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MORTALITY AMONG SHEET METAL WORKERS PARTICIPATING IN A RESPIRATORY SCREENING PROGRAM

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ABSTRACT

Background The Sheet Metal Occupational Health Institute Trust (SMOHIT) was formed in 1985 to examine the health hazards of the sheet metal industry in the U.S. and Canada through an asbestos disease screening program. This investigation updates findings concerning mortality patterns among screening program participants and further investigates predictors of increased mortality due to lung cancer, mesothelioma, and COPD.

Methods A cohort of 17,345 individuals with 20 or more years in the trade and who participated in the asbestos disease screening program were followed for vital status and causes of death between 1986 and 2010. Data from the screening program included chest x-ray results by ILO criteria, spirometry, and smoking history. Standardized Mortality Ratios (SMR) by cause were generated using U.S. death rates. Cox proportional hazards models were used to investigate predictors of death due to lung cancer, mesothelioma, and COPD

Results A significantly reduced SMR of 0.83 (95% CI=0.81-0.85) was observed for all causes combined. Statistically significant excess mortality was observed for pleural cancers, mesothelioma, and asbestosis in the SMR analysis. In Cox models, which controlled for smoking, increased lung cancer risk was observed among workers with ILO scores of 0/1 (RR=1.10, 95% CI=0.86-1.39), with a strong trend for increasing lung cancer risk with increasing ILO profusion scores greater than 0/0. Among workers with an ILO profusion score < 1/0, an FEV1 /FVC ratio less than 80% was associated with an increased risk for lung cancer. COPD mortality was predicted by increased initial markings on the chest x-ray, FVC below 70% of predicted, FEV1 below 70% of predicted, and an FEV1 /FVC ratio below 70%. The risk of death from cancers of the pleura and mesothelioma also were significantly increased among workers without radiological evidence of asbestosis or pleural abnormalities.

Conclusions Sheet metal workers are at increased risk for asbestos-related diseases. This study contributes to the literature demonstrating asbestos-related diseases among workers with largely indirect exposures and supports an increased lung cancer risk among workers with low ILO profusion scores.

KEY WORDS: sheet metal worker, construction trades, mortality, cancer, lung cancer

KEY FINDINGS

Statistically significant excess mortality was observed for pleural cancers, mesothelioma, and asbestosis among workers participating in the Sheet Metal Occupational Health Institute Trust (SMOHIT) medical screening program, diseases associated with a history of asbestos exposure.

After controlling for smoking, increased lung cancer risk was observed among workers with ILO profusion scores of 0/1, with a strong trend for increasing lung cancer risk with increasing ILO profusion score greater than 0/0.

Among workers with an ILO profusion score ≥ 1/0, an FEV1 /FVC ratio less than 80% was associated with an increased risk for lung cancer.

COPD risk was predicted by increased interstitial markings on the chest x-ray, FVC below 70% of predicted, FEV1 below 70% of predicted, and an FEV1 /FVC ratio below 70%.

The risk of cancers of the pleura and mesothelioma also were significantly increased among workers without radiological evidence of asbestosis or pleural abnormalities.

BACKGROUND

Numerous studies have documented the health effects of occupational exposure to asbestos [Becklake ,1976; Nicholson et al., 1982; Selikoff et al., 1978; IARC, 2009; American Thoracic Society, 2004]. Based on the results of studies undertaken in the 1980s [Zoloth and Michaels, 1985; Selikoff and Lilis, 1991], the Sheet Metal Workers International Association (SMWIA)

spirometry, performed according to American

as was done by Cullen et al. [2005]. A pleural abnormality was defined as bilateral pleural thickening or plaques, with or without calcification [Cullen et al., 2005]. .

Multivariate Modeling of Lung Cancer, Mesothelioma, and COPD Mortality Predictors

Within the overall cohort, further analyses were undertaken to examine the association between chest x-ray readings, spirometry, work history, and smoking and mortality due to lung cancer, mesothelioma, and COPD. Analyses of the relationship between chest film changes and lung cancer mortality were restricted to Cauc

Cox proportional hazards models were fit using PROC PHREG in SAS Version 9.3 [SAS, 2011]. The EXACT method of handing ties in PROC PHREG was used and the assumption of proportional hazards over the follow-up period was assessed with time-dependent covariates (the product of log-transformed time and the factor of interest). The ASSESS option for testing the proportional hazard assumption available in SAS Ver 9.3 also was used for this purpose.

RESULTS

There were 6,636 deaths as of December 31, 2010 among the 17,345 workers in the cohort (Table I). The cohort was almost entirely male and Caucasian with a mean age of 57.4 years at intake exam. Twenty-six percent of the cohort had never smoked cigarettes, and 25.4% were still smoking at the time of their intake exam. Radiographic parenchymal changes (profusion > 1/0) were observed in 10.4% of workers and 21.7% had radiographic pleural changes. There were 808 deaths from lung cancer, 85 deaths from mesothelioma with an additional 11 deaths coded to malignant neoplasm of the pleura, and 461 deaths from COPD.

Standardized mortality ratio analyses showed a significant deficit for all causes of death (Table II). The SMR for malignant neoplasm of the trachea, bronchus, and lung was 1.03 which was not significantly elevated. The SMR for mesothelioma and for malignant neoplasms of the pleura were both significantly elevated. The SMR was significantly decreased for a number of causes of death, including heart disease and diseases of the respiratory system, with the exception of a significantly elevated SMR of 11.74 for asbestosis.

Table III displays mortality for selected causes of death by time since entry into the sheet metal di

trade, and years since last sheet metal trade work at exam were also predictive of COPD mortality.

DISCUSSION

Sheet metal workers who participated in this nationwide screening program had a reduced SMR overall compared to the US population, consistent with a healthy survivor effect. No overall increase in lung cancer mortality was observed among this cohort when compared to the US population; however, SMR analyses revealed excess mortality for mesothelioma, malignant neoplasm of the pleura, and asbestosis. Additionally, the SMR analyses demonstrated significant excess risk for lung cancer and COPD among workers with parenchymal changes ≥ 1/0 in profusion. The SMR was significantly elevated for pleural cancers, mesothelioma, and asbestosis among workers who did not have parenchymal changes. Cox proportional hazards models controlling for smoking confirmed the excess risk of lung cancer among workers with a profusion score ≥ 1/0 and provided compelling evidence for excess lung cancer risk among workers with parenchymal profusion scores <1/0 on the ILO scale.

In addition to smoking and abnormal pulmonary function, which are known risk factors for COPD mortality, both increased interstitial markings on chest x-ray and years in the sheet metal trade were also predictive of death from COPD. These findings suggest a relationship between asbestos exposure and death from COPD. Previous research has shown that asbestos exposure is associated with obstructive disease on lung function testing [ATS, 2004, Dement, et al., 2010]. Exposure to dust, fumes, gases, and vapors is recognized as a cause of COPD, and of mortality from COPD among construction workers [Bergdahl, 2006]; asbestos is an important

Although prior research had found a relationship between the presence of pleural plaque and lung cancer mortality [Loomis et al., 1989; Hillerdal, 1994; Karjalainen et al., 1999; Cullen et al., 2005; Ameile et al, 2011] our study did not find an excess lung cancer risk among workers with pleural changes after adjustment for other more covariates including duration of sheet metal

REFERENCES

Allison PD 1995. Survival Analysis Using the SAS System – A Practical Guide. , Cary , NC: SAS Institute Inc. 1995

American Thoracic Society. Standardization of Spirometry -1987 update. 1987. Am Rev Respir Dis .136:1285-1298.

American Thoracic Society. (2004. Diagnosis and initial management of nonmalignant diseases related to asbestos.Am J Respir Crit Care Med 170(6): 691-715.

Ameille, J., P. Brochard, Letourneux M, Paris C, Giron JC . 2011. Asbestos-related cancer risk in patients with asbestosis or pleural plaques. Rev Mal Respir 28(6): e11-e17.

Anttila S, Karjalainen A, Taikina-aho O, Kyllonen P, Vainio H. 1993. Lung Cancer in the Lower Lobe is Associated with Pulmonary Asbestos Fiber Count and fiber Size. Environmental Health Perspectives 110(2):166-170.

Becklake MR. 1976. Asbestos-related diseases of the lung and other organs: their epidemiology and implications for clinical practice. Am Rev Respir Dis 114(1):187-227.

Bergdahl IA, Toren K, Eriksson K, Hedlund U, Nilsson T, Flodin R, Järvholm B (2004) Increased mortality in COPD among construction workers exposed to inorganic dust. Eur Respir J 23:402-406.

Baker EL, Dagg T, Greene RE.1985. Respiratory illness in the construction trades: 1. The significance of asbestos-associated pleural disease among sheet metal workers. J Occup Med 27:483-489.

Berry G. 1981. Mortality of workers certified by pemumoconiosis medical panels as having asbestosis. British Journal of Industrial Medicine. 38:130-137

Bilgrad R. 1995. National Death Index Plus: Cod Causes of Death Supplement to the National Death Index User's Manual, Centers for Disease Control and Prevention.

Boyle CA, Decoufle P. 1990. National sources of vital status information: Extent of coverage and possible selectivity in reporting. Am J Epidemiol. 131:160- 168.

Cookson WO, Musk AW, Glancy JJ; de Klerk NH, Yin R, Mele R, Carr NG, Armstrong BK, Hobbs MS. 1985. Compensation, radiographic changes, and survival in applicants for asbestosis compensation. Br J Ind Med. 42(7):461-8.

Coutts II JC, Turner-Warwich M. 1987. Mortality in cases of asbestosis diagnosed by pneumoconiosis medical panel. Thorax. 42:111-116.

Cullen M, Barnett MJ, Balmes JR, Cartmel B, Redlich CA, Brodkin C et al. 2005. Predictors of Lung Cancer among Asbestos-exposed Men in the a-Carotene and Retinol Efficacy Trial. Am J Epidemiol.161(3):260-270.

Dement J, Welch L, Haile E, Myers D. 2009. Mortality among sheet metal workers participating in a medical screening program. Am J Ind Med. 52(8):603-13.

Eisen EA, Robins AM, Greaves IA, Wegman DH. 1984. Selection effects of repeatability criteria applied to lung spirometry. Am J Epid. 120:734-742.

Finkelstein MM. 2010. Absence of radiographic asbestosis and the risk of lung cancer among asbestos-cement workers: Extended follow-up of a cohort. Am J Ind Med 53(11):1065-1069.

Finkelstein M, Kusiak R, Suranyl G. 1981. Mortality among workers receiving compensation for asbestosis in Ontario. CMA Journal.125:259-262.

Hankinson JL, Odencrantz JR, Fedan KB. 1999 Spirometric reference values from a sample of the General U.S. population. Am J Respir Crit Care Med. 159:179–187.

Hillerdal G. 1994. Pleural plaques and risk for bronchial carcinoma and mesothelioma: a prospective study. Chest. 105:144–50.

Horm J. 1996. Assignment of Probabilistic Scores to National Death Index Record Matches NDI User's Manual Addendum, Centers for Disease Control and Prevention.

Huuskonen MS. 1978. Clinical Features, Mortality and Survival of Patients with Asbestosis. Scand. Journ. Work Enviro. 4:265-274.

IARC 2009. Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 100 C, Arsenic, Metals, Fibres, and Dusts volume 100 C, A Review of Human Carcinogens, International Agency for Research on Cancer, 150 cours Albert Thomas, 69372 Lyon Cedex 08, France

ILO U/C. 1980. International Classification of Radiographs of Pneumoconiosis. Geneva: ILO.

Karjalainen A, Pukkala E, Kauppinen T, Partanen T. 1999. Incidence of cancer among Finnish patients with asbestos-related pulmonary or pleural fibrosis. Cancer Causes Control 10(1): 51-57.

Nicholson WJ, Perkel G, Selikoff IJ. 1982. Occupational exposure to asbestos: population at risk and projected mortality--1980-

Table I: Sheet Metal Cohort Demographics and Vital Status

Characteristic	Total Cohort	Lung Cancer Deaths
Number of Workers	17,345	808
Total Deaths, December 31, 2010	6,636	---
Percent Male	99.8%	100%
Percent Caucasian	99.2%	99.4
Age at Intake Exam (Mean, (SD))	57.4(8.7)	61.2 (7.7)
Smoking Status at Intake Exam (No. (%))[1]		
Never Smoked	26.0%	6.6%
Past Smoker	48.6%	42.7%
Current Smoker	25.4%	50.7%
Smoking Pack-Years for Ever Smoked (Mean, (SD))	32.3 (22.4)	44.3 (24.4)
Years of Sheet Metal Trade Work (Mean, (SD))	31.9 (7.2)	33.5 (7.7)
Prevalence of Radiographic Parenchymal Changes[2]	10.4%	19.7%
Prevalence of Radiographic Pleural Changes[3]	21.7%	26.1%

[1] 24 workers missing smoking data

Table II: Sheet Metal Worker Overall Mortality

Nervous system disorders	249	263.28	0.95	0.83	1.07
Heart diseases	1871	2486.51	0.75**	0.72	0.79
Other diseases of the circulatory system	509	645.79	0.79**	0.72	0.86
Diseases respiratory system	743	839.70	0.88**	0.82	0.95
Acute resp. infection, except. flu, pneumonia	3	1.22	2.46	0.51	7.19
Influenza	3	2.76	1.09	0.22	3.18
Pneumonia	129	196.57	0.66**	0.55	0.78
COPD	461	485.42	0.95	0.86	1.04
Asthma	5	7.28	0.69	0.22	1.60
Asbestosis	48	4.11	11.68**	8.61	15.48
Silicosis	0	0.68	0.00	0.00	5.44
Other pneumoconiosis	1	4.00	0.25	0.01	1.39
Other respiratory diseases	93	137.67	0.68**	0.55	0.83
Diseases digestive system	194	267.43	0.73**	0.63	0.84
Diseases skin & subcutaneous	5	8.21	0.61	0.20	1.42
Diseases musculoskeletal & connective	14	23.02	0.61	0.33	1.02
Diseases genito-urinary system	109	162.66	0.67**	0.55	0.81
Symptoms & ill-defined conditions	39	59.32	0.66**	0.47	0.90
Transportation injuries	62	71.80	0.86	0.66	1.11
Falls	63	56.42	1.12	0.86	1.43
Other injury	56	75.67	0.74*	0.56	0.96
Violence	65	90.62	0.72**	0.55	0.91
Other & unspecified causes	164	206.96	0.79**	0.68	0.92

* Two-Sided P < 0.05 ** Two-Sided P < 0.01

Table III: Sheet Metal Worker Mortality by Time since Entry into Sheet Metal Trade

Disease Category	Time Since Trade Entry (Years)	Obs.	Exp.	SMR	95% Confidence Limits Lower	Upper

Table IV: Sheet Metal Worker Mortality by Chest X-Ray Parenchymal Category

Disease Category	Parenchymal Change Category	Obs.	Exp.	SMR	95% Confidence Limits Lower	Upper
Lung Cancer	0/- to 0/1	649	693.46	0.94	0.87	1.01
	1/0 to 1/2	143	86.85	1.65**	1.39	1.94
	2/1 to 2/3	14	4.28	3.27**	1.79	5.48
	3/2 to 3/+	2	0.26	7.58	0.92	27.38
MN Pleura	0/- to 0/1	10	1.27	7.89**	3.78	14.51
	1/0 to 1/2	1	0.20	4.92	0.12	27.40
	2/1 to 2/3	0	0.01	0.00	0.00	300.99
	3/2 to 3/+	0	<0.01	0.00	0.00	6087.99

Table V: Sheet Metal Worker Mortality by Chest X-Ray Pleural Category

Disease Category

Table VI: Cox Model Chest Radiograph Predictors of Lung Cancer Mortality[1]

Table VII: Cox Model Spirometry Predictors of Lung Cancer Mortality[1]
Sheet Metal Workers with ILO Profusion Scores <1/0

Risk Predictor	Number in Model[2]	No. of Cancer Cases	Relative Risk[2]	95% Confidence Limits	
				Lower	Upper
FVC Percent Predicted[4]					
>=80	7354	226	1.00	Ref	Ref
70-79	1159	66	1.16	0.92	1.65
60-69	471	43	1.54	0.94	2.50
<60	240	28	1.73	0.95	3.16
FEV_1 Percent Predicted[4]					
>=80	7116	176	1.00	Ref	Ref
70-79	1020	70	1.58	1.13	2.22

Table VIII: Cox Model Predictors of Mesothelioma Mortality

Risk Predictor	Number in Model[1]	No. of Cancer Cases	Relative Risk[2]	95% Confidence Limits	
				Lower	Upper
Profusion Categories					
< 1/0	14407	72	1.00	Ref	Ref
≥ 1/0	1661	17	1.77	1.03	3.05
Pleural Abnormalities[2]					
Negative	13997	67	1.00	Ref	Ref
Positive	2071	22	1.79	1.09	2.94
Age[3]	16068	89	1.063	1.034	1.092

[1] Cox proportional hazard analyses based on 16068 Caucasian males with 20 or more years in sheet metal trade and having data on other model covariates. Smoking (p=0.24), years of sheet metal work beyond 20 years (p=0.73), years since last sheet metal work (p=41), percent predicted FVC (p=0.16), and percent predicted FEV_1/FVC (p=0.19) were not significant predictors of mesothelioma mortality and were

Table IX: Cox Model Predictors of COPD Mortality[1]

Risk Predictor	Number in Model[2]	No. of COPD