	Mound	Trenton	Universal Division	Axle	Kokomo	Syracuse	New Castle	Toledo	Total
Infectious disease									
n	159	219	38	194	256	106	32	34	1,038
%	15.3	21.1	3.7	18.7	24.7	10.2	3.1	3.3	100
Thyroid disease									
n	19	40	7	29	24	12	9	7	147
%	12.9	27.2	4.8	19.7	16.3	8.1	6.1	4.8	100
Peripheral circulatory disease									
n	69	128	16	92	280	80	69	48	782
%	8.8	16.4	2.0	11.8	35.8	10.2	8.8	6.1	100
Digestive disease									
n	110	153	38	135	514	162	117	103	1,332
%	8.3	11.5	2.9	10.1	38.6	12.2	8.8	7.7	100
Urinary stones									
n	38	76	9	43	233	74	75	39	587
%	6.5	12.9	1.5	7.3	39.7	12.6	12.8	6.6	100
Total controls									
n	331	505	93	422	1,161	396	272	200	3,380
%	9.8	14.9	2.8	12.5	34.3	11.7	8.0	5.9	100
Employees†									
n	992	1,742	–	802	5,307	1,717	1,046	842	12,448
%	7.9	14.0	–	6.4	42.6	13.8	8.4	6.8	100

* International Classification of Diseases, 9th Revision, diagnostic codes (5-digit codes; X = any numeral or blank) (Current Procedural Terminology, 4th Edition, codes not shown): Infectious Disease: 034.0X; Strep Throat: 038.XX; Septicemia: 042.XX; HIV Infection: 053.XX; Herpes Zoster: 055.XX; Measles (Red): 056.XX; Rubella: 070.XX; Infectious Hepatitis: 074.XX; Coxsackie Infections: 075.XX; Infectious Mononucleosis: 110.XX; Dermatophytosis: 111.XX; Dermatomycosis: 372.0X; Acute Conjunctivitis: 380.1X; Otitis Externa: 462.XX; Acute Pharyngitis: 464.XX; Acute Laryngitis, Trachelitis, Thyroid Disease: 240.XX; Simple Goiter: 242.XX; Thyrotoxicosis: 245.XX; Thyroiditis, Circulatory Disease: 451.XX; Phlebitis: Thrombophlebitis: 454.XX; Varicose Veins: 455.XX; Hemorrhoids: 457.XX; Lymphatic Disease–Noninfectious: Digestive Disease: 530.XX; Esophageal Disorders: 532.XX; Duodenal Ulcer: 535.0X; Acute Gastritis: 540.XX; Acute Appendicitis: 555.XX; Regional Enteritis: 564.XX; Functional Digestive Disorders: 565.XX; Anal Fissure: 574.XX; Cholelithiasis: 575.0X; Acute Cholecystitis, Urinary Stones: 592.XX; Calculus, Kidney & Ureter: 594.XX; Calculus, Lower Urinary Tract.

† Estimated active employees with Blue Cross coverage in 1993 (employer supplied data).

for a case or control condition, except in selected analyses when more than one claim was required.

In unmatched case-control designs, the assignment of onset for controls can fundamentally confound an exposure-outcome association, even with age-adjustment, because the age distribution of onset for cases (eg, heart disease) will generally differ from that of controls (eg, infectious disease). Age-adjustment corrects for differing background rates of diseases (defining cases and controls) with age but not for the differing exposure opportunity defined by onset. In this analysis, duration of employment at the plant was included in models to address this confounding because duration of employment (up to onset) would also be affected by onset assignment. Duration of employment in a study plant was weighted the same as the cumulative exposures in the model and entered as a continuous variable (with linear and quadratic terms). Other terms addressing potential confounding were date of hire, age at hire, and date of onset. Models of incidence odds ratios were fitted using unconditional logistic regression. To validate this approach, matched case-control analyses for simplified models were conducted with cases and controls being matched for age at first claim for the condition under study. These results were found to have good agreement with analogous unconditional regression results.

Other confounding demographic factors included gender, race, skill, and smoking status. Racial composition probably varied widely across the study plants and exposure categories, but race information was unavailable. Age at onset was included in models as a quadratic spline with linear and quadratic terms fit piecewise above ages 40, 50, and 60. Indicators of skilled-trade status and plant locations were included to reduce residual confounding. Specifically, effects for the Detroit area plants combined, and for one specific Detroit plant (Detroit Axle), were estimated in all models because they showed consistent differences. In addition to continuous cumulative exposure duration risk factors, indicators of being ever exposed were used to address possible confounding arising from race, health care coverage, utilization, or smoking behavior. The full panel of available confounding variables was used in each model

TABLE 3
Descriptive Findings Relating Asthma and OHD* to Demographic Factors and Two Exposure Categories

	Cases: Asthma†	Controls	Cases: OHD
n	1,143	3,380	3,369
Gender (% women)	13.8	9.7	9.1
Skilled trade (%)	16.4	19.0	19.5
Age at hire (mean yrs)	30.5	28.6	31.0
Date of hire (mean yr)	1969.0	1971.3	1966.5
Age at onset (estimated "earliest") (mean yrs)	48.0	44.0	49.1
Date of onset (mean yr)	1986.4	1986.6	1984.7
Duration at onset (progressive weighting; mean months)	47.4	39.9	51.3
Duration at onset (unweighted; mean months)	180.1	168.0	193.4
Tool grinding (progressive weighting; mean months)	0.876	0.533	0.962
Tool grinding (unweighted; mean months)	2.94	2.21	3.47
Welding (progressive weighting; mean months)	2.46	2.47	2.52
Welding (unweighted; mean)	8.71	10.32	8.98

* OHD, other heart disease.
† Includes 14 allergic alveolitis cases.

except when sparse data resulted in a non-convergence in maximum likelihood estimation (for example, if there were no cases below age 40).

The unconditional regression model had this form: $\ln(p/1 - p) = a + (\text{terms for age at onset}) + (\text{terms for demographic and employment features}) + (\text{terms for indicators of exposure and cumulative exposures})$.

Effects for cumulative exposure or employment duration were expressed as odds ratios predicted at the mean cumulative exposure (employment duration) of the cases. Estimation was accomplished using EGRET (Cytel Software Corp, Cambridge, MA).[34] "Earliest" onset assignment, used for the non-malignant conditions, generally produced stronger associations than "1st Claim." For malignancies, which are often fatal, onset defined by 1st Claim was thought to be most appropriate and generally yielded stronger effects.

For two of the eight plants, Blue Cross was the only insurance option, so the population at risk could be inferred from the work history. For these plants, a matched analysis using conditional logistic regression was performed for comparison with the unmatched logistic regression results. Matching was on date of birth and date of onset (within 2.0 years) using incidence density sampling for controls with a variable ratio of cases:controls averaging about 1:6.

Results

Counts of cases (Table 1) and controls (Table 2) revealed remarkable interplant differences that were unlikely to be accounted for by age, gender, or exposure distributions. The Kokomo transmission plant, with 42% of the currently employed population having Blue Cross coverage, contributed 13% of non-malignant respiratory diseases and 1.3% of pancreas cancer cases. Claims coded as pancreas cancer were concentrated in the Detroit area plants.

Descriptive statistics comparing cases and controls are presented for asthma and for other heart disease (OHD), two hypothesized outcomes for which associations with tool grinding exposures were observed in multivariate analyses. (Included with the 1143 cases in the asthma category were 14 cases of allergic alveolitis.) When comparing asthma cases with controls, the mean age at hire and year of hire were within 2 years, but the age at onset (earliest) was observed to be somewhat higher among the cases (48 vs 44 years), as was employment duration at onset (180 vs 168 months) (Table 3). A higher proportion of asthma cases compared with controls were women (13.8% vs 9.7%), and a smaller proportion were skilled-trades workers (16.4% vs 19.0%). Mean tool grinding cumulative measures were greater for asthma cases (progressive weight, 0.88; unweighted, 2.94) compared with controls (progressive weight, 0.53; unweighted, 2.22) (Table 3). For welding, asthma cases had similar or smaller mean exposures compared with controls. The rule allowing earlier onset assignment than the first claim (earliest), as intended, produced smaller age differences between cases and controls (by 2 to 4 years; data not shown).

Workers in the OHD case group were hired at a slightly older age and almost 5 years earlier than controls, and they were 5 years older at onset (earliest) (Table 3). The proportions of women and skilled trades among the OHD cases were about the same as among controls, but durations of employment (progressive and unweighted) and cumulative exposures for tool grinding were considerably greater among OHD cases than controls (Table 3). Welding exposure exhibited similar or diminished means among OHD cases compared with controls.

In logistic regression models designed to control the complex confounding anticipated in these data, the skilled workers had lower, and women higher, ORs for asthma, and skilled workers had lower ORs for OHD (Table 4). Both asthma (OR, 3.0; 95% CI, 0.90 to 10.0) and OHD (OR, 3.1; 95% CI, 1.26 to 7.6) showed increasing trends with tool grinding (progressive weighting), but with an unusual exposure-response: deficits among those who had minimal exposure (ever-exposed). There were substantial plant and regional (Detroit vs other) differences. Non-malignant respiratory disease and ischemic heart disease showed similar but smaller and non-significant

TABLE 4
Final Logistic Regression Models for Asthma and OHD*

Outcome†	*n*‡	OR§	95% CI	*P*
Asthma (ICD-9: 493, 495)				
Terms for age at onset		–		
Gender (0 = men, 1 = women)	158	1.49	1.18–1.87	<0.001
Skill (0 = 0 = nonskilled, 1 = skilled)	188	0.70	0.57–0.85	<0.001
Hire date (months)	–	1.00	0.98–1.02	0.902
Age at hire (yrs)	–	0.98	0.80–1.20	0.869
Date of onset (months)	–	1.01	0.99–1.02	0.563
Employment duration (months)	1,143	0.78	0.55–1.09	0.144
Indicator: Detroit plants (0 = never, 1 = ever)	717	2.16	1.63–2.87	<0.001
Employment duration: Detroit plants (months)	717	1.35	1.03–1.77	0.030
Indicator: Detroit Axle plant (0 = never, 1 = ever)	301	1.09	0.77–1.55	0.621
Employment duration: Detroit Axle plant (months)	301	1.40	1.00–1.95	0.048
Indicator: tool grinding (0 = never, 1 = ever)	16	0.50	0.15–1.73	0.275
Tool grinding (progressive weighting)	16	3.04	0.90–10.3	0.073
OHD (ICD-9: 391–398, 401–404, 415, 416, 422, 425)				
Terms for age at onset		–		
Gender (0 = men, 1 = women)	308	0.95	0.79–1.15	0.622
Skill (0 = 0 = nonskilled, 1 = skilled)	656	0.79	0.69–0.91	<0.001
Hire date (months)	–	1.00	0.98–1.01	0.598
Age at hire (yrs)	–	1.04	0.89–1.20	0.633
Date of onset (months)	–	1.00	0.99–1.02	0.609
Employment duration (months)	3,369	1.37	1.03–1.81	0.028
Indicator: Detroit plants (months)	2,171	4.06	3.29–5.02	<0.001
Employment duration: Detroit plants (months)	2,171	0.76	0.62–0.92	0.005
Indicator: Detroit Axle plant (0 = never, 1 = ever)	873	1.10	0.84–1.44	0.471
Employment duration: Detroit Axle plant (months)	873	1.27	0.98–1.65	0.074
Indicator: tool grinding (0 = never, 1 = ever)	52	0.32	0.13–0.77	0.011
Tool grinding (progressive weighting)	52	3.10	1.26–7.62	0.013
Indicator: heat treat/forge (0 = never, 1 = ever)	399	0.83	0.70–0.97	0.020

* OHD, other heart disease; OR, odds ratio; CI, confidence interval; ICD-9, International Classification of Diseases, 9th Revision.
† For Asthma and OHD, onset was *earliest* and weighting was progressive.
‡ *n*, number of exposed cases.
§ Age effects estimated for annual increments; date effects estimated for 1-month increments; durations and cumulative exposures estimated at mean for exposed cases.

associations with tool grinding (data not shown). In models comparing several skilled-trade and the nonskilled maintenance groups, the tool grinding association appeared to be unique (Table 5). Several explorations were conducted to elucidate the tool grinding associations. Defining onset for controls by the first available claim for any control condition (rather than randomly) produced only slightly smaller effect estimates for asthma and OHD. Requiring multiple claims to confirm a case substantially reduced the numbers of cases and increased the asthma association but decreased the OHD association (both now non-significant).

After restricting the analysis to two plants having exclusively Blue Cross coverage and therefore a specifiable population at risk for claims, the unconditional logistic regression approach (with random onset in controls) was compared with a conditional logistic regression analysis with incidence-density matched controls. The latter resulted in a smaller but more precise estimate of the tool grinding–OHD association trend (OR, 3.36; 95% CI, 1.44 to 7.83) with a less pronounced deficit for the ever-exposed (Table 6). Only three asthma cases among tool grinders were available for analysis.

Models were examined with alternate forms of exposure measures (ie, categorical, quadratic) to determine if the observed deficits among low-exposed workers may have resulted from miss-specification. For some specifications, the ever-exposed estimate was indeed near unity, with positive trends (Table 7, models 1 and 2). Nevertheless, the small number of cases among the low-exposed workers made all such inferences uncertain.

Being able to produce valid cancer relative rate estimates would be a valuable use of medical insurance surveillance. Unconditional logistic regression models using long-latency weighted exposures identified several associations across four cancer sites (Table 8). There was a doubling of stomach cancer with machining exposures at an engine plant where significant excess stomach cancer mortality (1970 to 1989) had been reported earlier,[13] and a possible association between welding and lung cancer (OR, 1.7; 95% CI, 1.04 to

TABLE 5
Adjusted OR for Intercepts and Trends for Respiratory and Cardiac Outcomes in Skilled-Trade and Other Maintenance Workers*

		Intercept§			Trend§		
Outcome†	n‡	OR	95% CI	P	OR	95% CI	P
Asthma (ICD-9: 493, 495)							
Tool grinding	16	0.47	0.14–1.62	0.232	2.86	0.84–9.69	0.092
Tool, die, jig, and fixture	33	0.80	0.42–1.51	0.485	0.88	0.53–1.47	0.626
Machine repair	42	0.84	0.45–1.58	0.592	1.05	0.61–1.79	0.866
Electrician	27	1.04	0.51–2.14	0.912	0.95	0.54–1.67	0.865
Millwright, welder, pipefitter	56	0.60	0.36–1.00	0.051	1.24	0.80–1.91	0.341
Non-skilled maintenance	71	0.93	0.62–1.39	0.710	1.11	0.82–1.52	0.489
OHD (ICD-9: 391–398, 401–404, 415, 416, 422, 425)							
Tool grinding	52	0.31	0.13–0.75	0.009	2.98	1.21–7.36	0.018
Tool, die, jig and fixture	134	1.08	0.72–1.61	0.714	0.78	0.57–1.07	0.120
Machine repair	152	0.95	0.62–1.46	0.828	1.00	0.69–1.45	0.984
Electrician	98	1.37	0.84–2.24	0.213	0.91	0.62–1.34	0.642
Millwright, welder, pipefitter	189	1.08	0.78–1.48	0.648	0.77	0.61–0.98	0.032
Non-skilled maintenance	212	0.96	0.72–1.28	0.774	1.10	0.86–1.39	0.454

* For definition of abbreviations, see Table 4.
† Latency weighting: for asthma and OHD, progressive.
‡ *n*, number of exposed cases.
§ A single model is displayed for each outcome. Intercept: OR estimate for ever in exposure group, at limit of no exposure duration. Trend: OR estimate at mean cumulative exposure of exposed cases. All models are based on date of onset, defined as earliest of: achieving 25 years of service, turning age 65, or submitting first claim for condition (during 1984 to 1993). All models are adjusted for age, gender, skilled-trade status, date of hire, employment duration (with latency weighting), date of onset, and plant locations (Detroit plants and Detroit Axle plant indicators and employment durations).

TABLE 6
Comparison of Unmatched With Matched Analysis in Two Plants Where Blue Cross was the Only Insurance Option*

		Original† Design			Matched‡ Design		
Outcome	n§	OR	95% CI	P	OR	95% CI	P
Asthma (ICD-9: 493, 495)							
Skill (0 = nonskilled, 1 = skilled)	50	0.77	0.53–1.11	0.160	0.77	0.54–1.11	0.158
Employment duration (months)	264	0.61	0.31–1.20	0.155	0.25	0.15–0.45	<0.001
Indicator: tool grinding (0, 1)	3	0.67	0.06–7.79	0.750	0.51	0.08–3.41	0.489
Tool grinding (progressive weighting)	3	1.90	0.18–19.6	0.589	2.35	0.48–11.4	0.291
OHD (ICD-9: 391–398, 401–404, 415, 416, 422, 425)							
Skill (0 = 0 = nonskilled, 1 = skilled)	140	0.72	0.56–0.92	0.010	0.71	0.57–0.89	0.003
Employment duration (months)	729	1.48	0.86–2.57	0.158	0.17	0.12–0.26	<0.001
Indicator: tool grinding (0, 1)	10	0.20	0.02–2.54	0.216	0.44	0.13–1.52	0.195
Tool grinding (progressive weighting)	10	5.87	0.73–46.9	0.095	3.36	1.44–7.83	0.005
Lung cancer (ICD-9: 162,231.1)							
Skill (0 = 0 = nonskilled, 1 = skilled)	45	0.82	0.52–1.28	0.383	0.86	0.59–1.26	0.441
Employment duration (months)	169	0.24	0.05–1.14	0.072	1.28	0.39–4.18	0.686
Indicator: welding (0, 1)	7	0.15	0.04–0.62	0.009	0.21	0.06–0.75	0.017
Welding (long-latency weighting)	7	3.46	0.85–14.0	0.082	2.35	0.74–7.47	0.147

* For definition of abbreviations, see Table 4.
† Models included multiple terms for age at onset, date of onset, age at hire, and date of hire.
‡ Cases matched approximately 1:6 to full plant population (with insurance opportunity), matching on date of birth, gender, and plant, with date of onset of case assigned to matched controls.
§ *n*, number of exposed cases.

2.9). Compared with other plants, Detroit plants had a 12-fold higher relative rate of apparent pancreas cancer cases and a 5-fold higher relative rate of prostate cancer cases (Table 8). However, a large decrease in lung cancer cases (from 732 to 457) was observed after requiring multiple claims to define a case, suggesting that some claims for cancer represent diagnostic or "rule-out" procedures subsequently interpreted as negative. For the two plants with known insurance coverage, the association of lung cancer with welding

TABLE 7
Effect Estimates for Tool Grinding and OHD From Final Models for Population With Known Insurance Coverage and in Full Study Population*

Outcome†	*n*‡	OR	95% CI	*P*
Two plants with only Blue Cross: matched analysis				
Model 1				
Employment duration (months)	729	0.17	0.11–0.25	<0.001
Indicator: tool grinding (0 = never, 1 = ever)	10	1.08	0.48–2.41	0.856
Tool grinding (progressive weighting, quadratic)	10	1.50	1.00–2.18	0.050
Model 2				
Employment duration (months)	729	25.60	5.28–124.	<0.001
Employment duration (months, quadratic)	729	0.23	0.15–0.36	<0.001
Indicator: tool grinding (0 = never, 1 = ever)	10	0.74	0.28–1.92	0.532
Tool grinding (progressive weighting, quadratic)	10	2.45	1.24–4.83	0.010
Model 3				
Employment duration (months)	729	24.66	5.09–119.	<0.001
Employment duration (months, quadratic)	729	0.24	0.15–0.37	<0.001
Tool grinding (progressive weighting, quadratic)	10	2.12	1.24–3.61	0.006
Two plants with only Blue Cross: unmatched analysis				
Model 1				
Employment duration (months)	729	1.49	0.85–2.60	0.163
Indicator: tool grinding (0 = never, 1 = ever)	10	0.32	0.04–2.30	0.254
Tool grinding (progressive weighting, quadratic)	10	6.05	0.80–46.0	0.083
Model 2				
Employment duration (months)	729	0.05	0.01–0.34	0.003
Employment duration (months, quadratic)	729	4.53	2.02–10.2	<0.001
Indicator: tool grinding (0 = never, 1 = ever)	10	0.32	0.04–2.34	0.262
Tool grinding (progressive weighting, quadratic)	10	5.49	0.72–41.8	0.100
Full study population: unmatched analysis				
Employment duration (months)	3,369	0.41	0.20–0.85	0.016
Employment duration (months, quadratic)	3,369	1.81	1.33–2.46	<0.001
Indicator: tool grinding (0 = never, 1 = ever)	52	0.47	0.24–0.93	0.029
Tool grinding (progressive weighting, quadratic)	52	2.15	1.09–4.22	0.027

* For definition of abbreviations, see Table 4.

† OHD: ICD-9: 391–398, 401–404, 415, 416, 422, 425. For matched analyses, cases matched approximately 1:6 to full plant population (with insurance opportunity), matching on date of birth, gender, and plant, with date of onset of case assigned to matched controls. Models included multiple terms for age at onset (unmatched models) and indicators and durations for Detroit plants (full study population only); progressive latency weighting.

‡ *n*, number of exposed cases.

was similar when comparing matched and unmatched analyses, but there were only seven exposed cases (Table 6).

Using age-specific cancer incidence rates from Michigan,[35] estimates of numbers of incident cases expected for several malignancies were calculated, allowing plausible assumptions about the population at risk (Table 9). Incident cases defined by one or more insurance claims vastly exceeded the expected incidence by 6.5- to 13-fold. The numbers of cases per year identified from claims declined somewhat between the 1984-to-1987 and 1988-to-1993 periods for all but prostate cancer (Table 9).

Discussion

Although this database offers a wealth of medical information linked with *unbiased* work history (recorded independent of outcomes), as with any source of administrative information created for other purposes, there are methodologic concerns. Diagnostic variability is expected to produce misclassification that is nondifferential (the same across exposure groups) because it is most likely driven by financial or random factors. It was reported that utilization review more carefully examines procedure codes (the basis for outpatient claims processing) than diagnostic codes. Miscoding of non-critical fields was observed. For example, a small number of claims for prostate or ovarian cancer were observed with inappropriate gender, most likely the result of incorrect coding of subscriber status by the health care provider (covered worker vs worker's spouse). Duplicate and adjusted claims were not readily dealt with. Workers' health coverage choices might be related to their health status and, although unlikely, to their exposure history. An exception might be publicized problems (eg, asbestos-related), for which some health insurance options may be preferred over others. The benefit structure itself imposes limitations related to severity (routine doctor

TABLE 8
Final Logistic Regression Models for Cancer Outcomes*

Outcome	*n*†	OR‡	95% CI	*P*
Lung cancer (ICD-9: 162, 231.1)				
Employment duration (months)	732	0.49	0.24–1.03	0.059
Indicator: Detroit plants (0 = never, 1 = ever)	481	3.75	2.48–5.66	<0.001
Employment duration: Detroit plants (months)	481	0.78	0.54–1.14	0.205
Indicator: Detroit Axle plant (0 = never, 1 = ever)	174	1.71	1.08–2.70	0.022
Employment duration: Detroit Axle plant (months)	174	0.62	0.41–0.94	0.024
Indicator: welding (0 = never, 1 = ever)	45	0.57	0.33–0.98	0.042
Welding (long-latency weighting)	45	1.73	1.04–2.89	0.035
Indicator: shipping/receiving (0 = never, 1 = ever)	54	1.39	0.95–2.03	0.093
Pancreas cancer (ICD-9: 157)				
Employment duration (months)	160	0.41	0.10–1.58	0.195
Indicator: Detroit plants (0 = never, 1 = ever)	140	12.71	5.16–31.3	<0.001
Employment duration: Detroit plants (months)	140	0.90	0.40–2.02	0.796
Indicator: non-skilled maintenance (0 = never, 1 = ever)	13	1.96	0.99–3.90	0.054
Electricians (long-latency weighting)	6	4.03	1.22–13.3	0.022
Prostate cancer (ICD-9:185)				
Employment duration (months)	723	0.16	0.05–0.51	0.002
Indicator: Detroit plants (0 = never, 1 = ever)	506	5.13	2.91–9.04	<0.001
Employment duration: Detroit plants (months)	506	0.71	0.39–1.29	0.264
Indicator: Detroit Axle plant (0 = never, 1 = ever)	191	1.67	0.86–3.24	0.129
Employment duration: Detroit Axle plant (months)	191	0.73	0.39–1.39	0.344
Tool grinding (long-latency weighting)	31	1.64	0.80–3.34	0.178
Indicator: heat treat/forging (0 = never, 1 = ever)	116	1.42	1.00–2.00	0.049
Indicator: non-skilled maintenance (0 = never, 1 = ever)	47	1.63	0.98–2.74	0.062
Stomach cancer (ICD-9:151,230.2)				
Employment duration (months)	95	0.19	0.03–1.13	0.068
Indicator: Detroit plants (0 = never, 1 = ever)	72	2.76	0.93–8.22	0.068
Employment duration: Detroit plants (months)	72	1.38	0.49–3.85	0.539
Indicator: Detroit Axle plant (0 = never, 1 = ever)	31	3.00	1.00–9.01	0.050
Employment duration: Detroit Axle plant (months)	31	0.57	0.23–1.43	0.232
Indicator: tool grinding (0 = never, 1 = ever)	2	1.40	0.28–6.95	0.678
Indicator: machining (0 = never, 1 = ever)	42	0.65	0.38–1.12	0.119
Indicator: machining–Mound Road plant (0, 1)	12	2.27	0.93–5.52	0.070

* For definition of abbreviations, see Table 4.
† *n*, number of exposed cases.
‡ Odds ratio predicted for mean exposure or employment duration of exposed cases. Models are adjusted for gender, skill, hire date, and age at hire (linear term); age at onset (linear and quadratic terms); date of onset (linear terms); and location: indicators of Detroit plants and Detroit Axle plant, along with corresponding employment durations; long-latency weighting used.

visits may not be covered) or specificity of coding.

During the study period, changes were implemented in the aggregation of chargeable procedures within claims, resulting in fewer but larger claims for hospital stays. This change may not have occurred uniformly in time across plant locations and may have affected case definitions, particularly if diagnostic codes reflected discharge rather than initial assignments. It probably contributed to smaller numbers of cancer claims per year during 1988 to 1993 (Table 9). Overall, however, it is reasonable to assume that these determinants of claim activity were relatively uniform across exposure groups within plant populations.

The absence of explicit onset information is a fundamental concern. The first claim in an episode for acute complaints, such as for some musculoskeletal disorders, is likely to be captured over a multiyear observation period,[1] whereas claims for chronic irreversible conditions, such as cardiac or respiratory, could have begun many years before observation. This study describes an analytic strategy to address this problem that seems to be successful and is not expected to generate false-positive associations.

The very substantial plant effects seemed to be well described by grouping Detroit versus non-Detroit plants (Table 4). This distinction could arise from several sources: the non-Detroit plants tended to be more rural or small city-based (less air pollution), to have lower proportions of black workers (possibly changing utilization patterns), and to be serviced by non-Michigan Blue Cross plans (having differing benefit practices and billing procedures).

Race is potentially an important confounder in medical insurance-based surveillance because exposure, utilization, and background rates may depend on race. Misclassification within broad exposure categories may be race-related ow-

TABLE 9
Incident Cancer Cases Inferred From Blue Cross Claims and Expected From State of Michigan Among Active Employees

Source	Cancer				
	Lung	Pancreas	Prostate	Stomach	Bladder
Blue Cross claims*					
Cases, 1984–1987 (3.5 yrs)	347	81	220	39	108
Cases per year	99	23	63	11	31
Cases, 1988–1993 (6.0 yrs)	385	79	503	56	137
Cases per year	64	13	84	9	23
Total cases, 1984–1993 (9.5 yrs)	732	160	723	95	245
Active cases† 1984–1993 (< age 68)	457	102	304	53	127
Michigan expected cases‡					
Active employees 1984–1993	79.5	7.7	34.1	8.2	16.1
Blue Cross cases/expected	5.7	13.2	8.9	6.5	7.9

* Includes incident and prevalent invasive, non-invasive, and presumably suspect cases for which diagnostic procedures were performed.
† Cases among current employees, not retirees.
‡ Based on age distributions of plant active workforces as of September 30, 1990, reported by employer, proportion with Blue Cross coverage as of June 1993, and Michigan incidence rates for invasive cancers in 1987. Rates for black men were used for Detroit-area plants, and rates for white men were used for other plants.

ing to possible discrimination in job assignments and skill levels. In some settings, black workers may have been less likely than others to seek medical care, for which there was evidence in a study of medical claims and musculoskeletal disorders.[1] In this study, a lower health care utilization rate on the part of black workers for the control conditions (which were, on average, less severe) could have contributed to the observed pattern of elevated odds ratios in the Detroit-area plants. Unfortunately, access to race information that could have clarified this issue was not provided by the employer.

Tool Grinding and Other Exposure Effects

Estimating the date of onset could have distorted the exposure-response for tool grinders and produced the negative intercepts. Other explanations include the selection of symptomatic workers out of employment or into different work assignments, differing ethnic composition between tool grinding and other workers, and sparse cases and low power in low-exposure strata. The natural history of cobalt-related disease could produce noticeable symptoms only after some minimum cumulative exposure. Fitting linear trends in this circumstance could result in negative estimates for model intercepts. Observing stronger effects with "progressive" latency weighting and with quadratic exposure terms supports this conjecture.

Taken together, the analyses provide some evidence for excess asthma and OHD related to tool grinding environments in automotive machining plants during the 1970s and 1980s and, possibly, continuing. Consideration should be given to conducting appropriate symptom history surveys for cardiac or respiratory conditions in tool grinders of typical machining operations, followed as appropriate with referrals for clinical evaluations. In some operations, hard-metal cutting tools have been replaced with ceramic materials, for which the potential health effects may be less well known.

Cancer Surveillance

The apparent decline in cancer cases identified per year over the 1984-to-1993 interval could be a result of the change in claim aggregation practices. It also could indicate that some prevalent rather than incident conditions were being identified in the early years of follow-up. The substantial increase in apparent incidence for prostate cancer claims after 1987 suggests that many of those claims were for Prostate Specific Antigen screening tests, which became common in this time period (Table 9).

Case inflation caused by false-positive diagnostic codes probably accounts for much of the dramatic excess in claim-derived cancer rates, particularly for pancreas cancer. Nevertheless, it raises the question of why there is so much diagnostic scrutiny in these cases. Some diagnostic procedures may have been prompted by the symptoms that arose from other work-related conditions, such as pancreatitis[36] or liver disease,[11,13,37] possibly related to exposures to some metalworking fluid and combustion-products. Similarly, atypical lung complaints are probably likely to stimulate clinical evaluations for lung cancer, which are observed to occur at almost six times the incidence for lung cancer (Table 9).

Medical Insurance as a Surveillance Basis

Medical insurance has not been widely used for the investigation of occupational disease. Recent contributions have examined the effects of business travel[38] and, in the context of the Health Maintenance Organiza-

tion, work-related adult onset or recurrent asthma.[39] The potential information resource of linked medical insurance and work history is enormous, relatively unbiased, and inexpensive in that the information was collected for other purposes. Therefore, the feasibility of surveillance or etiologic study should be of considerable interest, particularly for outcomes not well handled by workers' compensation systems.[40,41]

In this investigation involving workers from eight plants and over 100,000 person-years of potential observation (depending on insurance coverage), ambiguities remain. Nonetheless, the study suggests that generic methods for dealing with information deficiencies (such as unknown insurance coverage status or date of onset) can enable a first line of inference in forming decisions on further investigation or intervention for chronic diseases. Tests for association are relatively straightforward once a claims-work history database is established with exposure classification and supporting software. With advancing employer databases allowing the retrospective identification of covered populations, and increasing computational capacity, more fully saturated matched logistic regression analyses can replace attempts to model complex confounding conditions. The experience implies that etiologic investigations of chronic diseases are feasible provided that sufficient numbers of workers are exposed and routine administrative work histories are able to distinguish relevant exposures. Race information, as a surrogate for socioeconomic status, a possible utilization indicator, and a marker for past exposure differences, may be required for meaningful interpretation. The findings also imply that simplistic surveillance approaches that do not address the complex confounding inherent in this administrative data could easily miss important chronic disease associations. Comparisons of chronic disease rates from claims by current job classification across multiple plants would not be interpretable in many cases.

On the other hand, systematic evaluations of acute or subacute health effects related to current or recent work appear to be very feasible.[1,2] Priority issues in industry might include respiratory, neurologic, musculoskeletal, or other concerns in processes such as machining, welding, painting, assembly, electronics fabrication, or injection molding. For both acute and chronic conditions, medical claims for diagnostic tests interpreted as negative represent a potentially overwhelming false-positive threat, although observing excess diagnostic activity associated with an exposure may itself provide a useful sentinel marker of work-related morbidity.

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Population Changes in US Cities*

	NY City	Chicago	Philadelphia	Detroit	Los Angeles
1930	6.9	3.3	1.9	1.5	1.2
1940	7.4	3.4	1.9	1.6	1.5
1950	7.8	3.6	2.1	1.8	2.0
1960	7.7	3.5	2.0	1.6	2.4
1970	7.8	3.3	1.9	1.5	2.8
1980	7.0	3.0	1.6	1.2	2.9
1990	7.3	2.7	1.5	1.0	3.4

* US Census Bureau data (in millions).

—From Cawthon R. Report from: Detroit. *Philadelphia Inquirer*, May 30, 2000, p A3.