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Community Study of Spontaneous Abortions: Relation to Occupation and Air Pollution by Sulfur Dioxide, Hydrogen Sulfide, and Carbon Disulfide

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Summary. Spontaneous abortions were analyzed in an industrial community in Finland in relation to the occupation of women and their husbands, and to the level of air pollution in the family's residential area. Information on abortions and births was obtained from the hospital discharge register; information on the women and their families was obtained from the files of the population and housing census. Women who were employed in rayon textile jobs and paper products jobs had an increased rate ($P < 0.10$) of spontaneous abortions; the wives of men employed in transport and communication, in rayon textile jobs, and in chemical process jobs also had an increased rate of spontaneous abortions. In material stratified for age, parity, and socioeconomic class no evidence was found that the level of sulfur dioxide or carbon disulfide could be associated with a risk of spontaneous abortions. More spontaneous abortions were noted in all socioeconomic classes in areas where the mean annual level of hydrogen sulfide exceeded 4 $\mu g\, m^{-3}$. However, the difference (total rates 7.6 and 9.3, respectively) was not significant statistically.

Key words: Spontaneous abortion – Sulfur dioxide – Hydrogen sulfide – Carbon disulfide – Pollution – Occupation

Introduction

Spontaneous abortions have been recommended for environmental surveillance because of its frequency and partial genetic etiology [1–3]. However, so far most studies on spontaneous abortions have been concerned with occupational [4–16] or life-style exposures, such as tobacco [17, 18] and alcohol [19–21]. Surveillances of the effects of environmental exposures affecting the general population have been carried out in a few cases only—mainly because of difficulties in obtaining representative and unbiased data on spontaneous abortion cases [7, 13, 15]. In Finland the high frequency of hospitalization due to spontaneous abortions and the nationwide hospital discharge register provide a unique opportunity for various types of studies on spontaneous abortions [15].

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In the present study we apply the hospital discharge register for the first time to investigate the possible effects of environment pollution on the frequency of spontaneous abortions. Valkeakoski, the community selected for the study, is a town with over 20,000 inhabitants. Over 60% of the population, one of the largest percentages in Finland, is employed in manufacturing industries, such as pulp, paper, metal, viscose rayon, and the chemical industry. The frequency of hospitalized spontaneous abortions is relatively high in Valkeakoski when compared with all Finland, but not very different from the neighbouring towns. The pulp and viscose rayon industries emit hydrogen sulfide and the viscose rayon industry also emits carbon disulfide. A comprehensive urban air survey in Valkeakoski has shown that the levels of hydrogen sulfide and carbon disulfide markedly exceed most international air quality standards for these compounds [22]. In the present study the frequency of spontaneous abortions was related to the women's or their husbands' occupations as well as to the assumed levels of air pollution in the family's residential area.

Materials and Methods

The Finnish National Board of Health maintains a computerized hospital discharge registry that includes all the patients discharged from hospitals as described previously [14–16]. From the registry we obtained information on all the women of Valkeakoski who were treated for spontaneous abortions (diagnoses nos. 643 and 645) and induced abortions (diagnoses nos. 640–642), and on women giving birth to a child (diagnoses nos. 650–662) in any hospital in Finland from 1974 to 1977. The diagnoses were based on the 8th revision of the International Classification of Diseases. The patients discharged from the hospital with diagnosis no. 645 used twice within a short time period, in connection with a spontaneous or induced abortion, or misused as a code for threatened abortion, were excluded from the analysis ($n = 32$). After this correction the data consisted of 1,792 cases. The series contained 9 patients with two and one patient with three spontaneous abortions within the study period.

The patient information was obtained largely from the hospital of Valkeakoski, which does not use policlinical (outpatient) treatment. Thus our data on spontaneous abortion in Valkeakoski should be complete. The general coverage of the hospital discharge register has been reported elsewhere [16]. We did not analyse the quality of the hospital discharge data specifically in Valkeakoski; the ad hoc quality control studies in another hospital indicated that the diagnoses in the hospital discharge register agrees with hospital journals in about 90% of the cases (Niemi et al., unpublished observation). However, variation by hospital is likely. The mean gestational length of hospitalized spontaneous abortions is 2 to 3 months according to an ad hoc study in one large hospital (Niemi et al., unpublished observation).

Information on the woman's and their husband's occupations, places of work, number of children, and places of residence was collected, using personal identification numbers, from the population and housing census taken at the end of 1975. These data were obtained for 89% of the cases included in the hospital discharge registry. Probably most of the missing cases had moved out of Valkeakoski before the census or, moved to Valkeakoski, after the census. The examination of the persons missed revealed that their rate of spontaneous abortions was higher (13.1%) than the one for those found from the census (9.0%). However, the difference between the rates was not significant statistically.

Information on the regional mean concentrations of sulfur dioxide, hydrogen sulfide, and carbon disulfide was obtained from the maps of a special field study of the Institute of Meteorological Sciences concerning the pollutants of the air in Valkeakoski from 1977 to 1979 [22]. Using the maps and the addresses provided by the census, the subjects were classified into groups of different exposure levels. The subjects whose addresses were considered uncertain during pregnancy were excluded from this analysis.

Table 1. Frequency of spontaneous abortions according to women's and husbands' occupations in Valkeakoski in 1974–1977

Occupation	Woman			Husband		
	Number of spontaneous abortions	Rate[b] of spontaneous abortions	Ratio[c] of spontaneous abortions	Number of spontaneous abortions	Rate of spontaneous abortions	Ratio of spontaneous abortions
Technical, scientific, humanistic, and artistic work	22	11.0	14.4	16	7.5	9.5
Administrative, managerial, and clerical work	23	9.3	12.8	9	13.8	17.3
Sales work	7	10.1	15.6	3	7.5	9.7
Transport and communication	3	15.8	30.0	9	15.8*	23.7*
Industrial production work	13	6.8	10.5	59	8.4	11.4
Services	18	9.9	16.2	2	5.9	8.0
Economically active women	86	9.3	13.5	—	—	—
Economically inactive women	35	7.8	10.2	—	—	—
Total	121	8.8	12.4	98	8.6	11.4

[a] Women aged 20–39
[b] Rate = spontaneous abortions × 100/pregnancies
[c] Ratio = spontaneous abortions × 100/births
* $P < 0.05$, χ^2-test or binomial test

The number of spontaneous abortions was related to the number of pregnancies (births + induced abortions + spontaneous abortions; this is referred to as the rate of spontaneous abortion) and to the number of births (referred to as the ratio of spontaneous abortion) [14–16]. Two different proportions for spontaneous abortions were calculated because of the large number of induced abortions in Finland. However, when the rates or ratios were in good agreement, only rates are given. The statistical significance for the rates and ratios of spontaneous abortions was determined by the χ^2-test and by the binomial test (for small frequencies).

Results

Analysis by Occupation

The frequency of spontaneous abortions among the residents of Valkeakoski is shown in Table 1 according to women's and their husbands' occupations. Only women for the ages of 20 to 39 years were considered, in order to rule out bias by anomalous age distribution. The main occupational categories were considered because only a total of 121 or 98 spontaneous abortions were registered for women with an identified occupational status, and for women for whose husband information was acquired, respectively.

No statistically significant differences were found between women's occupations (Table 1). The highest frequencies were noted for women employed in the fields of transport and communication, followed by sales work, and technical, scientific, humanistic, and artistic work. Economically active women had more spontaneous abortions than housewives.

Analysis of the husbands' occupations revealed one group with a statistically increased frequency of spontaneous abortions: the wives of men employed in the fields of transport and communication had a rate and ratio of spontaneous abortions of 15.8 and 23.7, respectively, as compared to the community total of 8.6 and 11.4, respectively. The wives of men employed in transport and communication did not have more induced abortions than the wives of all the men in Valkeakoski (17.5 versus 16.1% induced abortions of all pregnancies).

A further analysis was extended to the factory and the type of employment. Table 2 lists the types of employment where the rate of spontaneous abortions was elevated. When the women were employed in textile work in the (viscose) rayon fiber industry, or in production work in a paper products factory, the rates were increased to 10.3 ($P < 0.10$) and 16.7 ($P < 0.10$). The reference group, women employed in industrial work in the whole community, had a rate of spontaneous abortions of 7.7, or of 6.9 if women with two or more spontaneous abortions were excluded. The women whose husbands were employed in textile work in the viscose rayon industry, and in chemical processing work in a chemical factory had increased rates of spontaneous abortion. None of the occupational groups considered deviated to a significant extent by the women's age, by number of children in the family, or by the frequency of induced abortions. All these factors failed to explain the differences noted. The frequency of induced abortions was similar for rayon fiber workers, paper product workers, and all women.

Analysis by Environmental Pollution

The Institute of Meteorological Sciences has surveyed the air of Valkeakoski for the most important gaseous pollutants from 1977 to 1979 [22]. The study provided maps of the mean concentration of the pollutants. Using the maps, the residents of Valkeakoski were divided into two to three groups, depending on the level of pollution in their residential area. The pollutants considered were sulfur dioxide, produced mainly by the heating of residential and industrial facilities, hydrogen sulfide, and carbon disulfide, both emitted from industrial facilities. The analysis was stratified according to socioeconomic class, constructed from occupational information, to reduce the effect of differential social structure in residential quarters. Furthermore, only women aged 20 to 39 years, and with one child or less before the pregnancy considered were included in the analysis.

The residential areas were divided into three groups according to the mean annual concentration of sulfur dioxide (< 5, 5–15, $> 15\,\mu g\,m^{-3}$) in the air (Table 3). The total frequency of spontaneous abortions was lowest in the intermediate pollution zone (rate 7.5) and highest in the most polluted zone (rate 9.3). However, the high rate of spontaneous abortions in the most polluted zone was entirely due to the contribution by employers and higher officials, while in other socioeconomic groups no clear gradient could be noted. Thus it is unlikely that the concentration of sulfur dioxide would be related to the frequency of spontaneous abortions.

Table 2. Frequency of spontaneous abortions, women's mean age, and mean number of children before pregnancy in some occupational groups in Valkeakoski from 1974 to 1977

Factory — occupation	Number of spontaneous abortions	Rate of spontaneous abortions		Women's mean age	Mean number of children before pregnancy
Viscose rayon fiber					
— textile work, woman	9 (9)[a]	10.3	(10.3°)[a]	28.2	1.1
— textile work, husband	10 (10)	14.9°	(14.9*)	26.2	1.2
Paper products factory					
— industrial production work, woman	6 (4)	16.7°	(12.1)	29.2	0.7
Chemical factory					
— chemical process work, husband	6 (4)	28.6**	(22.2*)	30.0	1.2
Industrial production work					
— all women	17 (15)	7.7	(6.9)	27.8	0.9
— all husbands	68 (58)	8.8	(7.6)	27.1	1.0

[a] The figures in the parenthesis indicate the number or the rate of spontaneous abortions for women with no more than one spontaneous abortion within the study period

° $P<0.10$, * $P<0.05$, ** $P<0.01$, χ^2-test or binomial test

Table 3. Rate of spontaneous abortions by mean annual concentration of sulfur dioxide in the air and the socioeconomic status in Valkeakoski from 1974 to 1977 (women aged 20–39 with one child or less)

Socioeconomic status	Mean annual concentration of sulfur dioxide ($\mu g\,m^{-3}$)					
	< 5		5–15		> 15	
	Number of spontaneous abortions	Rate of spontaneous abortions	Number of spontaneous abortions	Rate of spontaneous abortions	Number of spontaneous abortions	Rate of spontaneous abortions
Employers, own-account workers, managers, and higher administrative or clerical employees	1	11.1	2	11.1	4	21.1
Lower administrative or clerical employees	4	10.0	17	9.3	18	10.5
Workers	3	9.4	7	5.8	9	9.2
Others[a]	3	6.0	8	6.0	7	5.8
Total	11	8.4	34	7.5	38	9.3

[a] Includes economically inactives and family workers

Table 4. Rate of spontaneous abortions by mean annual concentration of hydrogen sulfide in the air and the socioeconomic status in Valkeakoski from 1974 to 1977 (women aged 20–39 with one child or less)

Socioeconomic status	Mean annual concentration of hydrogen sulfide ($\mu g\,m^{-3}$)			
	< 4		> 4	
	Number of spontaneous abortions	Rate of spontaneous abortions	Number of spontaneous abortions	Rate of spontaneous abortions
Employers, own-account workers, managers, and higher administrative or clerical employees	2	7.4	5	26.3
Lower administrative or clerical employees	21	9.9	18	10.0
Workers	10	7.0	9	8.4
Others	9	5.3	9	6.7
Total	42	7.6	41	9.3

Table 5. Rate of spontaneous abortions by mean annual concentration of carbon disulfide in the air and the socioeconomic status in Valkeakoski from 1974 to 1977 (women aged 20–39 with one child or less)

Socioeconomic status	Mean annual concentration of carbon disulfide ($\mu g\,m^{-3}$)			
	< 10		> 10	
	Number of spontaneous abortions	Rate of spontaneous abortions	Number of spontaneous abortions	Rate of spontaneous abortions
Employers, own-account workers, managers, and higher administrative or clerical employees	3	18.8	4	13.3
Lower administrative or clerical employees	14	12.8	25	8.8
Workers	6	8.3	13	7.3
Others	6	6.6	12	5.6
Total	29	10.1	54	7.6

Two zones of hydrogen sulfide concentration (> 4 and $\leq 4\,\mu g\,m^{-3}$) were considered (Table 4). The rate of spontaneous abortions was slightly higher (9.3) in the polluted zone as compared to the less polluted zone (7.6). Furthermore the trend appeared to hold for most socioeconomic groups leaving the possibility that the level of hydrogen sulfide might be associated with the frequency of spontaneous abortions.

Two zones of carbon disulfide concentration (> 10 and < $10\,\mu g\,m^{-3}$) were taken into analysis (Table 5). The frequency of spontaneous abortions appeared to be

lower in the polluted zone as compared to the less polluted zone, providing no evidence on the harmful effects of carbon disulfide.

Discussion

In the present study a novel scheme of using registered information on environmental health was tested. The data on pregnancies and spontaneous abortions were acquired from the hospital discharge register; the data on occupations, places of employment, size of family, and places of residence were obtained from the records of the national population census of 1975. The linking of these data was successful technically as almost 90% of the women with pregnancies could be identified from the population census. The use of registered data may be particularly helpful in attempts to resolve questions of environmental health, where public concern and discussion has been raised, making interview studies unreliable.

The present study, stratified for socioeconomic class, age, and parity of women, provided no clear evidence that ambient air sulfur dioxide, hydrogen sulfide, or carbon disulfide could be associated with the risk of spontaneous abortions. The study was based on the comprehensive environmental surveillance data of the Institute of Meteorological Sciences carried out in from 1977 to 1979. In general, the air in Valkeakoski was quite polluted when compared to various international standards (standards are lacking in Finland for many pollutants). Particularly, the annual concentrations of hydrogen sulfide of over $4\,\mu g\,m^{-3}$ appear high in community air.

One general problem with the present study was its cross-sectional design. In using residential data we were unable to check the actual time spent at home as compared to the time spent at work, where the level of pollution may be much higher than in the community air. Another general problem may be the quality of data on spontaneous abortions. Although the hospital discharge data on reproductive events appear generally reliable (Niemi et al., unpublished data), local aberrations may be present. Such uncertainties may mask underlying differences.

As a large fraction of one's time is spent at work, it was important to consider the occupations of the women and their husbands. In Valkeakoski industrial workers do not appear to have more hospitalized spontaneous abortions than all women, which is in contrast to the results from all of Finland [15]. However, some industrial occupations showed elevated rates of spontaneous abortions. A statistically insignificant increase ($P < 0.10$) was noted for textile workers in the rayon fiber industry, a group also noted in our previous study [14] and for paper products workers. The paper products factory produces stationary, packing material, and plastic-covered paper. Interestingly, the husbands' employment in transport and communication, the rayon fiber industry and the chemical manufacturing of glues, resins etc. was associated with an increased frequency of spontaneous abortions. The differences were not explained by the age, parity, or the number of induced abortions of the women, nor by any apparent risk factor for spontaneous abortions. In this type of study, with so many comparisons, chance correlations are likely to be present.

No data were available on the chemical exposure, if any, of the workers involved. In the viscose rayon industry, relatively high concentrations of carbon

disulfide are known to be present [23]. Carbon disulfide has been thought to be connected with many types of reproductive problems among exposed workers [9] and in experimental animals [24].

All the environmental and occupational data presented were based on small numbers, emphasizing the exploratory nature of the study. The absence of environmental effects of pollution on spontaneous abortions needs further confirmation. The possible occupational factors can only be resolved with sufficient exposure data, which were unavailable in this study.

The present study described a feasible study protocol for the study of occupational and environmental pollutants. In the future the protocol will be applied in other communities with different types of occupational and environmental exposure.

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