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Mortality from infectious pneumonia in metal workers: a comparison with deaths from asthma in occupations exposed to respiratory sensitizers

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Abstract

Introduction

National analyses of mortality in England and Wales have repeatedly shown excess deaths from pneumonia in welders. During 1979-1990 the excess was attributable largely to deaths from lobar pneumonia and pneumonias other than bronchopneumonia, limited to working-aged men, and apparent in other metal fume-exposed occupations. We assessed findings for 1991-2000 and compared the mortality pattern with that from asthma in occupations exposed to known respiratory sensitizers.

Methods

The Office of National Statistics supplied data on deaths by underlying cause among men aged 16-74 years in England and Wales during 1991-2000, including age and last held occupation. We abstracted data on pneumonia for occupations with exposure to metal fume and on asthma for occupations commonly reported to surveillance schemes as at risk of occupational asthma. We estimated expected numbers of deaths by applying age-specific proportions of deaths by cause in the population to the total deaths by age in each occupational group. Observed and expected numbers were compared for each cause of death.

Results

Among working-aged men in metal fume-exposed occupations we found excesses of mortality from pneumococcal and lobar pneumonia (54 deaths vs. 27.3 expected) and from pneumonias other than bronchopneumonia (71 vs. 52.4), but no excess from these causes at older ages, or from bronchopneumonia at any age. The attributable mortality from metal fume (45.3 excess deaths) compared with an estimated 62.6 deaths from occupational asthma.

Conclusion

Exposure to metal fume is a material cause of occupational mortality. The hazard deserves far more attention than it presently receives.

Introduction

Successive analyses of occupational mortality for England and Wales have demonstrated increased death rates from pneumonia in welders, in a pattern that extends back more than five decades. During 1949-53, 70 deaths were observed with 31 expected;[1] in 1959-63 101 deaths as compared with 54.9 expected;[2] and in 1970-72 66 deaths with 42.0 expected.[3] More recently, an analysis covering the period 1979-80 and 1982-90 confirmed the association and showed that the excess was attributable largely to deaths from pneumonias other than bronchopneumonia (principally lobar pneumonia), was limited to men below the normal retirement age of 65 years (55 deaths from lobar pneumonia observed, 21.6 expected), and was also evident for several other occupations entailing exposure to metal fume, such as moulders and coremakers and furnacemen in foundries.[4] In a subsequent case-control study of working-aged men,[5] community-acquired pneumonia was associated with occupational exposure to metal fume in the previous 12 months but not in earlier periods, supporting the hypothesis of a hazard that is reversible following cessation of exposure and that affects the incidence of disease (and not just its fatality). Risks were highest for recent exposure to ferrous metal fume with lobar pneumonia as the outcome,[5] and emerging hypotheses posit ferrous fume as a cause of oxidative damage to host lung defences or as a growth nutrient in the iron-restricting environment of the lung's linings.[6]

Despite this growing body of evidence, the hazard of infectious pneumonia in men with occupational exposure to metal fume seems to be little appreciated and accorded limited priority in terms of research and preventive effort. To confirm its continuing relevance under more recent working conditions, we extended our analysis of occupational mortality for England and Wales to the latest period for which data are now available (1991-2000). Also, to place risks in context, we compared the estimated excess of deaths from exposure to metal fume with estimates in relation to asthma for occupations exposed to known respiratory sensitizers. This was chosen as another occupational lung disease which, by comparison with metal fume related pneumonia, receives considerable and appropriate preventive attention. Thus, as well as providing a comparison with mortality from metal fume-associated pneumonia, we offer a national estimate of the burden of asthma deaths arising from occupational causes (for which there is little prior information and some inherent problems in estimation).

Methods

The UK Office of National Statistics supplied us with data on deaths by underlying cause among men aged 16-74 years in England and Wales during 1991-2000, including details of age, last occupation held, and social class. Occupations were coded according to the Office of Population Censuses and Surveys (OPCS) 1990 Classification of Occupation[7] and causes of death according to the International Classification for Diseases, 9th Revision.[8]

From the supplied data, we estimated expected numbers of deaths by applying age-specific proportions of deaths by cause in the general population to the total number of deaths at each age in each occupational group. Expected numbers were adjusted for social class.

We abstracted data on: (1) pneumonia (ICD-9 480-483, 485, 486), for occupations with exposure to metal fume defined *a priori*[4,6] (welders, moulders and coremakers, furnace operatives, sheet metal workers, and other metal manufacturers); and on (2) asthma

(ICD-9 125) for a selection of occupations commonly reported to European surveillance schemes as at special risk of sensitizer-induced occupational asthma (e.g. workers in textiles, plastics, healthcare, agriculture, animal handling, baking, spray painting, woodworking, and electrical assembly)[9-12] and/or in which deaths have from occupational asthma have been documented[13-17] (see Table 1).

Table 1 Occupations at risk of mortality from occupational asthma

Author (Year)	Occupation/Exposure
Occupations commonly reported to European surveillance schemes as at particular risk of occupational asthma	
Ameille (2003)[9]	Bakers and Pastry Makers, Health Workers, Spray Painters, Hairdressers, Woodworkers, Farmers and Stockbreeders, Cleaners, Laboratory Technicians, Welders, Textile Workers.
Kogevinas (1999)[10]	Farmers, Other Painters, Plastics, Cleaners, Spray Painters, Agricultural, Other Non-Metal Non-Electrical, Textiles, Glass and Ceramics, Chemicals, Construction and Mining, Welders, Bakers, Metal-Making, Other Food
McDonald (2000)[11]	Laboratory Technicians and Assistants, Nurses, Farm and Farm Hands, Woodworkers, Food Processors (excluding Bakers), Bakers, Plastic Workers, Chemical Processors, Other Material Processors (excluding Metal and Electrical), Welders Solderers and Electronic Assembly Workers, Coach and Other Spray Painters.
Karjalainen (2000)[12]*	Veterinary Workers, Agricultural Forestry and Fishery Workers, Farmers, Animal Husbandry Workers, Other Farming and Animal Husbandry Work, Welders and Flame Cutters, Floor Layers, Plywood and Fibreboard Workers, Woodworking Machine Operatives, Other Painters and Lacquerers, Bakers, Butchers and Sausage Makers, Process Food Preparers, Other Food and Beverage Manufacturing Work, Other Chemical Processing Workers, Plastic Product Workers, Chefs, Cooks and Cool Buffet Managers, Hairdressers and Beauticians.
Exposures/occupations linked with deaths from occupational asthma	
Fabbri (1988),[13] Carino (1997)[14]	Isoscyates
Ehlich (1994)[15]	Baker
Liss (1999)[16]	Wood dust, persuphate
Ortega (2002)[17] (Review)	Laboratory work, food processing, baking, milling, autobody painting

*Male occupations with an annual incidence rates at least twice that of all occupations combined

In compiling the final choice of occupational codes for asthma we focussed on occupations where we judged exposure to sensitizers to be fairly common and excesses of mortality to be plausibly related to occupation rather than to chance. Two of us (KTP and PC) chose the codes independently with any differences of opinion resolved by consensus; choices were made blind to data on mortality by occupation.

Observed and expected numbers were compared for each cause of death and proportional mortality ratios (PMRs) calculated, with 95% confidence intervals (CI) based on the Poisson distribution. Deaths from pneumonia in metal fume-exposed occupations were analysed separately for men aged 16-64 and 65-74 years as well as overall. To estimate attributable deaths from pneumonia in metal fume-exposed workers, we calculated the difference between observed and expected numbers of deaths at ages 16-64 years, since the elevation of risk is known to be short-lived and unlikely to extend beyond retirement.[4,5] However, given the known persistence of airways irritability in cases of occupational asthma, and the potential for attributable deaths to occur after retirement, we counted excess deaths from asthma at ages 16 through to 74 years.

Results

Among working-aged men (16-64 years) who had worked in occupations with exposure to metal fume (Table 2) there were excesses of mortality from pneumococcal and lobar pneumonia (ICD-9 481: 54 deaths vs. 27.3 expected), and from other pneumonias (ICD-9 480, 482-3, 486: 71 deaths vs. 52.4 expected), especially viral pneumonia (PMR 299) and other bacterial pneumonia (PMR 237). However, no excess was found from these causes at older ages or from bronchopneumonia (ICD-9 486) at any age.

Table 2 Mortality from pneumonia among men in metal working occupations* in England and Wales, 1991-2000

Types of Pneumonia§	Ages 16 – 64				Ages 65 - 74			
	Observed	Expected	PMR	(95% CI)	Observed	Expected	PMR	(95% CI)
Pneumococcal and unspecified lobar (481)	54	27.3	198	(149-258)	44	40.4	109	(79-146)
Other and unspecified pneumonia:								
Viral (480)	6	2.0	299	(110-650)	0	0.9	0	(0-400)
Other Bacterial (482)	10	4.2	237	(114-436)	2	3.7	54	(6-194)
Organism unspecified (486)	53	44.4	119	(89-156)	106	101.9	104	(85-126)
Other Specified Pneumonia (483)	2	1.8	108	(13-392)	0	1.1	0	(0-322)
Bronchopneumonia (485)	117	123.9	94	(78-113)	400	415.3	96	(87-106)

* Occupations as defined in Table 3.
§ International Classification for Diseases, 9th revision codes given in parentheses.

Among working-aged men, excesses of pneumococcal and lobar pneumonia were noteworthy in welders (PMR 242), in moulders and coremakers (PMR 300), and in sheet metal workers (PMR 268) (Table 3).

Table 3 **Mortality from pneumonia among men aged 16 – 64 years in metal working occupations in England and Wales, 1991-2000**

Occupations*	Pneumococcal and unspecified lobar pneumonia (ICD-9 481)§				Bronchopneumonia (ICD-9 485)§				Other and unspecified pneumonia (ICD-9 480, 482, 483, 486) §			
	Obs	Exp	PMR	(95% CI)	Obs	Exp	PMR	(95% CI)	Obs	Exp	PMR	(95% CI)
Welders (149)	32	13.2	242	(166 - 342)	54	59.4	91	(68 - 119)	45	25.9	174	(127 - 233)
Furnace Operators (metal) (112)	1	1.0	96	(2 - 536)	10	5.5	183	(88 - 336)	2	2.1	94	(11 - 338)
Moulders and Coremakers (metal) (116)	5	1.7	300	(97 - 701)	7	8.3	84	(34 - 173)	2	3.4	59	(7 - 213)
Other Metal Manufacturers (120)	3	6.5	46	(10 - 135)	21	27.8	76	(47 - 115)	12	11.2	107	(56 - 188)
Sheet Metal Workers (145)	13	4.8	268	(143 - 459)	25	22.9	109	(71 - 161)	10	9.9	102	(49 - 187)

Obs = observed; Exp = expected

* As defined in OPCS classification of occupation - OPCS codes given in parentheses.

§ International Classification for Diseases, 9th revision code

Assuming the excess of attributable deaths was confined to working-aged men dying of pneumococcal and lobar pneumonia, and pneumonias other than bronchopneumonia, Table 2 suggests an attributable mortality from occupational metal fume (excess of observed vs. expected) of 45.3 deaths. This compared with an estimated 62.6 excess of observed vs. expected deaths from asthma over the same time interval among men aged 16-74 years from the occupations listed in Table 4 (see online supplement - overall PMR 110, 95%CI 102-118), among whom synthetic fibre makers (PMR 740), other textile processing operatives (PMR 254), dental technicians (PMR 230) and other health professionals (PMR 223) showed the most noteworthy relative elevations in mortality.

Discussion

In keeping with national analyses of occupational mortality covering earlier periods, we found an excess of deaths from pneumonia among male welders during 1991-2000. Following the model of one previous analysis,[4] we also confirmed that the excess risk extended to other workers with occupational exposure to metal fume, was principally confined to deaths from lobar pneumonia, and was limited to men below the normal retirement age of 65 years. As in an earlier report, the absence of an association with bronchopneumonia provided evidence against confounding by smoking. Assuming a short-term reversible effect of work, the estimated excess of deaths among 16-64 year-olds was about 45 over the decade in question, and was material in comparison with, although lower than, the 63 deaths we ascribed to occupational asthma.

This analysis and interpretation has several limitations. Death certification over the study period is likely to have been almost complete, but with the potential for misclassification of cause of death. For example, some deaths from occupational asthma in bakers could have been ascribed to chronic obstructive pulmonary disease, a recognised problem in recording asthma deaths in general.[18] This would lead to an underestimate of mortality from asthma in the occupations selected for study, but in both the observed and expected counts, and so would not necessarily bias an estimate of risk difference. On the other hand, a part of the excess asthma mortality in the occupations in Table 4 may have arisen by chance rather than as a consequence of occupational sensitisation (the risk ranking of occupations by mortality did not correspond exactly to what might be expected from statistics on morbidity[11]); we did not have access to detailed clinical data or post-mortem findings on individuals. Deaths from chemical pneumonitis might have been ascribed to unspecified pneumonia, but large-scale misdiagnosis as pneumococcal or lobar pneumonia (the main outcome) seems unlikely, and there is empirical evidence against it from earlier investigations.[4]

Misclassification of exposure is another possibility. Death certificates in the UK record the last held occupation, which for some subjects may have preceded death by several years. Cases of occupational asthma may have arisen during earlier employments that were changed because of chronic symptoms or health advice (unhealthy worker selection bias). Under-attribution of deaths from occupational asthma could thus arise in the occupations chosen for analysis. This is less likely in relation to deaths from pneumonia as fatal cases of the illness will typically have had a rapid onset, with less opportunity to occasion a change of employment.

Other ways in which exposure misclassification can arise include heterogeneity of exposure experience in workers who share a common job title, and the selection of occupations for inclusion in our analysis. All welders are likely to have been exposed to metal fume within their job, and all bakers to flour dust; but only a proportion of textile process workers will have been exposed to reactive dyes, and similarly only a minority of coach painters and vehicle body repairers to isocyanates.

Other factors being equal, the inclusion of an occupation in which a minority of workers have relevant exposure will not bias estimates of risk difference (observed minus expected numbers); but the larger the pool of occupations selected, the greater the potential for plays of chance or unrecognised confounding to conceal genuine differences measured on an absolute scale. The risk of including too many occupations in analysis, however, has to be weighed against the potential to include too few and thereby omit occupations in which cases may arise. Table 4, although based on an appraisal of current awareness, may not have included every occupation in which an attributable case of fatal asthma arose. In fact, as Leigh *et al* point out, "no data are available that unambiguously count the number of deaths nationally from occupational asthma",[19] and the methodology for doing so is not yet well established. (Thus for example, a Swedish registry survey,[20] which highlighted differences in asthma mortality by occupation, could not estimate the occupation-attributable mortality in the absence of a rule for counting attributable deaths.)

The estimates for asthma in this paper are tentative therefore, and do not include the additional toll arising from work-aggravated asthma. They serve to illustrate, however, that the mortality risk of occupational exposure to metal fume is not inconsiderable relative to another well-recognised respiratory hazard of public health significance and concern.

Occupational and work-aggravated asthma have other well-advertised and important consequences, in terms of chronic ill health and hospitalisation episodes. To a degree, infectious pneumonia induced by exposure to metal fume is also a source of morbidity: only a minority of cases are fatal, but the increased risk extends to non-fatal cases admitted to hospital with serious illnesses.[5]

In sum, the hazard of occupational exposure to metal fume is an ongoing problem, still detectable after more than five decades, and the hazard deserves far more priority than it presently receives.

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Table 4: Mortality from asthma among men aged 16-74 years in occupations commonly reported to European surveillance schemes as being at a particular risk of occupational asthma

Occupation*	Deaths Obs	Deaths Exp	PMR	(95% CI)
Doctors (015)	7	8.4	83	(33 - 171)
Dentists (016)	3	1.9	155	(32 - 453)
Nurses (017)	15	10.1	149	(83 - 246)
Dental Technicians (110)	3	1.3	230	(47 - 671)
Medical Radiographers (019)	0	0.3	0	(0 - 1095)
Ambulance Staff (062)	9	5.1	175	(80 - 333)
Other Health Professions (021)	11	4.9	223	(111 - 398)
Veterinarians (022)	1	0.7	134	(3 - 746)
Biological scientists (026)	0	3.1	0	(0 - 117)
Chemical Engineers and Scientists (027)	4	6.2	64	(17 - 164)
Electrical and Electronic Engineers (professional) (029)	2	3.1	66	(8 - 237)
Laboratory Technicians (032)	6	9.4	64	(23 - 139)
Butchers (042)	31	18.6	167	(113 - 237)
Bakers (076)	16	12.0	133	(76 - 216)
Fishmongers, Poultry Dressers (043)	1	1.5	67	(2 - 376)
Caterers (046)	26	26.6	98	(64 – 143)
Cooks and Kitchen Porters (059)	43	32.6	132	(95 - 177)
Farmers (047)	113	110.5	102	(84 - 123)
Hairdressers (052)	8	6.6	122	(53 - 241)
Beauticians & Related Occupations (195)	0	0.2	0	(0 - 2366)
Fishing & Related Workers (066)	1	4.5	22	(1 - 124)
Tannery Production Operatives (067)	1	0.9	106	(3 - 588)
Warp Preparers, Bleachers, dyers & finishers (073)	4	3.1	129	(35 - 330)
Other Textile Processing Operatives (074)	11	4.3	254	(127 - 454)
Chemical workers (075)	12	23.5	51	(26 - 89)
Other Food, Drink & Tobacco Process Operatives nec (078)	16	17.1	93	(53 - 152)
Synthetic Fibre Makers (087)	4	0.5	740	(202 - 1896)
Plastic goods makers (093)	12	7.0	171	(89 - 299)
Printers (097)	34	23.8	143	(99 - 199)
Carpenters & Joiners (104)	69	67.8	102	(79 - 129)
Cabinet Makers (105)	5	6.5	76	(25 - 178)
Case & Box Makers (106)	2	1.3	149	(18 - 539)
Pattern Makers (moulds) (107)	1	1.8	55	(1 - 308)
Woodworking Machine Operatives (108)	9	7.4	122	(56 - 232)
Other Woodworkers (109)	2	2.2	89	(11 - 323)
Furnace Operatives (metal) (112)	2	3.3	61	(7 - 221)
Moulders, Core Makers, Die Casters (116)	5	5.3	94	(31 - 220)
Electroplaters (117)	4	2.5	162	(44 - 415)
Machine Tool Setter Operatives (123)	21	18.9	111	(69 - 170)
Machine Tool Operatives (124)	93	88.8	105	(85 - 128)
Radio, TV & Video Engineers (141)	8	4.9	162	(70 - 319)
Other Electrical/Electronic Trades nec (142)	27	26.4	102	(67 - 149)
Welding Trades (149)	30	31.6	95	(64 - 135)

Jewellery Workers (151)	2	1.4	140	(17 - 507)
Vehicle body repairers, panel beaters (153a)	5	3.7	135	(44 - 316)
Coach Painters (158)	11	9.7	114	(57 - 203)
Assemblers/Lineworkers (electrical/electronic goods) (161)	9	6.0	150	(69 - 284)
Assemblers/Lineworkers (vehicles & other metal goods) (163)	17	16.1	106	(61 - 169)
All	716	653.4	110	(102 - 118)

Obs = observed; Exp = expected; nec= not elsewhere classified

* As defined in OPCS classification of occupation - OPCS codes given in parentheses.