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Mortality experience among chromeplating workers¹

Initial findings

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FRANCHINI I, MAGNANI F, MUTTI A. Mortality experience among chromeplating workers: Initial findings. *Scand j work environ health* 9 (1983) 247-252. A retrospective cohort study was conducted in nine chromeplating plants to examine the mortality of workers employed for at least one year during the period January 1951-December 1981. The study group totaled 178 individuals, 116 of whom were from "hard" and 62 from "bright" chromeplating plants. Vital status ascertainment was 97 % complete. The total number of deaths was fairly close to the expected figure (15 observed, 15.2 expected), whereas deaths from tumors exceeded the expected number (8 observed, 4.2 expected). Individuals were distinguished into two subcohorts depending on the exposure intensity, which was much higher in hard than in bright chromeplating. Most deaths from cancer occurred among hard chromium platers, the excess against the expected rate being statistically significant (7 observed, 2.7 expected, $p = 0.02$). All deaths from lung cancer occurred in this subcohort (3 observed, 0.7 expected, $p = 0.03$). The increased mortality from cancer among chromium platers seems to be related to exposure intensity and strongly suggests the need for further studies on larger cohorts to confirm the carcinogenicity of chromic acid in man.

Key terms: chromic acid, chromium, epidemiology, lung cancer, mortality, neoplasms.

An association between chromium exposure and cancer has been suggested by several studies on mortality among workers in monochromate and dichromate production (2, 8, 11, 13, 14, 18, 19, 22, 27). On the basis of these reports, it was long assumed that only some insoluble hexavalent (VI) chromium compounds resulting from the roasting of chromite ore could cause cancer (21). However, the importance of the water solubility of chromates to carcinogenicity does not appear to be supported by available evidence.

An excess of respiratory cancer was found among workers in chrome pigment manufacturing (6, 7, 17) and among zinc

chromate spray painters (5). Significant excesses of tumors were also found among ferro-chromium workers (16, 24) and electroplaters (3, 25, 26, 28). However a working group at the International Agency for Research on Cancer has judged that epidemiologic data concerning chromium-exposed workers in industries other than the chromate-producing plants do not provide sufficient evidence (15).

The purpose of the present paper is to report the initial findings of a cohort study conducted among electroplaters exposed to water-soluble hexavalent chromium.

Subjects and methods

A survey of mortality has been carried out among employees and retirees from nine chromeplating plants in the province of Parma. Three of these plants produce a type of chromeplating that is called "hard" or "thick," because the metal piece is processed in such a way as to be coated with a chromium plate of varying thickness,

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and exceeding 5 μm , which makes it especially resistant and solid where friction is supposed to be greater – such as in crusher propellers and in camshafts for ship engines. The remaining six plants produce chromium plates of the “bright” type, in which the layer of chromium is much thinner (0.5–1 μm) and has a decorative, as well as a protective, function, ie, in microphones and automobile and bicycle parts.

A total of 178 subjects, 116 of whom had worked at hard and 62 at bright chromeplating plants, were eligible for the study, which involved all male employees who had worked for at least one calendar year in one of the plants during the period 1 January 1951–31 December 1981. With the use of a latency period of 10 years, only those workers who started exposure before January 1972 were included in a further analysis.

The causes of death were available from the official certificates obtained through individual inquiries at the registry offices of the workers' place of residence and in their place of birth. For those workers who had died, the causes of death stated on their certificates were coded according to the Eighth Revision of the International Classification of Disease (ICD VIII).

The expected deaths were calculated with the use of mortality rates relevant to the Italian male population of the same age during the follow-up period. The calculations of p-values were based on the Poisson distribution (1).

Exposure

Airborne chromium concentrations in the electroplating plants of the province of Parma were measured as late as 1980, when the hygienic conditions had already been substantially improved. Out of a total number of 10 measurements in the case of hard chromeplating, the air concentration of chromium averaged 7 (range 1–50) $\mu\text{g}/\text{m}^3$ as chromium trioxide (CrO_3) near the baths and 3 (range 0–12) $\mu\text{g}/\text{m}^3$ in the middle of the room. These values appear to be considerably lower than those reported by Guillemin & Berode (12). They may still however be regarded as a useful landmark for the exposure levels that might have existed prior to the improve-

ments in industrial hygiene, as well as for a comparative evaluation of exposure in hard chromeplating as opposed to the bright form. According to these authors, mean chromium trioxide concentrations of 109 (SD 172) $\mu\text{g}/\text{m}^3$ near the baths and 35 (SD 26.4) $\mu\text{g}/\text{m}^3$ in the middle of the room in hard chromeplating correspond to values of 11 (SD 11.6) and 4.7 (SD 2.3) $\mu\text{g}/\text{m}^3$, respectively, in bright chromeplating.

A biological monitoring program based on the determination of urinary chromium was started in 1974 in the two major plants and was progressively extended to include all the others. Table 1 shows the urinary chromium concentrations found at the end of a workweek during the first inspection carried out between 1974 and 1976. The values found in 1980, after the industrial hygiene had been considerably improved in all plants, are also reported. In addition the daily variation of urinary chromium is reported as a more reliable index of the actual exposure. Such variation is expressed as the difference between the values found at the end of the workshift versus those observed at the beginning of the workday.

The end-shift urinary chromium concentrations that we found during our first investigation overlap when compared to the values reported in the previously mentioned study of Guillemin & Berode, who found 18 (SD 15.6) $\mu\text{g}/\text{g}$ of creatinine corresponding to 39 $\mu\text{mol}/\text{mol}$ of creatinine in hard chromeplating and 5.3 (SD 3.2) $\mu\text{g}/\text{g}$ of creatinine corresponding to 11 $\mu\text{mol}/\text{mol}$ of creatinine in bright chromeplating workers. Such values were also measured in different samples of the cohort (4, 9, 10, 20) and may be considered as typical of an industry which, in spite of the presence of some ventilating exhaust systems, lacks an adequate standard of technological safety.

Measurements were not available for the whole follow-up period. However, the overall exposure can be reasonably assumed to have been definitely higher than that measured during our first investigation.

Results

Almost all individuals had been traced as of 31 December 1981, and their vital status is summarized in table 2. About two-thirds of the subjects and two-thirds of the

person-years totaled during the follow-up was accounted for by people working in hard chromeplating plants. The remainder

of the subjects was employed in the bright ones. For the 15 deceased, certificates of death were obtained. Table 3 shows the

Table 1. Main steps in the biological monitoring of chromium exposure in the plating industry of the province of Parma during the period 1974–1981. (CrU = urinary chromium)

Index	1974–1976			1977–1979			1980–1981		
	Number of subjects	Median	Range	Number of subjects	Median	Range	Number of subjects	Median	Range
<i>Hard plating</i>									
End of shift CrU									
μmol/mol creatinine	52	50.2	9–252	68	24.8	2–61	74	12.4	2–30
μg/g creatinine	52	23.1	4–116	68	11.4	1–28	74	5.7	1–14
ΔCrU									
μmol/mol creatinine	52	16.3	2–120	68	7.0	0–17	74	0.0	0–9
μg/g creatinine	52	7.5	1–55	68	3.2	0–8	74	0.0	0–4
<i>Bright plating</i>									
End of shift CrU									
μmol/mol creatinine	—	—	—	47	12.6	2–39	62	7.6	2–20
μg/g creatinine	—	—	—	47	5.8	1–16	62	3.5	1–9

Table 2. Characterization of the cohort and vital status as of 31 December 1981. Figures in parentheses are based on a 10-year latency period, and they exclude those workers who have been employed after 31 January 1972.

	Hard chrome-plating	Bright chrome-plating	Total
Total in study (number of subjects)	116(93)	62(31)	178(124)
Traced (number of subjects)	113(91)	60(30)	173(121)
Alive (number of subjects)	102(81)	56(27)	158(108)
Dead (number of subjects)	11(10)	4(3)	15(13)
Lost to follow-up (number of subjects)	3(2)	2(1)	5(3)
Person-years	1,651(1,493)	766(542)	2,417(2,035)
Mean age (years)	40.9(42.7)	38.1(41.6)	39.9(42.4)
Duration of exposure (years)	14.3(16.4)	12.3(18.1)	13.6(16.8)

Table 3. Number of observed and expected deaths in the cohort.

Cause of death ^a	Observed	Expected	p-Values ^b
<i>Latency period ≤ 10 years</i>			
All causes	15	15.4	.
All malignant neoplasms (140–209)	8	4.2	0.07
Lung (162)	3	0.9	0.06
Gastrointestinal (151–159)	4	1.4	0.05
Stomach (151)	2	0.5	0.09
Pancreas (157)	2	0.11	0.01
Prostate (185)	1	0.12	.
Accidents and suicide (E800–E999)	2	1.5	.
<i>Latency period > 10 years</i>			
All causes	12	12.3	.
All malignant neoplasms	7	3.5	0.07
Lung	3	0.8	0.05
Gastrointestinal	3	1.2	.
Stomach	1	0.4	.
Pancreas	2	0.1	0.01
Prostate	1	0.1	0.10
Accidents and suicide	2	1.3	.

^a According to the International Classification of Disease, eighth revision.

^b Poisson test.

Table 4. Observed and expected mortality relating to all causes of death and to mortality from cancer in two subcohorts distinguished by exposure intensity, which was much higher in hard than in bright chromeplating.

Cause of death ^a	Hard chromeplating		Bright chromeplating	
	Observed	Expected	Observed	Expected
<i>Latency period ≤ 10 years</i>				
All causes	11	12.2	4	3.2
All malignant neoplasms (140–209)	7**	2.7	1	1.5
Lung (162)	3*	0.7	—	—
Gastrointestinal (151–159)	3	1.1	1	0.3
Stomach (151)	2	0.4	—	—
Pancreas (157)	1	0.08	1*	0.03
Prostate	1	0.1	—	—
<i>Latency period > 10 years</i>				
All causes	9	9.4	3	2.9
All malignant neoplasms	6*	2.2	1	1.3
Lung	3**	0.6	—	—
Gastrointestinal	2	1.0	1	0.26
Stomach	1	0.3	—	—
Pancreas	1	0.06	1**	0.02
Prostate	1	0.08	—	—

^a According to the International Classification of Disease, eighth revision.

* $p < 0.05$, ** $p < 0.02$, Poisson test.

expected and observed mortality experience as verified for 173 of 178 individuals. The total number of deaths is fairly close to that expected, whereas the mortality from tumors exceeds the expected figure. On the assumption of a Poisson's distribution, only digestive system, and particularly pancreas, carcinomas seem to be significantly higher than expected by chance. When a 10-year latency period is required, the observed: expected ratios for death from malignancies and, above all, from lung cancer are slightly increased. On the contrary, the mortality from tumors of the digestive tract and from stomach cancer are reduced to figures not significantly higher than expected. In fact one of the subjects who died from stomach cancer should be excluded, since his exposure started in 1973. It should be noted that he was employed for eight years, until the tumor was diagnosed. Yet, if the subjects are distributed depending on the degree of exposure to chromium, the mortality from tumors appears to be significantly higher than expected for the workers with the highest degree of exposure, ie, working in the hard chromeplating plants (table 4). In this subcohort, a significant excess was found for both all tumors and lung cancer, whereas the association between exposure to chromium and malig-

nancies of the digestive system does not increase to a significant level, above all when a 10-year latency period is required. Of the individuals working in bright chromeplating, one died from pancreas carcinoma. Although statistically significant, the excess over the expected rate might be due to chance. With a 10-year latency period, the observed: expected rate for hard chromeplating workers is even higher for all observed tumors but stomach cancer, whereas in the bright chromeplating subcohort no substantial changes were found in the mortality pattern.

Discussion

Most chromium electroplating plants are very small shops. Moreover exposure data show that only in hard chromium plating is there a real and sometimes hazardous exposure to chromic acid. For practical reasons, it is very difficult to obtain a large cohort of *exposed* workers. The present investigation is a pilot study, which provides some evidence that a causal association might occur between exposure to chromic acid and cancer.

The mortality experience from tumors among electroplaters was found to be doubled as compared to the expected rate. It should be pointed out that malignancies

were almost entirely observed among the group of workers who were really exposed to chromic acid in hard chromeplating plants. This subcohort also showed a significant excess of deaths from lung cancer ($p = 0.03$) and a higher mortality from stomach tumors, which was close to statistical significance when compared to the expected rate ($p = 0.06$). These results are in agreement with most earlier reports. In a mortality study of the electroplating industry in Great Britain, the exposed subjects experienced an excess of deaths from tumors as compared to a group individually matched to the platers by sex, age, and smoking habits (25). On the other hand, a significant excess of lung cancer has also been reported among workers in electroplating (28) or electroplating and die-casting plants (26). Recently Blair (3) reported the results of a cross-sectional study of 1,292 deaths among workers in the metal polishing and plating industry. A proportionate mortality ratio analysis suggested statistically significant excesses for esophageal and liver cancer among platers assumed to be exposed to chromium, nickel, and degreasing agents.

Negative results were obtained in a study of Japanese chromium platers (23). However the negative findings were not related to well-documented exposure data. Moreover the follow-up period was very short, and the ascertainment of the vital status of the cohort was incomplete.

Because of the small size of the cohort, the occurrence of confounding variables was not assessed in the present study. Moreover the correction for initiation dose and development time (latency period) might lead to conflicting results when applied to such a small cohort. In fact, when a 10-year latency period is considered, a "dilution factor" is excluded, making the increased mortality from malignancies, and particularly from lung cancer, statistically significant. On the contrary, deaths from digestive and, above all, stomach cancer are reduced to non-significant rates. If a latency period of eight instead of ten years is assumed, also the significance of stomach cancer is increased further, and not consistently reduced. Therefore the results cannot point to a definite conclusion. There is some positive evidence to support the hypothesis that an excess of deaths from cancer

could occur among chromeplating workers. The increased mortality from cancer seems to be related to the exposure intensity, and a significant excess of lung cancer was found among the most exposed workers.

The results suggest that a distinction between hard and bright chromeplating workers should always be made when mortality patterns in the electroplating industry are analyzed.

The mortality experience of the study cohort should be followed for several more years, and further investigations involving larger cohorts are needed to confirm the carcinogenicity of chromic acid in man.

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