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Tissue Burden of Asbestos in Nonoccupationally Exposed Individuals From East Texas

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Background *The potential for asbestos exposure among members of the general population is appreciable, considering its widespread use in many products. This study examined tissue burden of asbestos in such a population.*

Methods *A group of 33 individuals who had no work history of occupational exposure to asbestos were included in the study. Tissue sections from areas adjacent to those sites sampled for digestion were found to be without ferruginous bodies (FB) or histopathology consistent with asbestos-induced changes. All individuals had 20 or less FBs per gram of digested wet lung, a number considered to reflect general population levels. Tissue analysis of uncoated fiber burden was carried out by analytical electron microscopy. There was a trend of a higher likelihood of FB and asbestos fiber content correlated with age.*

Results *The data are not consistent with the findings that chrysotile is readily found in lung tissue from the general population, in that none was found in 19 of the cases. It was almost as likely that one would find anthophyllite (12 of 33 cases) in this study. The commercial amphiboles (amosite and crocidolite) were occasionally found in the tissue from the general population and, when observed, were few in numbers. Twenty-six of the patients had no FBs and ten had no uncoated asbestos fibers within the limits of detectability in this study.*

Conclusions *The total tissue burden of asbestos in this study is much less than earlier reported observations from other general populations.* Am. J. Ind. Med. 35:281–286, 1999. © *1999 Wiley-Liss, Inc.*

KEY WORDS: asbestos; general population; electron microscopy

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INTRODUCTION

The potential for asbestos exposure in our society includes both occupational and environmental contact. Estimates of probable exposure to asbestos in a wide range of job titles can vary from possible to likely [Hammar and Dodson, 1994]. Some professions would more readily be expected to have contact with asbestos-containing materials (ACM) while carrying out their jobs. Many, including building occupants, are potentially exposed to asbestos as a background component in their daily work environment. Therefore, a work history may often not include exposures that were not remembered or recognized at the time they occurred.

A retrospective assessment of past exposure can be achieved by tissue analysis. Tissue analysis reflects that part of the asbestos burden that has not been cleared by the time the sample is collected, and applying such techniques has offered insight as to past exposures often within occupationally exposed cohorts [Hammar and Dodson, 1994]. Ferruginous coatings form on a population of asbestos fibers that are greater than 8 μm and, when seen in tissue sections in combination with fibrosis, are important in establishing the diagnosis of asbestosis [Craighead et al., 1982; Churg, 1989].

The use of tissue sections as a screen for ferruginous bodies (FBs) has inherently limited sensitivity due to the

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restricted areas scanned. Thus, digestion techniques permit a larger area to be sampled, yielding an inherent increase in sensitivity from data obtained from tissue sections [Whitwell et al., 1977].

Tissue digestion studies by Roggli et al. [1986] from North Carolina and Dodson et al. [1984] in a cohort from East Texas and Houston indicated a general population tissue burden of 0–20 FBs per gram wet weight.

Complicating the interpretation of such data is the concern that, in some individuals, appreciable asbestos burden may exist with few or no asbestos bodies being found in tissue sections [Warnock and Wolery, 1987] or the fact that some individuals with appreciable fiber burden simply do not readily coat the fibers [Dodson et al., 1985]. An FB, when detected, indicates that some level of past exposure has occurred, and a portion of that exposure included longer fibers (>8 μm). While the increase in the number of asbestos bodies indicates an increase in intensity or duration of exposure, the lack of FBs as determined by light microscopy cannot be used to extrapolate the number of uncoated fibers in the tissue. Light microscopy is of limited value in counting such uncoated fibers, since the majority are too small to be visible [Churg and Warnock, 1980; Dodson et al., 1990, 1991].

As Srebro et al. [1995] noted, electron microscopy analysis may be needed to offer a characterization of the quality and quantity of mineral fibers when asbestos body counts are within the range of background values. Much of the present data on uncoated fiber burden has been from cohorts with known past exposures to asbestos in occupational or para-occupational settings, and a limited number of these used counting methodologies, magnification, and analytical transmission electron microscopy as necessary to see thin, as well as short (<5 μm), uncoated fibers.

In some of the more comprehensive studies on uncoated fiber burden in the general populations, Churg [1982] and Churg and Warnock [1980] used analytical transmission electron microscopy and counted uncoated fibers ≥1 μm in length. Their [Churg and Warnock, 1980] conclusions were that the average lung in the urban environment contained mainly shorter fibers of chrysotile and noncommercial amphiboles. In a subsequent study [Churg, 1982] the mean number of asbestos fibers was given as 1×10^6/gm dry lung, with more than 80% of the fibers being chrysotile of less than 5 μm in length.

In order to add to the base of knowledge on what types and levels of asbestos fibers are found in another, more rural-based general population, tissue from 33 individuals with no known occupational exposures were prepared for light and electron microscopy analysis. Since histories are sometimes not indicative of exposures, the criteria for analysis was that none of the individuals would have more than 20 FBs per gram wet weight as determined by light microscopy and that no histopathology consistent with asbestos-induced disease were present. The individuals were from rural areas or from communities in eastern Texas.

TABLE I. Age, Sex, Total Uncoated Asbestos Fibers and Ferruginous Bodies per Case for Nonoccupationally Exposed East Texans

		Total asbestos		Ferruginous bodies	
CASE	Age/Sex	Fib/gm dry	Fib/gm wet	FB/gm dry	FB/gm wet
1	12/F	0	0	0	0
2	15/M	0	0	0	0
3	17/M	0	0	0	0
4	18/M	0	0	0	0
5	19/M	0	0	0	0
6	21/M	0	0	0	0
7	21/F	34,000	6,400	0	0
8	22/M	39,000	8,300	0	0
9	24/F	110,000	23,000	0	0
10	25/F	92,000	18,000	0	0
11	26/M	0	0	0	0
12	28/F	42,000	6,900	0	0
13	28/M	100,000	17,000	0	0
14	30/F	42,000	8,100	0	0
15	30/M	190,000	37,000	0	0
16	31/M	130,000	28,000	0	0
17	34/M	32,000	8,400	0	0
18	35/M	140,000	33,000	85	20
19	37/F	0	0	0	0
20	37/M	0	0	0	0
21	38/M	260,000	54,000	0	0
22	38/M	290,000	57,000	101	20
23	40/M	130,000	29,000	93	20
24	41/M	0	0	0	0
25	41/M	36,000	8,100	0	0
26	44/M	87,000	17,000	85	20
27	47/M	42,000	8,400	0	0
28	49/M	68,000	17,000	0	0
29	50/M	210,000	44,000	98	20
30	51/M	140,000	27,000	0	0
31	68/F	290,000	50,000	120	20
32	72/F	180,000	42,000	0	0
33	73/F	75,000	17,000	87	20

METHODS

Autopsy samples from 33 patients (Table I) who met the criteria described below were selected for the study. These individuals were from the eastern portion of Texas, an area which by definition is rural in that there are no communities of 250,000 or greater populations. However, the cities in the region do have considerable industry, including those producing forestry products, foundries, petrochemically related industries, as well as various other types of manufacturing facilities. Many of these industries have various asbestos products in use in their facilities, with some having considerable potential for its disturbance. As with most of the country, there is appreciable asbestos in place in schools, public buildings, and homes. Therefore, while the area may be defined as rural, the potential for contact with asbestos-containing materials is common.

The first criterion used to classify these individuals as part of the general population included an apparent lack of job-related activities associated with occupational exposure to asbestos. Two blocks of tissue were sampled from the areas of the lung. The first was embedded in paraffin and sectioned for histopathological screening. If FBs were found in a section or changes were observed which could be suggestive of asbestos-induced diseases, the patient was excluded from the study. The second series of blocks were used for digestion procedures (described below). To be included in the study, the individuals also were confirmed via the analysis of the digests to have ferruginous body burdens of equal to or less than 20 FBs/gm wet weight.

The lung tissue was prepared for light and electron microscopy using Williams' modified bleach digestion procedure [Williams et al., 1982]. Briefly, 12 sites were sampled from normal upper and lower left lung parenchyma and pooled prior to bleach digestion. The pools averaged 0.6391 ± 0.2307 gm dry weight. Dry weights were calculated using wet/dry ratios determined for each case. All reagents were prefiltered through 0.2 μm polycarbonate filters just prior to use. Pooled aliquots were collected on 0.22 μm mixed cellulose ester filters (25 mm diameter) for FB counts by light microscopy and on 0.2 μm polycarbonate filters (25 mm diameter) for FB and uncoated fiber counts by electron microscopy. The mixed cellulose ester filters averaged 0.0414 ± 0.0046 gm dry weight of tissue. One-fourth of each filter was made transparent with acetone vapor and analyzed by light microscopy at 100x and 200x for establishing the levels of FBs in the tissue.

The polycarbonate filters averaged 0.00827 ± .000926 gm dry weight of tissue. The entire surface of each filter was analyzed by light microscopy at 100x and 200x for FBs. Carbon extraction replicas of each filter were made by the direct method. An area of 1.14 mm^2 was analyzed by ATEM at 16,000x for uncoated fibers and FBs. The mean detection limits were 8,800 f/gm wet and 44,000 f/gm dry. An additional area of 5.5 mm^2 was examined at 1,600x for FBs. A JEOL 100CX ATEM interfaced to an EDAX NX-2 X-ray analyzer was used for the analyses. Selected area electron diffraction (SAED) was used for further analysis of asbestos fibers. Uncoated fibers were defined as those ≥0.5 μm long with aspect ratios ≥3:1. Reagent and filter blanks were analyzed as part of the quality control procedure.

RESULTS

Seven of the individuals were found to have 20 FBs/gm wet weight. No FBs were observed in the remaining 26 individuals (Table I). There was a higher likelihood of finding an FB in the older half of the study population, beginning at age 35. Four females were in this group, two of whom (Cases 31 and 33) were found to have 20 FBs/gm wet. Five males in this group were also positive for FBs with 20/gm wet. There was a significant positive correlation between the FB and total uncoated asbestos concentrations ($P < 0.01$). Also, there was a positive correlation between age and total uncoated asbestos concentrations ($P < 0.01$). The highest concentrations of uncoated asbestos fibers, 290,000 fibers/gm dry, occurred in a 68-year-old white female (Case 31) and a 38-year-old male (Case 22) (Table I). However, the composition of the asbestos burden in these two cases differed greatly. The individual who had been a housewife was found to have predominantly anthophyllite fibers, with a lesser component of the burden being tremolite. No other asbestos types were found. In the male (Case 22), the prevalent type of asbestos was chrysotile, with a smaller component consisting of an equal amount of amosite and actinolite.

The most commonly encountered type of asbestos among the group was chrysotile, found in 14 of 33 cases (Table II, Fig. 1). Chrysotile was found as the highest concentration of the asbestos types in six cases. No chrysotile was found in 19 of the cases. Amosite was found in only three of the cases and was the predominant type of fiber in only one (Case 9).

The other amphibole commonly thought of as a commercial component, crocidolite, was found in three of the cases and was not the prevalent type of asbestos in any of these. The second most commonly encountered asbestos type was anthophyllite (12 of 33 cases). Anthophyllite was the predominant asbestos type in seven of the cases and the only asbestos found in three of them. Tremolite was found in eight of the cases, making it a more commonly encountered asbestos than either of the commercial amphiboles. Four of the cases were found to have actinolite fibers; 10 of the 33 patients had no asbestos fibers detected.

The average concentration of uncoated asbestos fibers for the 33 samples was 84,000/gm dry, while that for the 23 patients that were positive for fibers was 120,000/gm dry. The asbestos concentrations were skewed as seen in Figure 2, which is typical of these data. Most of the asbestos and nonasbestos fibers were classified as short fibers (<5 μm) (Tables III, IVA,B). The only asbestos fibers that met the Stanton hypothesis criteria (length ≥8 μm and diameter <0.25 μm) were 5% of the anthophyllite fibers. None of the nonasbestos fibers met the criteria (Table IVA).

The percentage of fibers that met the NIOSH counting criteria for PCM are found in Table IVB. When the asbestos fibers were considered as a group, 79% were less than 5 μm in length compared to 95.1% of the nonasbestos fibers. Only 9.7% of the asbestos and 4.5% of the nonasbestos could have been counted by NIOSH/PCM criteria (>5μm length).

TABLE II. Uncoated Fiber Data per Case (Fibers/g Dry) for Nonoccupationally Exposed East Texans

CASE	Total asbestos	Chrysotile	Amosite	Crocidolite	Tremolite	Actinolite	Anthophyllite	Nonasbestos
1	0	0	0	0	0	0	0	97,000
2	0	0	0	0	0	0	0	400,000
3	0	0	0	0	0	0	0	340,000
4	0	0	0	0	0	0	0	230,000
5	0	0	0	0	0	0	0	510,000
6	0	0	0	0	0	0	0	130,000
7	34,000	34,000	0	0	0	0	0	1,160,000
8	39,000	0	0	0	0	0	39,000	160,000
9	110,000	35,000	70,000	0	0	0	0	110,000
10	92,000	46,000	0	46,000	0	0	0	320,000
11	0	0	0	0	0	0	0	740,000
12	42,000	41,000	0	0	0	0	0	1,880,000
13	100,000	51,000	0	0	51,000	0	0	500,000
14	42,000	0	0	0	42,000	0	0	470,000
15	190,000	0	0	0	46,000	0	140,000	930,000
16	130,000	0	43,000	0	0	43,000	43,000	470,000
17	32,000	32,000	0	0	0	0	0	730,000
18	140,000	71,000	0	0	0	0	71,000	210,000
19	0	0	0	0	0	0	0	490,000
20	0	0	0	0	0	0	0	450,000
21	260,000	130,000	0	0	44,000	44,000	44,000	1,630,000
22	290,000	210,000	42,000	0	0	42,000	0	1,380,000
23	130,000	48,000	0	0	0	45,000	45,000	1,530,000
24	0	0	0	0	0	0	0	700,000
25	36,000	0	0	0	0	0	36,000	760,000
26	87,000	43,000	0	0	43,000	0	0	1,170,000
27	42,000	0	0	0	0	0	42,000	130,000
28	68,000	34,000	0	0	0	0	34,000	1,300,000
29	210,000	85,000	0	0	0	0	130,000	2,430,000
30	140,000	93,000	0	46,000	0	0	0	3,670,000
31	290,000	0	0	0	97,000	0	190,000	1,070,000
32	180,000	0	0	36,000	36,000	0	110,000	1,530,000
33	75,000	0	0	0	75,000	0	0	340,000
Avg. all cs.	84,000	29,000	4,700	3,900	13,000	5,300	28,000	850,000
Avg. "+" cs.	120,000	68,000	52,000	43,000	54,000	43,000	77,000	850,000

The highest total of uncoated asbestos fibers found in the group was 290,000 fibers/gm dry weight (Cases 22 and 31). Three of the four heaviest burdens of uncoated fibers were in individuals in whom at least one FB had been found (Cases 22, 29, and 31). However, the third highest level of uncoated asbestos fibers was found in an individual in whom no FBs were detected (Case 21).

The nonasbestos fibers consisted of 39.3% aluminum silicates, 31.5% mixed silicates, 6.9% magnesium silicates, 5.6% silica, 10% titanium, and 6.7% iron.

DISCUSSION

The work of Churg and Warnock [1980] suggested substantial amounts of asbestos, mainly chrysotile and noncommercial amphiboles, in the average lung in an urban environment. In the same study, the asbestos body content for 21 subjects was reported to be from 3 to 84 per gm of wet lung. The FB data in the present study are more consistent with the previous levels encountered in our laboratory for general populations and the levels reported by Roggli et al. [1986].

Churg and Warnock [1980] also reported that 80% of the uncoated asbestos fibers in this general population group were chrysotile and 90% of the chrysotile were <5 μm in length. In the present cohort, 35% of the uncoated asbestos fibers were chrysotile and 86% were <5 μm. Seventy-nine percent of all asbestos fibers were <5 μm. The study further concluded that 95% of the amphiboles were noncommercial

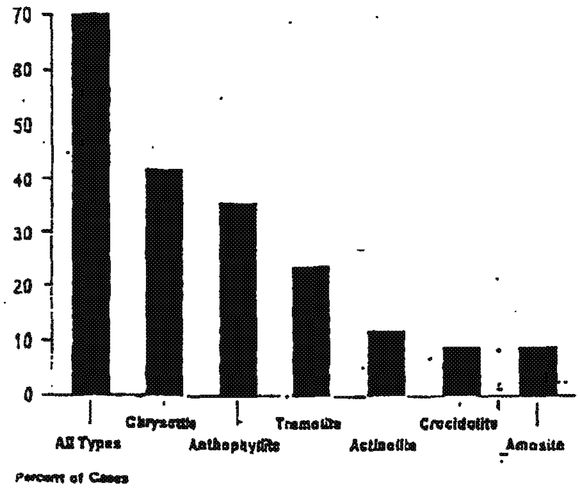

FIGURE 1. Percent distribution of asbestos type in lung samples from 33 East Texans not occupationally exposed to asbestos, 1996.

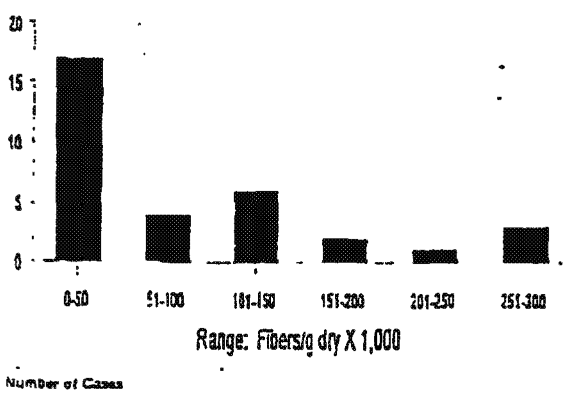

FIGURE 2. Distribution by total asbestos concentration in 33 East Texans, 1996.

types and that two-thirds of all amphiboles were <5 μm in length. Eighty-three percent of the amphiboles in the present study were noncommercial types and 73% of these were <5 μm in length. The source of anthophyllite in the general population from East Texas is presumed to be from exposure to products which contain the fibers as an associated component. For example, anthophyllite has been reported as coexisting with chrysotile [Kohyama et al., 1996] talc, cordierite, and phlogopite. There are no naturally occurring outcrops containing anthophyllite in eastern Texas. Anthophyllite has been used in very limited commercial applications worldwide [Selikoff and Lee, 1978], with one plant in the Northeast using the material as a component in the manufacture of plastic tanks. There was no indication of contact by members of this study group with such commercial products. While this study consisted of individuals from larger cities, the potential for exposure to asbestos-containing products existed for these individuals, as with those in the present study from sources at work, schools, and homes. Furthermore, the method of analysis and counting criteria allow a comparison between these "general population" groups. In contrast to a common presence of chrysotile

TABLE III. Fiber Characteristics: Geometric Means for Nonoccupationally Exposed East Texans

Fiber type	Length (μm)	Width (μm)	Aspect ratio
Chrysotile	1.81	0.08	29.29
Amosite	1.60	0.14	11.70
Crocidolite	2.11	0.17	12.79
Tremolite	2.40	0.26	9.11
Actinolite	1.50	0.24	6.11
Anthophyllite	2.97	0.23	12.05
All nonasbestos	1.37	0.16	8.55

TABLE IV(A). Fibers Fitting the Stanton Hypothesis* for Nonoccupationally Exposed East Texans

Fiber type	Percentage
Chrysotile	0.0
Amosite	0.0
Crocidolite	0.0
Tremolite	0.0
Actinolite	0.0
Anthophyllite	5.0
All nonasbestos	0.0

*Length >8.0 μm and diameter <0.25 μm.

TABLE IV(B). Fibers Meeting and Countable by NIOSH Criteria for Nonoccupationally Exposed East Texans

Fiber type	Percentage >5 μm	Percentage detectable by light microscopy*
Chrysotile	13.6	0.0
Amosite	25.0	25.0
Crocidolite	0.0	0.0
Tremolite	11.0	11.0
Actinolite	0.0	0.0
Anthophyllite	30.0	15.0
All nonasbestos	5.0	4.5

*>5 μm length and >0.25 μm diameter.

in members of the general population, less than 50% of the individuals in this study (14 individuals) had detectable levels of chrysotile.

While there may certainly be higher "background" levels in other general populations than those present in East Texas, the area has no shortage of asbestos in industry, private homes, schools, and public buildings. It should also be remembered that chrysotile clears more readily than amphibole and thus, over time, the lung burden represents a small fraction of inhaled chrysotile. Within the detectable limits of the present study it was, in fact, more likely that an individual would be found to have a "noncommercial" amphibole (17 out of 33) than chrysotile (14 out of 33).

Tremolite has been linked to chrysotile exposure in some settings, as discussed in a recent review [McDonald and McDonald, 1997]; however, there was no similar correlation found in the present study. Eight (23%) of the 33 patients were positive for tremolite and only three of these had chrysotile fibers. The small percentage with tremolite in this more rural population contrasts with data from the study of Srebro and Roggli [1994] in which this asbestos type was considered "nearly ubiquitous and represents the most common amphibole fiber in the lungs of urbanites." It is not possible in either study to define the source of the tremolite, but it should be appreciated that chrysotile is not the only mineral in which tremolite may be present.

The commercial amphiboles were the least likely form of asbestos to be encountered. Three of the patients had amosite fibers, which in the heaviest concentration was 70,000 fibers/gm dry weight. None of these individuals were from the Tyler area, which had been the site of an amosite manufacturing facility between 1954 and 1972. Twenty-five percent of the amosite fibers were >5μm in length (Table IVB). Three of the patients had crocidolite fibers, with similar concentrations in the range of 36,000 to 46,000/gm dry. When crocidolite fibers were found, they were <5 μm long.

CONCLUSIONS

The conclusions from this study are that there were few FBs found in nonoccupationally exposed members of the general population from East Texas, in that none were observed in 26 of 33 samples. The uncoated tissue burden of asbestos in this group was found to total from 0 to 290,000 fibers/gm dry weight. Chrysotile and noncommercial amphiboles make up the predominant uncoated fiber types encountered, with commercial amphiboles being found in few patients and, when present, in numbers of less than 70,000 fibers/gm dry weight.

In the present study, ten individuals within the limits of applicable detectability were not found to have either asbestos bodies or asbestos fibers. The overall tissue burdens tended to be highest in the older individuals in the study.

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