The pathology of parietal pleural plaques

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SYNOPSIS The incidence, morbid anatomy, histology, and relationship of hyaline pleural plaques to exposure to asbestos has been studied.

Plaques were found in 12.3% of 334 hospital necropsies (in an urban population in Glasgow, 41 cases). In 85.3% (35 cases) asbestos bodies were found in the lungs. There is evidence of a dose-response relationship between the number of asbestos bodies found in the lungs and the presence of pleural plaques.

The selective distribution of plaques within the pleural cavities suggests that mechanical factors play a part in their localization.

Histological examination contributed little to understanding the mechanism of plaque formation; that asbestos bodies have been detected in only a few cases suggest that their presence in the parietal pleura is not essential to plaque formation. The suggested mechanisms of plaque formation are discussed.

In the earlier literature on asbestosis there is reference to changes in pleural cavities (Cooke, 1927; Oliver, 1927; Stewart, Tattersall, and Haddow, 1932; Gloyne, 1933 and 1935; Lynch and Smith, 1935; Wyers, 1949) but in most reports it is difficult to be certain whether the changes described refer to the parietal or visceral pleura; in cases with fibrous obliteration of the cavities, distinction between the two layers is often difficult.

It is now believed that there is a relationship between hyaline plaque formation on the parietal pleura and exposure to asbestos unaccompanied by pulmonary fibrosis (asbestosis) (Kiviluoto, 1960; Meurmann, 1966). The epidemiological value of radiology in detecting plaques to assess the extent of exposure to asbestos in a community has been shown by several workers (Hourihane, Lessof, and Richardson, 1966; Kiviluoto, 1960; Anton, 1968).

Pathological studies are, however, few (Hourihane *et al*, 1966; Meurmann, 1966), and in most of the 'community studies' on the incidence of asbestos bodies in routine hospital necropsies, pleural plaques are not mentioned (Thomson, Kaschula, and Macdonald, 1963; Cauna, Totteun, and Gross, 1965; Anjilvel and Thurlbeck, 1966; Thomson and Graves, 1966; Ashcroft, 1968).

In a study of the incidence of asbestos bodies in hospital necropsies in Glasgow (Roberts, 1969) asbestos bodies were found in 123 of 400 consecutive

necropsies (30.8%); the pleural cavities were personally examined for plaques in 334 cases. This paper presents my findings on the incidence, morbid anatomy, histology, and relationship of pleural plaques to asbestos bodies in the lungs.

Methods and Materials

The necropsies were performed in the pathology department of a general hospital serving a population of approximately 250,000 in south-west Glasgow. This is a heavily industrialized urban population, close to the Clyde with its concentration of heavy industry, in particular shipbuilding.

The pleural cavities of 334 cases were examined for hyaline plaques, except for the plaques from 13 cases found in the first 100 necropsies (Roberts, 1967). Whether plaques were unilateral or bilateral and their sites in the pleural cavities was noted; no distinction was made between calcified and non-calcified plaques. The diaphragm and pericardial sac were also examined and the presence or absence of fibrous pleural adhesions noted.

The histology of the plaques was studied in 28 cases and asbestos bodies looked for in 5 μ and 25 μ thick sections, and also by Gold and Kerr's extraction technique (1967). In these 28 cases random sections of the basal segments of both lower lobes, which included the visceral pleura, were also available.

Thick smears from the basal segments of both

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lower lobes were made at necropsy and examined for asbestos bodies; 300 consecutive low-power fields (16 mm objective) were examined from each slide and asbestos bodies counted (Roberts, 1967 and 1969).

In none of the cases was a detailed occupational history available, but a note was made of the patient's present or last known occupation when available in the clinical notes.

Results

Hyaline pleural plaques were found in 41 of 334 (12.3%) necropsies (Table I). The highest incidence of plaques was found in the seventh decade (21 cases, 51.2%); this is the age group which also showed the highest incidence of asbestos bodies in the 400 necropsies (39.4% of 142 cases, 58.1% of 86 males). Only once were plaques seen in a female (case 27). In 35 of the 41 cases (85.3%) asbestos bodies were

found in the basal smears; plaques were present in six cases without bodies being found in the smears (14.7%). This difference is statistically significant ($\chi^2 = 22.0$, $P < 0.001$).

In 57 cases in which fewer than five bodies were counted plaques were found in nine (15.8%) while in 52 cases with five to 50 bodies, 32.6% (17 cases) showed plaques. In eight cases in which more than 100 bodies were found plaques were present in all. There was one example of classical asbestosis and the lungs of this case showed bilateral plaques as did those of one of two cases of pleural mesothelioma.

Occupation

The occupations were mentioned in the clinical notes in 33 of the 40 males in whom plaques were found. In 13 the shipyards were specifically mentioned as the place of work (riveter, joiner, shipwright, plater, boilermaker, dock foreman). Other occupations mentioned were engineer, coppersmith, labourer, electrician, driller. Further occupational details would undoubtedly have revealed a higher proportion of shipyard workers.

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MACROSCOPIC

Parietal pleural plaques occurred as discrete, raised, irregularly shaped areas, separated either by normal or slightly thickened pleura. The thinner plaques were only slightly raised above the pleural surface; they were smooth and of a greyish-white colour. The thicker plaques were ivory white or cream coloured; they were either smooth or showed a fine or coarse nodularity. They varied in size from a few millimetres to 10 centimetres.

Plaques on the costal pleura could easily be stripped away from the intercostal muscles; plaques on the diaphragm were firmly adherent and could not be removed from the underlying tendon. Most of the plaques had a leathery consistency and when removed from the body could be bent; others more heavily calcified were brittle and fractured easily.

Plaques were most commonly found on the posterior wall of the lower half of the pleural spaces, those in the intercostal space tended to have an elliptical shape and ran parallel to the ribs above and below. No plaques were found at the apices of the pleural cavities, in the costophrenic angles, or on the anterior wall close to the costochondral junction.

In 28 cases the distribution of the plaques was noted. In 10 cases the plaques were unilateral (left 6, right 4), asbestos bodies being found in the basal smears in nine (90%). In two cases where plaques were found in the left pleura the right pleural space

Case No.	Sex	Age (yr)	Occupation	Asbestos Bodies per 600 lpf
1	m	62	Riveter (shipyard)	6
2	m	46	Joiner (shipyard)	50
3	m	84	Retired engineer	6
4	m	78	Retired engineer	2
5	m	74	Riveter (shipyard)	430
6	m	63	Coppersmith	18
7	m	48	Baker	0
8	m	61	Joiner	112
9	m	74	Turner	3
10	m	65	?	73
11	m	65	Shipwright	0
12	m	57	?	357
13	m	67	Dock watchman	4
14	m	63	Plater (shipyard)	168
15	m	67	Labourer	30
16	m	76	Retired riveter (shipyard)	46
17	m	65	Shipwright	9
18	m	63	Asphalter	2
19	m	82	Retired electrician	15
20	m	67	Boiler maker (shipyard)	42
21	m	71	Retired boiler maker	19
22	m	59	Riveter (shipyard)	1
23	m	83	Retired riveter (shipyard)	5
24	m	65	?	27
25	m	67	?	22
26	m	44	Sheet iron worker	33
27	f	68	Retired factory worker	1
28	m	47	Dock foreman	3
29	m	77	?	0
30	m	53	Storeman	843
31	m	63	Shipyard worker	6
32	m	57	Electrician	24
33	m	45	Driller	0
34	m	76	Metal pickler	0
35	m	64	?	1064
36	m	62	Coppersmith	32
37	m	66	Blacksmith	1
38	m	67	Labourer	284
39	m	71	Retired engineer	0
40	m	63	?	4
41	m	61	Joiner (shipyard)	590

Table I Details of 41 cases of pleural plaques

was obliterated by fibrous adhesions. In 18 cases bilateral plaques were found, asbestos bodies being found in the smears of 15 (82.1%); in one case plaques were found on both halves of the diaphragm and in the left pleura, the right pleural space being obliterated by fibrous adhesions.

HISTOLOGY

Plaques from 28 cases were sectioned. All were composed of slightly undulating dense bands of avascular collagen, lying parallel to the surface and in places showing a finely reticulated meshwork pattern (Fig. 1). In the nodular plaques the collagen showed a whorled pattern while sections parallel to the

Fig. 1 Hyaline pleural plaque showing reticulated meshwork pattern. (Verhoeff-Van Gieson $\times 80$.)

surface of plaques showed a coarsely woven trabeculated pattern. When stained with Verhoeff's method for elastic fibres, counterstained with Van Gieson's solution (Culling, 1963), some plaques stained black as for elastic tissue rather than red for collagen (Fig. 1).

The plaques were relatively acellular and only an occasional spindle-shaped fibroblast could be identified (Fig. 2); focal areas of calcification showed either as fine particles or more massive areas (Fig. 3). In one case small amounts of fibrin were present on the surface of the plaques; none was covered with mesothelial cells, but a single layer of small cuboidal cells extended up to the margin of the plaques in some cases. In the fatty adipose tissue beneath the

Fig. 2 Reticulated pleural plaque showing spindle-shaped fibroblasts. (H.E. $\times 240$.)

Fig. 3 Calcified pleural plaque. (Von Kossa $\times 200$.)

Fig. 4 Edge of pleural plaque showing connective tissue of pleura passing deep to the plaque. (Verhoeff-Van Gieson $\times 80$.)

plaque dilated, congested vessels surrounded by variable numbers of lymphocytes and plasma cells were a constant finding. In no case were inflammatory cells present in the plaques.

The boundary between a plaque and the surrounding pleura was always sharply demarcated and the ordinary connective tissue of pleura could be identified passing deep to the plaque (Fig. 4).

No asbestos bodies were seen in any of the plaques sectioned at $5\ \mu$ and $25\ \mu$; in two cases scanty but typical bodies were found by the extraction technique.

Histological evidence of minimal basal asbestosis was found in seven of the 28 cases (25.0%).

Discussion

The results support the causal relationship between hyaline parietal pleural plaques and exposure to asbestos based on radiological examinations during life, and on necropsy findings (Kiviluoto, 1960; Lawson, 1963; Hourihane *et al*, 1966; Meurmann, 1966; Anton, 1967 and 1968). Plaques were found in 41 of 334 necropsies (12.3%) which is close to the findings at the London Hospital (11.2% of 134

necropsies) (Hourihane *et al*, 1966). Both these figures are considerably lower than the findings of Meurmann (1966) in Finland where plaques were found in 39.3% of 438 consecutive necropsies; a higher incidence of asbestos bodies was also found in the necropsies in Finland (57.6% as compared to 24.3% and 30.8% in London and Glasgow respectively).

Plaques, like asbestos bodies, were commoner in males. Of the 41 cases in the present series only one was a female, a 'retired factory worker' of 68 years, who died from a carcinoma of the vulva; one asbestos body was found in the basal smears. Meurmann (1966) found that of 119 cases showing bilateral plaques, 85 were in males (61.1%) whereas Hourihane *et al* (1966) found that 75% of his 56 cases were males.

There is a statistically significant difference in the incidence of pleural plaques in cases with and without asbestos bodies in the smears. Asbestos bodies were found in the smears from 35 of the 41 cases (85.3%), as against Meurmann's (1966) percentage of 79 and the 100% of Hourihane *et al* (1966).

In six cases (14.7%) no asbestos bodies were found in the basal smears; Meurmann (1966) was unable to find asbestos bodies in approximately 20% of the cases showing plaques, even when up to 10 sections were examined from different parts of the lung. In none of the six cases of plaques but without asbestos bodies in the present series was there evidence of pulmonary tuberculosis, which is a recognized cause of pleural plaque formation, especially if unilateral (Hourihane *et al*, 1966). Neither was there evidence in the clinical histories or in the necropsy findings that these plaques were the result of calcified haemothoraces. It may be that although exposure to asbestos is the commonest cause of pleural plaques, there still exist unidentified causes.

There seems to be a relationship between the incidence of plaques and the number of asbestos bodies found in the lungs, and that plaques are more likely to be found if asbestos bodies are numerous, suggesting that there is a 'dose-response' relationship (Hourihane and McCaughey, 1966). Of 57 cases in which less than five bodies were counted, plaques were found in nine (15.8%); plaques were present in 32.6% of 52 cases where five to 50 bodies were found. In eight cases where more than 100 asbestos bodies were counted pleural plaques were present in all. Hourihane and McCaughey (1966) suggested that the dosage of asbestos related to the number of pleural plaques is of a size between that necessary for the development of mesothelioma in the general population in whom small amounts of

asbestos will be found in the lungs, and classical asbestosis in subjects with large amounts of asbestos in the lungs, a history of industrial exposure, and an increased incidence of mesothelioma.

Plaques were found posteriorly in the lower half of the pleural cavities, in the paravertebral fossae, and on the diaphragm. In none of the cases were plaques found at the apices, in the costophrenic angles, or on the anterior wall close to the costochondral junctions. This selective distribution within the pleural cavities was also observed by Meurmann (1966), who suggested that mechanical factors were involved, possibly the varying pressures and stretching to which the pleura is subjected during respiration. Fibrous adhesions which would restrict free respiratory movement might be expected to hinder the formation of plaques; thus in three cases showing plaques on the costal pleura the other pleural space was obliterated by fibrous adhesions and was clear of plaques. Meurmann (1966) also commented that plaques occurred in areas of pleural surface which were free of adhesions.

The mechanism by which asbestos induces the formation of plaques is uncertain, and histological examination does little to resolve this uncertainty. Kiviluoto (1960) suggested that the sharp points of asbestos fibres protrude through the visceral pleura into the pleural cavity. During respiration the parietal and visceral layers rub against each other and the points of the asbestos fibres have an abrasive action on the parietal pleura which leads to a slight but continuously produced fibrinous exudation. Subsequently, fibrous organization takes place and poor nourishment at the centre of the plaques leads to degenerative changes followed by calcification. Similarly Siegal, Smith, and Greenburg (1943) suggested that mechanical factors combined with haemorrhage as a possible explanation; it was suggested that small particles caused small pulmonary and pleural haemorrhages which subsequently calcified as larger haemorrhages are known to do.

Histologically all the plaques in the present series were composed of relatively acellular bands of laminated collagen, and, although lymphocytes and plasma cells were seen in the fatty tissue beneath plaques, no evidence of an inflammatory exudate or granulation tissue was seen within plaques. Neither was haemosiderin identified as would be expected if pleural haemorrhage had played an important part in their formation (Siegal *et al.* 1943). Only in one case was there a small amount of fibrin on the surface of a plaque. Hourihane *et al.* (1966) found fibrin incorporated into the surface layer of a plaque in only one of 50 cases, and Meurmann saw no fibrinous exudation in 172 cases.

Pleural plaques stained black as for elastic in the Verhoeff-Van Gieson method (Culling, 1963); Gillmann, Penn, Bronks, and Roux (1955) described such 'pseudo elastic fibres' in skin scars, gallbladders, and arteries and suggested that they were derived from alteration in the composition of preformed collagen. These pseudo-elastic fibres were frequently calcified, and Gillmann and his colleagues (1955) suggested that this was an aging process. This might be an explanation for calcification in some plaques and an alternative to the suggestion that calcification is a degenerative change as a result of poor nourishment at the centres of the plaques (Kiviluoto, 1960). Spencer (1963) found that the fibrous tissue of a pulmonary scar carcinoma was also composed of these pseudo-elastic fibres, and suggested that collagen exposed to repeated stretching develops elastic properties. Such an explanation would account for the tinctorial reaction in pleural plaques which are constantly and repeatedly stretched during respiration.

Although earlier workers (Gloyne, 1933; Wyers, 1949) reported that asbestos bodies could be found in the pleura, it is not always clear whether this refers to the parietal or visceral layer. In more recent years it is only in a relatively few cases that asbestos bodies or fibres have been found in the parietal pleura. Meurmann (1966) found no asbestos bodies or fibres in sections of 172 plaques despite the use of polarized light. Hourihane *et al.* (1966) found asbestos fibres in four of 12 cases using a technique of maceration and phase-contrast microscopy. In the present 28 cases scanty asbestos bodies were revealed in two by the extraction technique (Gold and Kerr, 1967).

That asbestos fibres or bodies have been detected in so few parietal plaques suggests that the presence of these foreign bodies is not necessary to produce plaques.

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