Cancer in Persons Working in Dry Cleaning in the Nordic Countries

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U.S. studies have reported an increased risk of esophageal and some other cancers in dry cleaners exposed to tetrachloroethylene. We investigated whether the U.S. findings could be reproduced in the Nordic countries using a series of case–control studies nested in cohorts of laundry and dry-cleaning workers identified from the 1970 censuses in Denmark, Norway, Sweden, and Finland. Dry-cleaning work in the Nordic countries during the period when tetrachloroethylene was the dominant solvent was not associated with an increased risk of esophageal cancer [rate ratio (RR) = 0.76; 95% confidence interval (CI), 0.34–1.69], but our study was hampered by some unclassifiable cases. The risks of cancer of the gastric cardia, liver, pancreas, and kidney and non-Hodgkin lymphoma were not significantly increased. Assistants in dry-cleaning shops had a borderline significant excess risk of cervical cancer not found in women directly involved in dry cleaning. We found an excess risk of bladder cancer (RR = 1.44; 95% CI, 1.07–1.93) not associated with length of employment. The finding of no excess risk of esophageal cancer in Nordic dry cleaners differs from U.S. findings. Chance, differences in level of exposure to tetrachloroethylene, and confounding may explain the findings. The overall evidence on bladder cancer in dry cleaners is equivocal. The purpose of this study was to determine whether dry cleaning work in the Nordic countries around 1970, when tetrachloroethylene was the dominant dry-cleaning solvent, was associated with an increased risk of the selected cancers. We used the nested case–control design to avoid confounding from socioeconomic group and related lifestyle risk factors.

Materials and Methods

Study base, cases, and controls. The cohorts included all laundry and dry-cleaning workers from the 1970 censuses in Denmark, Finland, Norway, and Sweden. They had either the occupation code “laundry and dry-cleaning worker” or the industry code “laundry and dry-cleaning” (International Labour Office 1997 and 2001). Cancer cases were identified using combined topography and morphology codes from the International Classification of Diseases for Oncology (Percy 1990).

Controls were randomly selected from the cohort using frequency match by country, sex, 5-year age group, and 5-year calendar period at the time of diagnosis of the case. For esophageal cancer, we selected controls equal to six times the number of cases. For the other cancer sites, three times the number of cases. The registry part of this study was approved by each of the national data protection agencies. The interview part of this study was approved by the ethics committees in Norway and Sweden; after national legislation, all participants gave active informed consent before participating in the interview.

These studies have reported an increased risk of esophageal and some other cancers in dry cleaners exposed to tetrachloroethylene (Henschler et al. 1995), and bladder and pancreatic cancer found in recent updates of U.S. cohorts (Blair et al. 2003; Ruder et al. 2001). Gastric cardia cancer was included because adenocarcinomas are on the increase in esophagus and cardia in some Western countries (Botterweck et al. 2000).

The purpose of this study was to determine whether dry-cleaning work in the Nordic countries around 1970, when tetrachloroethylene was the dominant dry-cleaning solvent, was associated with an increased risk of the selected cancers. We used the nested case–control design to avoid confounding from socioeconomic group and related lifestyle risk factors. The authors received funding from the HSIA for professional services.

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The person's specific occupational task as dry cleaner or laundry worker at the 1970 census was written in free text on the original census form. These forms were retrieved from the National Archives in Denmark and Norway. The forms had not been stored in Finland and Sweden.

A blinded personal telephone interview, eventually with a next-of-kin, was undertaken with cases and controls in Norway and Sweden. The questionnaire asked about occupational tasks in 1970, and if this was dry cleaning, then about length of employment in the shop, size of the work force, solvents used, and smoking and drinking habits. In Norway, interviews were obtained with 57% of cases (72% with next-of-kin) and with 64% of controls (42% next-of-kin). In Sweden, interviews were obtained with 63% of cases (77% next-of-kin) and with 60% of controls (39% next-of-kin). One-fourth of interviewed next-of-kin was 1970 spouses, and one-third of non-interviewed subjects had no next-of-kin.

Denmark and Finland have nationwide databases with individual records on all paid pension scheme contributions, and we used these pension scheme data for this study. In Denmark, these data started for employees in 1964; we used these data to assess length of employment, with 37% from book, 57% from telephone books, and no data for 6%. Family workers were assumed to have worked for the same length as their spouses. We used the book (Hammershøj 1971) and pension scheme data for the self-employed persons' shops to assess the size of the work force.

For Finland, we used the pension scheme data in combination with other sources (Anonymous 1984; Kyyronen et al. 1989) to assess type and size of company (Table 1). For Finland and Sweden, we coded as unexposed those cases and controls we assumed from the census codes not to be dry cleaners (e.g., “presser” in “textile industry”).

We identified 1,616 cases and 2,398 controls (Table 2). Together they represented 3,883 persons. For Denmark and Norway, about 20% of the records were classified as coming from the exposed dry-cleaner group and 70–80% came from the unexposed group (Table 4). For Finland and Sweden, respectively, 41% and 35% of the records were unclassifiable as to whether the persons had dry-cleaning work in 1970.

Use of tetrachloroethylene peaked in the Nordic countries around 1970, and the compound was used almost exclusively for dry cleaning (Figure 1). In Denmark, import of the new fully automated German and English machines using tetrachloroethylene started in 1959 (Direktoratet for Arbejdstilsynet 1959). In 1967, 30% of conventional shops had machines obtained within the last 10 years (Schleisner 1967), and new coin-operated machines using only tetrachloroethylene made up 40% of the market in 1968 (Anonymous 1968).

In 1968, tetrachloroethylene constituted 75% of the solvents used for dry cleaning in Denmark, 85% in Finland, and 72% in Sweden (Anonymous 1968); in 1971 it was estimated to constitute 90% of dry-cleaning solvent used in Scandinavia (Anonymous 1971). In the questionnaires, 76% of dry cleaners in Norway and 84% in Sweden reported use of tetrachloroethylene in 1970, but information on chemicals and time periods was missing in many interviews. Tetrachloroethylene was thus clearly the dominant dry-cleaning solvent throughout our study period. Work as a dry cleaner in 1970 was therefore a good proxy for exposure to tetrachloroethylene, which is the underlying exposure variable of interest in this study. The probability of being exposed to tetrachloroethylene outside dry cleaning was extremely low because virtually all tetrachloroethylene was used in this industry (Mikkelsen et al. 1983). Available data did not allow further subdivision of dry cleaners as to whether or not they used tetrachloroethylene. Other solvents in use were white spirit and chlorofluorocarbons (Johansen et al. 2005).

In 1970, the occupational safety limit for tetrachloroethylene was 670 mg/m3 in Finland, 350 mg/m3 in Denmark and Norway, and 200 mg/m3 in Sweden. In 1980, these limits were 335, 200, and 135 mg/m3, respectively. Only 168 tetrachloroethylene measurements were made in dry-cleaning shops in the Nordic countries between 1964 and 1979. There was a large variation in exposure level across shops; the median annual level of all measurements was, however, fairly stable during 1964–1979 (Figure 2). In the analysis, we therefore assumed exposure level to tetrachloroethylene to be constant from 1964 to 1979 and used length of employment as a proxy for relative, cumulated dose. For comparison with external data, the mean of 53 measurements of ≥ 60 min for dry cleaners was 164 mg/m3.

Analysis. The analysis was based on records for cases and controls, because a given person could appear more than once. For a given cancer site, we used all controls fulfilling the selection criteria in the analysis. We estimated rate ratios (RRs) for dry cleaners versus unexposed controls using logistic regression adjusted for matching criteria and, where relevant, for smoking and alcohol use. For a comprehensive reporting of the data, we explained by sick leave and so on at the 1970 census. Pension scheme data were found for 75% of Finnish records.

In Denmark, we used a biography of dry-cleaning shop owners (Hammershøj 1971) and the yellow pages of local telephone books for self-employed persons to assess length of employment, with 37% from the book, 57% from telephone books, and no data for 6%. Family workers were assumed to have worked for the same length as their spouses. We used the book (Hammershøj 1971) and pension scheme data for the self-employed persons’ shops to assess the size of the work force.

For Finland, we used the pension scheme data in combination with other sources (Anonymous 1984; Kyyronen et al. 1989) to assess type and size of company (Table 3). For Finland and Sweden, we coded as unexposed those cases and controls we assumed from the census codes not to be dry cleaners (e.g., “presser” in “textile industry”).

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Analysis. The analysis was based on records for cases and controls, because a given person could appear more than once. For a given cancer site, we used all controls fulfilling the selection criteria in the analysis. We estimated rate ratios (RRs) for dry cleaners versus unexposed controls using logistic regression adjusted for matching criteria and, where relevant, for smoking and alcohol use. For a comprehensive reporting of the data, we

![Figure 1. Use of tetrachloroethylene in the Nordic countries 1950–2000. The kilograms of tetrachloroethylene used in a given country was calculated as (kg manufactured + kg imported – kg exported). For calculation of kilograms per inhabitant per year, we divided the average tetrachloroethylene used in a 5-year period by the population size in the middle of the period.](image-url)
also calculated the RR for the other persons in dry cleaning and for the unclassifiable persons, although the underlying hypothesis did not include these groups. RRs were estimated for all countries together and for Denmark and Norway together. We calculated RRs for the exposed group by length of employment. We used the R survival package (R Development Core Team 2004; Therneau and Lumley 2004) for these analyses.

**Results**

Eight esophageal cancer cases belonged to the dry-cleaner group, giving an RR of 0.76 (95% confidence interval (CI), 0.34–1.69) (Table 5). The estimate for Denmark and Norway gave an RR of 0.91 (95% CI, 0.38–2.20). Six exposed cases came from Denmark. Eighteen cases were unclassifiable, giving an RR of 2.04 (95% CI, 0.91–4.62); nine cases came from Finland (seven with missing pension scheme record) and nine non-interviewed cases came from Sweden. Nine gastric cardia cancer cases belonged to the dry-cleaner group, giving an RR of 0.69 (95% CI, 0.31–1.53).

Eleven exposed liver cancer cases gave an RR of 0.76 (95% CI, 0.38–1.52), and 57 exposed pancreatic cancer cases gave an RR of 1.27 (95% CI, 0.90–1.80). The highest risks were found for those with short or unknown length of employment (Table 6). Thirty-six exposed cervical cancer cases gave an RR of 0.98 (95% CI, 0.65–1.47), with the highest risk for those with short length of employment. There was a borderline significantly elevated risk of cervical cancer among other workers in dry-cleaning shops based on 22 cases, with an RR of 1.73 (95% CI, 1.00–2.97). Eleven cases were Danish (four pressers, three shop assistants, three office workers, one seamstress), seven were Finnish (six in laundries where dry cleaning was probable, one packer in a dry-cleaning shop of unspecified size), and four were Norwegian (two shop assistants, one laundry help, one spot cleaner).

Twenty-nine kidney cancer cases belonged to the dry-cleaner group, giving an RR of 0.67 (95% CI, 0.43–1.05). There was an elevated risk of bladder cancer among the dry cleaners based on 93 exposed cases (RR = 1.44; 95% CI, 1.07–1.93), with 62 exposed cases coming from Denmark and Norway, giving an RR of 1.69 (95% CI, 1.18–2.43). The risk did not increase with length of employment. Significantly elevated risks were observed for those with short or unknown length of employment.

Table 2. Cancer cases and selected controls identified in the Nordic dry-cleaner study.

| Cancer site          | Topography | Morphology | Men Denmark | Finland | Norway | Sweden | Total | Women Denmark | Finland | Norway | Sweden | Total | All |
|----------------------|------------|------------|-------------|----------|--------|--------|-------|---------------|----------|--------|--------|-------|-----|-----|
| Esophagus            | C15.0–C15.9| 8000–8580b | 15          | 2         | 3      | 6      | 26    | 19            | 12       | 5      | 10     | 46    | 72  |-----|
| Gastric cardia       | C16.0      | 8000–8580b | 10          | 1         | 2      | 16     | 29    | 7             | 4        | 4      | 6      | 21    | 50  |-----|
| Liver, primary       | C22.0–C22.1| 8000–8580b | 9           | 2         | 2      | 10     | 23    | 16            | 4        | 26     | 72     | 95    |-----|
| Pancreas             | C25        | 8000–8580b | 26          | 5         | 14     | 19     | 64    | 74            | 39       | 39     | 83     | 235   | 299 |-----|
| Cervix uteri         | C53.0–C53.9| 8000–8580b | 128         | 29        | 49     | 87     | 128   | 44            | 87       | 288    | 288    |-----|-----|
| Kidney               | C64.9      | 8312.3     | 17          | 3         | 12     | 24     | 56    | 37            | 21       | 19     | 77     | 154   | 210 |-----|
| Bladder              | C57        | 8000–8580b | 71          | 4         | 32     | 70     | 177   | 60            | 20       | 17     | 60     | 176   | 353 |-----|
| NHL                  | All        | 9690–9695, 9670–9698, 9711–7273b | 18 | 7 | 12 | 30 | 67 | 42 | 48 | 30 | 62 | 182 | 249 |

| Total cases          | 166        | 24         | 77          | 175       | 442     | 393    | 189    | 181           | 411      | 1,174   | 1,616  |-----|-----|
| Controls             | 294        | 72a        | 160         | 291       | 817     | 537    | 282c   | 237           | 465      | 1,581   | 2,398  |-----|-----|

*In total, 3,883 subjects, because a given subject can be included more than once. *Behavior code 3 only. *One male NHL, one female liver, two female bladder, and one female NHL have been excluded from the analysis because there was no matching control. *Twelve male controls and six female controls have been excluded from the analysis because there was no matching case. Topography and morphology codes based on Percy (1996).

Table 3. Data sources used for the exposure classification in the Nordic dry-cleaner study.

| Variable                          | Denmark | Finland | Norway | Sweden |
|-----------------------------------|---------|---------|--------|--------|
| **Inclusion in the study**        | 1970 census | 1970 census | 1970 census | 1970 census |
| **Occupation code in 1970**       | Computerized census data | Computerized census data | Computerized census data | Computerized census data |
| **Industry code in 1970**         | Computerized census data | Computerized census data | Computerized census data | Computerized census data |
| **Detailed occupation in 1970**   | Census forms | No data | Census forms | Interviews |
| **Detailed industry in 1970**     | Census forms plus other sourcesa | No data | Census forms | Interviews |
| **Size of the workplace where the person worked in 1970** | Employees: pension schemes | No data | Pension schemes | Interviews |
| **Length of employment in the workplace where the person worked in 1970** | Employees: pension schemes | No data | Pension schemes | Interviews |
| **Tobacco smoking and alcohol intake** | No data | No data | No data | Interviews |

*Questionnaire data on shop characteristics collected from employers in 1984 for a study on tetrachloroethylene and reproductive outcome (Kyrönens et al. 1989), records of persons biologically monitored for exposure at the Finnish Institute of Occupational Health, register of industrial hygiene measurements from the same institute, yearly calendars of the Finnish Association of Laundry and Dry Cleaning Employers, and a directory of Finnish companies and company facilities (Anonymous 1984). *All shops had a telephone, and the telephone book, in most cases, listed the telephone number together with both the name of the shop and the name of the shop owner.

Table 4. Cases and controls in the Nordic dry-cleaner study by country and exposure category.

| Exposure category            | Denmark | Finland | Norway | Sweden | Total |
|------------------------------|---------|---------|--------|--------|-------|
| Unexposed                    | 1,088 (78a) | 234 (41) | 498 (70b) | 600 (45) | 2,423 (60) |
| Dry cleaner and other exposed| 244 (18) | 41 (7) | 153 (21) | 257 (19) | 695 (17) |
| Other in dry cleaning         | 58 (4) | 62 (11) | 51 (7) | 12 (1) | 183 (5) |
| Unclassifiable                | 0 (0) | 230 (41) | 13 (2) | 473 (35) | 716 (18) |
| Total                         | 1,390 (100) | 567 (100) | 715 (100) | 1,342 (100) | 4,014 (100) |

*aIncludes 12 original forms erroneously coded as laundry and dry-cleaning workers in the 1970 census. *Includes 55 original forms erroneously coded as laundry and dry-cleaning workers in the 1970 census."
found for 2–4 years and ≥ 10 years of employment. A similar pattern was seen when the analysis was based only on the uncensored employment periods from 1965 through 1978. The combined estimate for interviewed cases and controls from Norway and Sweden was RR = 1.34 (95% CI, 0.86–2.08), which was only slightly reduced after control for smoking (RR = 1.25; 95% CI, 0.79–1.98). The excess risk within the exposed group did not come from the owners of dry-cleaning shops and their employed dry cleaners (33 exposed cases, RR = 0.98; 95% CI, 0.64–1.51) but from the supporting staff in small shops (17 exposed cases, RR = 2.20; 95% CI, 1.18–4.11) and from owners of combined laundry and dry-cleaning shops (40 exposed cases, RR = 1.92; 95% CI, 1.23–2.98). There were 42 exposed NHL cases, giving an RR of 0.95 (95% CI, 0.65–1.41).

**Discussion**

We studied the cancer risk in Nordic dry cleaners during the period where tetrachloroethylene was by far the dominant solvent, and we used laundry workers as the comparison group. Dry-cleaning work was not associated with an increased risk of esophageal cancer, but we found a borderline increased risk among persons we were unable to classify as dry cleaners or laundry workers. Dry-cleaning work was not associated with significantly increased risks of cancer of the gastric cardia, liver, pancreas, or kidney or with NHL. Female supportive staff in large dry-cleaning shops had a borderline significant excess risk of cervical cancer not found among women directly involved in dry cleaning. We found a 44% excess risk of bladder cancer among Nordic dry cleaners. The excess risk came from Denmark and Norway, the two countries with the best data. There was no clear pattern with length of employment. Adjustment for smoking in Norway and Sweden changed the estimated risk only slightly. The risk was concentrated among supporting staff in small dry-cleaning shops and among owners of combined laundry and dry-cleaning shops.

**Strengths and weaknesses of the study.** Our study had several advantages. First, we covered a period where tetrachloroethylene was the dominant solvent. Second, the study was nationwide, including all persons working in dry cleaning in 1970. Third, we used a series of data on exposure levels and employment periods.

**Table 5.** RRs for studied cancer sites for dry cleaners in the Nordic countries 1970–2000 in the Nordic dry-cleaner study.

| Cancer site       | Denmark, Finland, Norway, and Sweden | Denmark and Norway only |
|-------------------|--------------------------------------|-------------------------|
|                   | Unexposed | Dry-cleaner* | Other in dry-cleaning | Unclassifiable | Unexposed | Dry-cleaner* | Other in dry-cleaning | Unclassifiable |
| Esophagus Cases (n) | 41       | 8           | 5                   | 18            | 33       | 7          | 2                   | 0            |
| Controls (n)      | 342      | 86          | 31                  | 108           | 242      | 55         | 20                  | 1            |
| RR                | 1        | 0.76        | 1.22                | 2.04          | 1        | 0.91       | 0.66                | NR           |
| 95% CI            | NR       | 0.34–1.69   | 0.41–3.63           | 0.91–4.62     | NR       | 0.38–2.20  | 0.14–3.01           | NR           |
| Gastric cardiac Cases (n) | 31      | 9           | 1                   | 9             | 19       | 4          | 0                   | 0            |
| Controls (n)      | 201      | 80          | 8                   | 68            | 125      | 42         | 7                   | 0            |
| RR                | 1        | 0.69        | 0.84                | 0.76          | 1        | 0.51       | NR                  | NR           |
| 95% CI            | NR       | 0.31–1.53   | 0.10–7.10           | 0.31–1.90     | NR       | 0.16–1.62  | NR                  | NR           |
| Liver Cases (n)   | 58       | 11          | 2                   | 23            | 36       | 4          | 1                   | 0            |
| Controls (n)      | 398      | 95          | 22                  | 121           | 248      | 42         | 15                  | 1            |
| RR                | 1        | 0.76        | 0.42                | 1.11          | 1        | 0.62       | 0.41                | NR           |
| 95% CI            | NR       | 0.38–1.52   | 0.09–8.19           | 0.59–2.09     | NR       | 0.21–1.89  | 0.05–3.25           | NR           |
| Pancreas Cases (n) | 173      | 57          | 18                  | 51            | 109      | 32         | 10                  | 2            |
| Controls (n)      | 789      | 206         | 59                  | 242           | 751      | 112        | 42                  | 1            |
| RR                | 1        | 1.27        | 1.26                | 0.87          | 1        | 1.38       | 1.06                | 6.17         |
| 95% CI            | NR       | 0.90–1.80   | 0.70–2.26           | 0.59–1.31     | NR       | 0.87–2.20  | 0.50–2.25           | 0.56–68.21   |
| Cervix Cases (n)  | 186      | 36          | 22                  | 44            | 136      | 19         | 15                  | 2            |
| Controls (n)      | 744      | 150         | 51                  | 186           | 516      | 77         | 34                  | 3            |
| RR                | 1        | 0.98        | 1.73                | 1.11          | 1        | 0.92       | 1.64                | 2.62         |
| 95% CI            | NR       | 0.65–1.47   | 1.00–2.97           | 0.72–1.71     | NR       | 0.54–1.59  | 0.87–3.11           | 0.42–16.26   |
| Kidney Cases (n)  | 129      | 29          | 9                   | 43            | 63       | 15         | 6                   | 1            |
| Controls (n)      | 589      | 196         | 34                  | 241           | 342      | 99         | 21                  | 3            |
| RR                | 1        | 0.67        | 1.15                | 0.76          | 1        | 0.77       | 1.50                | 1.22         |
| 95% CI            | NR       | 0.43–1.05   | 0.52–2.53           | 0.50–1.16     | NR       | 0.41–1.44  | 0.55–4.08           | 0.12–12.11   |
| Bladder Cases (n) | 189      | 93          | 12                  | 57            | 129      | 62         | 7                   | 0            |
| Controls (n)      | 904      | 292         | 52                  | 234           | 639      | 173        | 38                  | 3            |
| RR                | 1        | 1.44        | 1.08                | 1.24          | 1        | 1.69       | 1.13                | NR           |
| 95% CI            | NR       | 1.07–1.93   | 0.50–2.11           | 0.83–1.83     | NR       | 1.18–2.43  | 0.51–2.50           | NR           |
| NHL Cases (n)     | 145      | 42          | 8                   | 52            | 83       | 16         | 3                   | 0            |
| Controls (n)      | 720      | 219         | 48                  | 255           | 424      | 107        | 25                  | 2            |
| RR                | 1        | 0.95        | 0.70                | 0.91          | 1        | 0.73       | 0.64                | NR           |
| 95% CI            | NR       | 0.65–1.41   | 0.31–1.55           | 0.61–1.36     | NR       | 0.40–1.32  | 0.19–2.23           | NR           |

NR, not relevant.

*Includes persons stated to be dry cleaners, owners of dry-cleaning shops, and other persons employed in dry-cleaning shops with < 10 workers.
The study did, however, also have disadvantages. First, because of the limited data sources and mixture of processes, a high proportion of cases and controls from Sweden and Finland were unclassifiable as to whether they had dry-cleaning or laundry work in 1970. We therefore reported risk estimates for all countries and for Denmark and Norway only. Second, data on employment were available only from 1964 through 1979, but the 16-year period allowed a clear distinction to be made between short-term and stable workers. Third, the limited number of air measurements did not allow subdivision of study subjects by exposure level. However, because the data indicated a fairly stable exposure level throughout the study period, duration of employment was an acceptable proxy measure for relative cumulated dose.

**Esophageal cancer.** There was a clear excess risk of esophageal cancer in the two U.S. cohort studies of tetrachloroethylene-exposed dry-cleaning workers, with standardized mortality ratios (SMRs) of 2.2 (95% CI, 1.5–3.3; Blair et al. 2003) and 2.47 (95% CI, 1.35–3.14; Ruder et al. 2001), respectively. A non-significantly elevated risk was seen in the U.S. aircraft manufacturing workers exposed to tetrachloroethylene (SMR = 1.47; 95% CI, 0.54–3.21; Boice et al. 1999). Two dry cleaners with squamous cell carcinoma of the esophagus were found in a U.S. case–control study (odds ratio (OR) = 3.6; 95% CI, 0.5–27.0) (Vaughan et al. 1997).

Our estimated risk of esophageal cancer after dry-cleaning work in the Nordic countries of RR = 0.76 (95% CI, 0.34–1.69) is in contrast with the U.S. findings (Blair et al. 2003, Ruder et al. 2001), although the difference in the outcome of the four studies could be due to chance. No case of esophageal cancer was found in a small Finnish cohort (Anttila et al. 1995). Unfortunately, in our study 18 cases were unclassifiable, and they had a statistically nonsignificantly increased risk (RR = 2.04; 95% CI, 0.91–4.62). We know little about these cases. However, even in the extreme and unlikely situation where all unclassifiable persons were exposed, our risk estimate would be RR = 1.19 (95% CI, 0.67–2.12). If all unclassifiable persons were unexposed, our risk estimate for the exposed group would be RR = 0.66 (95% CI, 0.30–1.45).

The excess risk of esophageal cancer in U.S. dry cleaners (Blair et al. 2003, Ruder et al. 2001) but not found in Nordic dry cleaners may be due to chance, different confounders, and/or different exposures. Esophageal cancer is associated with smoking, alcohol consumption, hot drinks, and poor nutrition (Muñoz and Day 1996). The mortality of the U.S. dry cleaners (Blair et al. 2003, Ruder et al. 2001) was compared with that of the national population, without control for possible confounders. However, national smoking data showed laundry and dry-cleaning workers to be only marginally more frequent smokers than the general U.S. population (Blair et al. 2003; Ruder et al. 2001), but the average earning of dry cleaners was only two-thirds of the average for private sector workers (Blair et al. 2003). We used laundry workers with similar jobs apart from the solvents as the comparison group. The self-employed Danish dry cleaners were members of Lions Club, Rotary, and so forth (Hammershøj 1971).

In 1991, about one-third of U.S. dry-cleaning plants used an open transfer process where solvent-wet clothes were manually moved from washer to dryer (Mundt et al. 2003). Based on large U.S. samples of time-weighted-average measurements for machine operators from the 1980s, the exposure level was higher at transfer machines than at dry-to-dry machines: mean concentrations were

### Table 6. RRs for the studies cancer sites in dry cleaners in the Nordic countries 1970–2000 by length of employment in the Nordic dry-cleaner study.

| Cancer site | Unexposed | Dry cleaner–a length of employment | 0–1 year | 2–4 years | 5–9 years | ≥ 10 years | Unknown |
|-------------|-----------|-----------------------------------|---------|----------|----------|-----------|---------|
| Esophageal  |           | Cases (n)                          | 41      | 1        | 3        | 3         | 1        |
|             |           | Controls (n)                       | 261     | 0        | 5        | 29        | 27       | 4        |
| Res          |           | RR                                | 1       | NR       | 1.20     | 0.66      | 0.70     | 1.05     |
| Res          |           | 95% CI                            | NR      | NR       | 0.14–10.41| 0.19–2.29 | 0.20–2.49| 0.18–14.98|
| Gastric cardiac |       | Cases (n)                          | 31      | 0        | 0        | 2         | 6         | 1        |
|             |           | Controls (n)                       | 189     | 4        | 5        | 26        | 36        | 2        |
| Res          |           | RR                                | 1       | NR       | 0.46     | 0.97      | 3.00     |          |
| Res          |           | 95% CI                            | NR      | NR       | 0.10–2.02| 0.36–2.58 | 0.28–38.19|
| Liver        |           | Cases (n)                          | 58      | 0        | 0        | 5         | 5         | 1        |
|             |           | Controls (n)                       | 359     | 5        | 7        | 26        | 45        | 2        |
| Res          |           | RR                                | 1       | NR       | 1.21     | 0.70      | 2.88     |          |
| Res          |           | 95% CI                            | NR      | NR       | 0.43–3.44| 0.26–1.92 | 0.21–38.81|
| Pancreas     |           | Cases (n)                          | 172     | 6        | 7        | 14        | 23        | 7        |
|             |           | Controls (n)                       | 707     | 12       | 19       | 52        | 88        | 13       |
| Res          |           | RR                                | 1       | 2.14     | 1.38     | 1.18      | 1.20     | 2.44     |
| Res          |           | 95% CI                            | NR      | 0.76–6.06| 0.54–3.50| 0.62–2.25 | 0.72–1.99| 0.90–6.68|
| Cervix       |           | Cases (n)                          | 185     | 8        | 26       | 47        | 50        | 3        |
|             |           | Controls (n)                       | 678     | 8        | 26       | 47        | 50        | 3        |
| Res          |           | RR                                | 1       | 2.68     | 0.78     | 0.47      | 1.18     | 1.14     |
| Res          |           | 95% CI                            | NR      | 0.89–8.11| 0.31–1.94| 0.20–1.13 | 0.64–2.15| 0.12–11.00|
| Kidney       |           | Cases (n)                          | 125     | 1        | 4        | 8         | 14        | 2        |
|             |           | Controls (n)                       | 505     | 12       | 19       | 47        | 71        | 11       |
| Res          |           | RR                                | 1       | 0.24     | 0.86     | 0.70      | 0.75     | 0.70     |
| Res          |           | 95% CI                            | NR      | 0.03–2.04| 0.28–2.67| 0.32–1.55 | 0.39–1.42| 0.15–3.36|
| Bladder      |           | Cases (n)                          | 188     | 6        | 10       | 17        | 53        | 6        |
|             |           | Controls (n)                       | 826     | 17       | 21       | 80        | 135       | 14       |
| Res          |           | RR                                | 1       | 1.50     | 2.39     | 0.91      | 1.57     | 1.97     |
| Res          |           | 95% CI                            | NR      | 0.57–3.95| 1.09–5.22| 0.52–1.59 | 1.07–2.29| 0.64–6.05|
| NHL          |           | Cases (n)                          | 145     | 5        | 3        | 14        | 15        | 5        |
|             |           | Controls (n)                       | 632     | 13       | 18       | 60        | 94        | 14       |
| Res          |           | RR                                | 1       | 1.35     | 0.61     | 0.92      | 0.66     | 1.47     |
| Res          |           | 95% CI                            | NR      | 0.44–4.14| 0.17–2.21| 0.40–1.72 | 0.36–2.12| 0.49–4.47|

NR, not relevant.

*aIncludes persons stated to be dry cleaners, owners of dry-cleaning shops, and other persons employed in dry-cleaning shops with < 10 workers.*

*bAnalysis based only on the uncensored employment periods from 1965 through 1978 gave the following RR: 0–1 year = 1.43 (95% CI, 0.52–3.97); 2–4 years = 2.38 (95% CI, 1.08–5.24); 5–9 years = 1.21 (95% CI, 0.58–2.50); ≥ 10 years = 2.84 (95% CI, 0.97–8.33); unknown = 2.12 (95% CI, 0.65–8.85).
338 mg/m³ and 157 mg/m³, respectively (IARC 1995). This transfer process was not needed in the Danish, widely exported, semi-automated machines used since the 1930s (Ingvorsen 1975), and manual handling of wet clothes became prohibited in 1953 (Arbejds-og Fabrikstilsynet 1953). The mean concentration of Nordic measurements ≥ 60 min for machine operators from 1980 through 1990 was 95 mg/m³. The currently recommended threshold from the American Conference of Governmental Industrial Hygienists is 170 mg/m³ [Occupational Safety and Health Administration (OSHA) 2005], whereas the current safety limit is 70 mg/m³ in Denmark, Finland, and Sweden and 40 mg/m³ in Norway (Arbejdstilsynet 2002, 2003; Ministry of Social Affairs and Health 2005; Swedish National Board of Occupational Safety and Health 1997). U.S. dry cleaners thus had a higher probability of dermal tetrachloroethylene exposure than did Nordic dry cleaners, and they were very probably exposed to a higher air concentration. Differences in exposure to tetrachloroethylene along with differences in socioeconomic status may therefore have contributed to the excess risk of esophageal cancer found in U.S. but not in Nordic dry cleaners.

Other cancers. Data on primary liver cancer were reported in only two U.S. studies (Blair et al. 2003; Ruder et al. 2001) with no excess risk. This is in line with the present result. One U.S. dry-cleaner cohort had a borderline excess risk of pancreatic cancer (SMR = 1.53; 95% CI, 0.91–2.42; Ruder et al. 2001), as did aircraft manufacturing workers (SMR = 1.50; 95% CI, 0.72–2.76; Boice et al. 1999). However, the other U.S. dry-cleaner cohort (Blair et al. 2003), the Finnish cohort (Anttila et al. 1995), and the present study did not confirm this finding.

The two U.S. dry-cleaner cohorts had excess risks of cervical cancer (Ruder et al. 2001: SMR = 1.95; 95% CI, 1.00–3.40; Blair et al. 2003: SMR = 1.6; 95% CI, 1.0–2.3), an observation confirmed in the Finnish cohort based on small numbers (Anttila et al. 1995) but not among the U.S. aircraft workers (Boice et al. 1999). In U.S. dry cleaners, the risk was increased both for work with tetrachloroethylene only and for mixed solvents (Ruder et al. 2001), and the risk did not vary with exposure status (Blair et al. 2003). In our study, dry cleaners had no excess risk of cervical cancer (RR = 0.98; 95% CI, 0.65–1.47). There was, however, a borderline significant elevated risk among supporting staff in larger dry-cleaning shops (RR = 1.73; 95% CI, 1.00–2.97). We thus confirmed previous findings of an excess risk of cervical cancer among women in dry-cleaning shops, but the fact that they were not engaged in the dry-cleaning process did not point to tetrachloroethylene as the explanatory risk factor, nor did it point to social class, because the comparison group was laundry workers.

Kidney cancer was not increased in the previous cohort studies (Blair et al. 2003; Boice et al. 1999; Ruder et al. 2001) or in our study. The risk of bladder cancer was increased in one U.S. dry-cleaner cohort (SMR = 2.22; 95% CI, 1.06–4.08; Ruder et al. 2001) but not in the other (SMR = 1.3; 95% CI, 0.7–2.4; Blair et al. 2003) and not in aircraft workers (Boice et al. 1999). The Finnish study did not report on bladder cancer (Anttila et al. 1995). The excess risk in the United States was limited to those working with mixed solvents (Ruder et al. 2001), found only in whites, and equally so in those with little or no exposure and those with medium or exposure (Blair et al. 2003). The U.S. bladder cancer case-control study reported an excess risk for dry-cleaning work in non-white men (OR = 2.80; 95% CI, 1.10–7.40; Silverman et al. 1989a) but not in white women (OR = 1.40; 95% CI, 0.80–2.50; Silverman et al. 1990), and data were not reported for white men (Silverman et al. 1989b). The risks for all laundry and dry cleaners of both sexes and races were 1.31 (95% CI, 0.85–2.03) for nonsmokers, 2.99 (95% CI, 1.80–4.97) for former smokers, and 3.94 (95% CI, 2.39–6.51) for current smokers (Smith et al. 1985). The joint analysis of European case-control studies showed a smoking-adjusted RR of 1.24 (95% CI, 0.67–2.31) for male launderers, dry cleaners, and pressers (Kogevinas et al. 2003). The case-control study from Montreal, Canada, gave an RR of 1.6 (95% CI, 0.9–3.1) for launderers and dry cleaners, but the risk was not elevated for exposure to tetrachloroethylene (Siemiatycki 1991). We found an elevated bladder cancer risk among dry cleaners (RR = 1.44; 95% CI, 1.07–1.93) that did not increase with length of employment. Taking the studies together, there appears to be an excess risk of about 45%, which does not seem to be explained by excessive smoking. The risk does not vary with the exposure indices. Overall, the current picture of the association between dry-cleaning work with tetrachloroethylene and risk of bladder cancer is equivocal.

In a 1995 monograph on dry cleaning (IARC 1995), an excess risk of NHL was described based on studies then available (Anttila et al. 1995; Blair et al. 1998; Boice et al. 1999). However, whereas the previous analysis of the largest cohort included only International Classification for Diseases, version 8 [ICD-8; World Health Organization (WHO) 1965] code 200 (Blair et al. 1999), the update included ICD-8 codes 200 and 202 (Blair et al. 2003), showing no excess risk. At present, the three studies together give 22 observed cases and 18.80 expected. Our results are in line with this.

Conclusion

Dry-cleaning work in the Nordic countries, during a period when tetrachloroethylene was the dominant solvent, was not associated with significantly increased risks of cancer of the gastric cardia, pancreas, or kidney or with primary liver cancer or NHL. Dry-cleaning work was not associated with an increased risk of esophageal cancer, but our study was hampered by some unclassifiable cases. The result for esophageal cancer contrasts findings from U.S. tetrachloroethylene-exposed cohorts, which could be due to chance, confounding, or differences in exposure level. In line with findings from previous studies, our study indicated an excess risk of cervical cancer in supporting staff in larger dry-cleaning shops, but not in women directly involved in dry cleaning. We found an elevated risk of bladder cancer among Nordic dry cleaners. The international data together point to an excess risk of bladder cancer in dry cleaners of about 45%, but there is no pattern with exposure indices. The evidence for an association between exposure to tetrachloroethylene and risk of bladder cancer is equivocal.

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