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Sarcomatoid mesothelioma: a clinical–pathologic correlation of 326 cases

Sonja Klebe[1], Noel A Brownlee[2], Annabelle Mahar[3], James L Burchette[4], Thomas A Sporn[4], Robin T Vollmer[5] and Victor L Roggli[4]

[1]*Department of Anatomical Pathology, Flinders University and Medical Centre, Adelaide, Australia;* [2]*Pathology Associates of Greenville, Greenville, SC, USA;* [3]*Department of Anatomical Pathology, Royal Prince Alfred Hospital, Camperdown, NSW, Australia;* [4]*Department of Pathology, Duke University Medical Center, Durham, NC, USA and* [5]*Department of Pathology, Durham VA Medical Center, Durham, NC, USA*

Sarcomatoid mesothelioma is the least common, but most aggressive of the three major histological types of mesotheliomas. This study comprises 326 cases of sarcomatoid mesotheliomas among 2000 consecutive malignant mesothelioma cases received in consultation (16%). Patients included 312 men (96%) and 14 women (4%), with a median age of 70 years (range 41–94 years). Most tumors were pleural (319; 98%), and 7 were peritoneal (2%). Some desmoplastic features were identified in 110 cases (34%), and 70 (21%) were classified as desmoplastic. Rare subtypes included two cases with a lymphohistiocytoid pattern (<1%) and eight heterologous mesotheliomas (2%). Labeling for cytokeratins (CKs) was observed in 261/280 cases (93%), and for calretinin and vimentin in 31 and 91%, respectively. Pleural plaques were present in 79% of cases for which information was available, and asbestosis was diagnosed in 34/127 cases (27%). Median survival was 3.5 months. Fiber analysis was performed in 61 cases. The median asbestos body count was 1640/g wet lung tissue (by light microscopy). Amosite fibers were the most commonly identified fibers using energy-dispersive X-ray analysis and were significantly higher in the sarcomatoid cases, as were uncoated fibers using scanning electron microscopy. This study represents the largest series of sarcomatoid and desmoplastic malignant mesotheliomas to date and confirms the diagnostic usefulness of CK immunohistochemistry. The relationship with asbestos exposure—particularly amosite—and an association with pleural plaques and less often asbestosis is confirmed.
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Primary tumors of the pleura are rare overall, and diffuse malignant mesothelioma is the most common of these neoplasms. The causal relationship to past inhalation of asbestos fibers—especially amphibole asbestos—is well recognized, and despite bans or restrictions on the use of asbestos, malignant mesothelioma will continue to represent a significant public health problem for many years to come, because of the long latency interval between the commencement of exposure and the subsequent malignant mesothelioma. The World Health Organization classifies malignant mesothelioma into epithelial, sarcomatoid, and biphasic types, each of which can be subdivided further.[1] This classification has implications for both diagnosis and prognosis. Prognosis is poor for all malignant mesotheliomas, but sarcomatoid malignant mesotheliomas have a particularly poor response rate to treatment, with a median survival of 6 months in one study, 5.8 months in another, 5.5 months for cases in the German Mesothelioma Register, and 6.2 months survival for desmoplastic malignant mesotheliomas.[2–5]

Histological diagnosis of sarcomatoid malignant mesothelioma—notably the desmoplastic and lymphohistiocytoid subtypes—can be more problematic than for epithelioid or biphasic malignant

Correspondence: Dr S Klebe, MD, PhD, Department of Anatomical Pathology, Flinders University and Flinders Medical Centre, Bedford Park, SA 5042, Australia or Dr VL Roggli, MD, Department of Pathology, Duke University Medical Center, M255 Davison Building, Erwin Road, Durham, NC 27710, USA.
E-mail: sonja.klebe@health.sa.gov.au or Roggl002@mc.duke.edu
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mesotheliomas, because of similarity with benign fibrous pleuritis in the case of desmoplastic malignant mesothelioma, and with non-mesothelial tumors such as malignant fibrous histiocytoma and even non-Hodgkin's lymphoma, and because of restricted or inconsistent expression of mesothelial markers on immunohistochemistry.[6–8] We consider the correct diagnosis to be imperative because of the different prognostic implications of other disorders that mimic sarcomatoid malignant mesothelioma (eg, desmoplastic malignant mesothelioma *vs* fibrous pleuritis), including the choice of treatment regimes (eg, sarcomatoid malignant mesothelioma *vs* pleural synovial sarcoma), and because of the medicolegal implications.

In this study, we examined the clinical and pathologic features of 326 cases of sarcomatoid mesothelioma identified in the database of one of the researchers (VLR), including demographic and survival data, immunohistochemical findings, presence of asbestosis or pleural plaques, and asbestos fiber analysis of lung parenchyma. This study confirms the usefulness of immunohistochemistry for cytokeratins (CKs; and calretinin expression if detectable), reveals an association with amosite asbestos fiber exposure and accompanying pleural plaques or asbestosis, and confirms the distinctly worse prognosis compared with other types of mesotheliomas.

Materials and methods

After approval by the institutional ethics committee, 326 patients with a diagnosis of sarcomatoid, desmoplastic, lymphohistiocytoid, or heterologous sarcomatoid malignant mesotheliomas were identified in 2000 consecutive cases of mesotheliomas, which comprised mainly professional and medicolegal consultation cases. The diagnosis was based upon histology, the results of immunohistochemical studies, and the gross distribution of tumor as determined using radiological or autopsy studies, or clinical observations at the time of surgical exploration. Desmoplastic mesothelioma was defined by at least 50% of the tumor showing typical collagenous stroma with paucicellular atypical invasive mesothelial proliferation. Tumors with $>10\%$ but $<50\%$ desmoplastic features were classified as sarcomatoid mesotheliomas with focal desmoplastic features.[6] Information was sought on gender, age, asbestos exposure history, and the presence or absence of asbestosis or pleural plaques for each case. Asbestosis was defined as lung tissue showing diffuse interstitial fibrosis, with or without honeycomb change, with asbestos bodies present.[9,10] Patient survival was evaluated by clinical follow-up for periods of up to 22 months.

Immunohistochemical studies were performed using the avidin biotinylated complex technique. CK immunohistochemistry has evolved considerably during the 25 years over which these cases were collected. In the early 1980s, we used a polyclonal antibody prepared by injecting an NZW rabbit with ground calluses. Serum collected before immunization was used for negative controls. This antibody was originally used with an HRP-labeled secondary antibody and later with Vector Laboratories' original avidin biotinylated complex methodology (Burlingame, CA, USA). This was replaced in 1987 with a Dako rabbit polyclonal antibody (Carpinteria, CA, USA). In 1988, we began using a commercially available Hybritech AE1/AE3 cocktail (Fullerton, CA, USA), with antigen retrieval using trypsin and the avidin biotinylated complex Elite detection system (Vector Laboratories). In the early 1990s, a cocktail of AE1/AE3 and Becton-Dickinson (Franklin Lakes, NJ, USA) CAM5.2 was used. In 1990, trypsin was replaced with Brigati's stable pepsin solution (Invitrogen, Carlsbad, CA, USA). The Dako MNF.116 antibody was incorporated into the AE1/AE3/CAM5.2 cocktail in 1996. The vimentin monoclonal antibody that we have used is Dako antibody (no. M7020, clone 3B4), used in a dilution of 1:150, and enzymatic antigen retrieval. The calretinin antibody used was Zymed (San Francisco, CA, USA).

For 61 cases, lung tissue was available for analysis of mineral fiber content using the sodium hypochlorite digestion technique.[11] Digested lung tissue was collected on 0.4-μm pore size Nuclepore filters. For light microscopic analysis, the filter was mounted on a glass slide. Asbestos bodies were quantified using a magnification of $\times 400$. Only ferruginous bodies showing typical morphology with thin linear translucent cores were counted as asbestos bodies.[11] The results were reported as asbestos bodies per gram of wet lung tissue (asbestos bodies/g), with a detection limit of approximately three asbestos bodies/g for a 0.3 g sample. For scanning electron microscopic analysis, the filter was mounted on a carbon disc with colloidal graphite and then sputter-coated with gold. A JEOL JSM-6400 scanning electron microscope (JEOL, Peabody, MA, USA) with a screen size of $22.7 \times 17.3\,cm^2$ was used to quantify uncoated fibers and asbestos bodies at a screening magnification of $\times 1000$. Only fibers 5 μm or greater in length with a length-to-width ratio of at least 3:1 and approximately parallel sides were counted. Fibers meeting these criteria were quantified by examining 100 consecutive fields, with a total area of approximately $2.53\,mm^2$, or until a fiber count of 200 was reached. The limit of detection is approximately 500 fibers/g for a 0.3 g sample.[12]

The chemical composition of fibers was determined by energy-dispersive X-ray analysis. Asbestos fibers were classified as commercial amphiboles, specifically amosite and crocidolite, non-commercial amphiboles, including tremolite, anthophyllite, and actinolite or chrysotile.[9] Tissue concentration of amosite and crocidolite, tremolite, anthophyllite,

actinolite, and chrysotile was calculated in each case using the proportion of each type of fiber and the total asbestos fiber concentration (results were expressed as fibers/g wet lung). Non-asbestos mineral fibers were classified according to their morphology and X-ray spectra. For statistical analysis, we used the non-parametric Kruskal–Wallis test, because the distribution of asbestos fibers seemed to be non-normal.[13]

Results

Within 2000 consecutive cases of mesotheliomas from the database of one of the researchers (VLR), 326 cases of sarcomatoid mesothelioma were identified (16%). The median patient age was 70 years with a range of 41 to 94 years. In all, 312 cases occurred in men (96%) and 14 in women (4%). Tumors arose from the pleura in 319 patients (98%) and the peritoneum in 7 cases (2%). The sarcomatoid malignant mesotheliomas typically showed marked pleural thickening and encasement of the lung parenchyma at post-mortem examination (Figure 1a). *Ante mortem* computed tomography examination in another sarcomatoid malignant mesothelioma patient showed prominent pleural thickening with focal bone formation (Figure 1b).

Several histological subtypes of sarcomatoid mesothelioma were identified (summarized in Table 1). 'Conventional' sarcomatoid malignant mesothelioma of no special subtype accounted for 143 tumors (44%), desmoplastic features were observed in 110 tumors (34%), and 70 (21%) were classified as desmoplastic malignant mesotheliomas. Eight tumors showed osteosarcomatous and/or chondrosarcomatous features (2%), and a lymphohistiocytoid histology was present in two tumors (<1%).[7] The spectrum of histological features of sarcomatoid malignant mesothelioma is illustrated in Figures 2 and 3.

The results of immunohistochemical studies are summarized in Table 2. A total of 261 cases out of a group of 280 (93%) were immunoreactive with keratin antibodies, showing strong and diffuse cytoplasmic staining (Figure 4a); 101 cases out of 111 were immunoreactive for vimentin (91%), and 12/39 (31%) were positive for calretinin, in which labeling was often focal (Figure 4b).

The additional clinical and pathologic features identified are summarized in Table 3. Pleural plaques were present in 144/182 patients (79%) and histological asbestosis was found in 34/127 patients (27%).

Asbestos fiber quantification using light microscopy and energy-dispersive X-ray analysis of asbestos fiber composition using scanning electron microscopy was available for 61/326 (19%) patients in this study (Table 4). An elevated asbestos content, as determined using light and scanning electron microscopy, was present in 57/61 patients (93%).

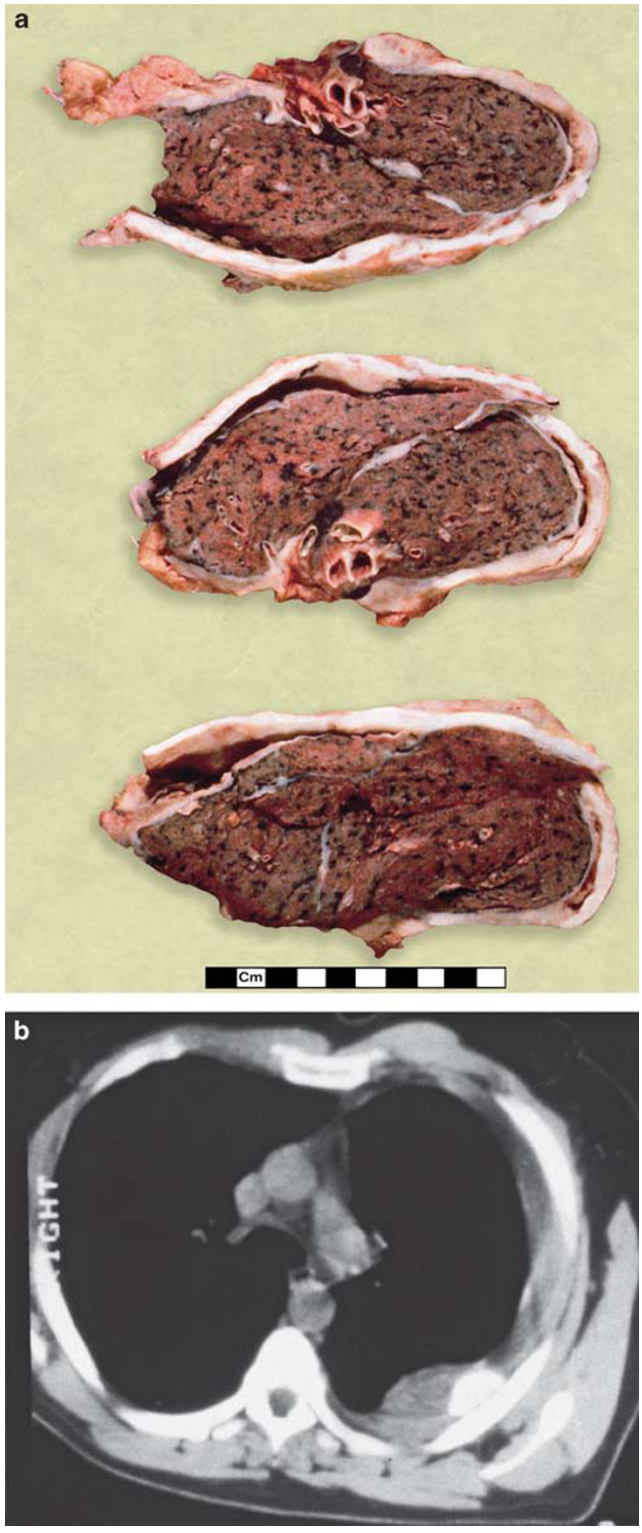

Figure 1 Gross distribution of disease. (**a**) Horizontal sections of the post-mortem lung showing encasement by pleural sarcomatoid mesothelioma. (**b**) Computed tomography of chest showing tumor as an area of pleural thickening with focal bone formation. Figure 1b reprinted with permission from Sporn and Roggli (2004).[15]

Asbestos fibers were classified using energy-dispersive X-ray analysis, based upon chemical composition, as commercial amphiboles (amosite and crocidolite), non-commercial amphiboles (tremolite, anthophyllite, and actinolite) or chrysotile. The median asbestos body/g wet lung tissue based upon light microscopy was highest for sarcomatoid mesothelioma at 1640 asbestos bodies (range <3 to 436 000). In comparison, the median asbestos body count for non-sarcomatoid mesothelioma histologies was 348 (range <0.2 to 1.6 million). However, these differences were not statistically significant due to the large overlap in values between the two groups ($P=0.07$). The reference population lung tissue (non-asbestos-exposed individuals) had a median asbestos body count of 2.9 (range 0.2–22).

Table 1 Histological features of 326 sarcomatoid mesotheliomas

Tumor histology	*Number of cases (%)*
'Conventional' sarcomatoid MM of no special subtype	145 (44%)
Sarcomatoid with desmoplastic areas	70 (21%)
Desmoplastic	110 (34%)
Osteosarcomatous and/or chondrosarcomatous	8 (1%)
Lymphohistiocytoid	2 (<1%)

Energy-dispersive X-ray analysis revealed that sarcomatoid mesotheliomas had a median commercial amphibole (amosite + crocidolite (A+C)) count of 15 600 (range <280 to 494 000) when compared with non-sarcomatoid tumors with a median count of 6640 (range 120–11.9 million), and the reference population had a median A+C count of <600 (no uncoated commercial amphiboles

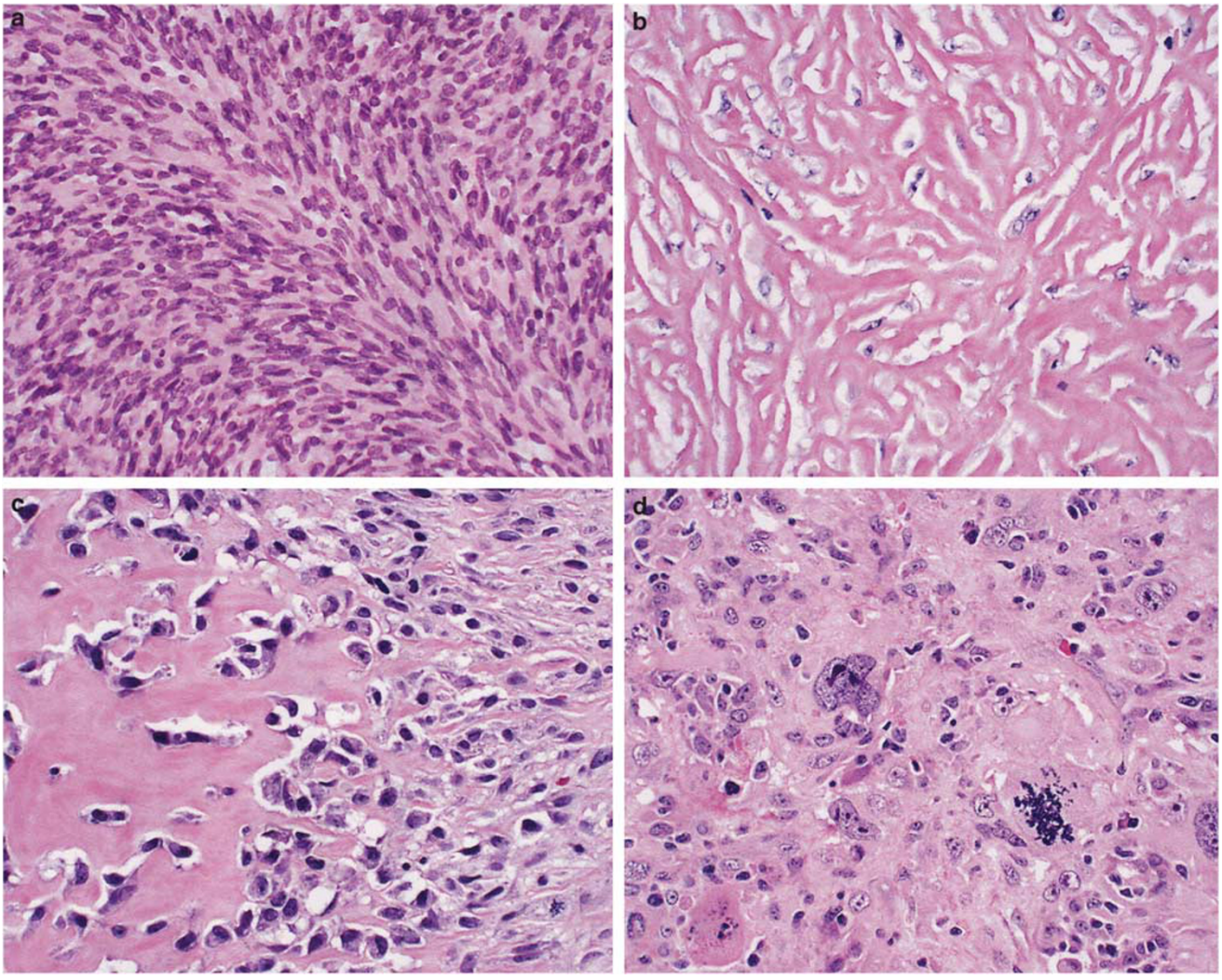

Figure 2 Hematoxylin and eosin-stained sections (medium power) of pleural sarcomatoid malignant mesothelioma subtypes. (**a**) The sarcomatous pattern is characterized by a hypercellular spindle-cell neoplasm characterized by elongated nuclei, numerous mitotic figures, and eosinophilic cytoplasm. (**b**) Desmoplastic malignant mesothelioma is predominantly hypocellular with scattered atypical cells among dense collagenous tissue. (**c**) Osteosarcomatous pattern characterized by malignant cells with pleomorphic nuclei, numerous mitoses, and osteoid deposition. (**d**) The malignant fibrous histiocytoma-like pattern consists of markedly atypical cells with pleomorphic/giant-cell nuclei containing multiple nucleoli, abundant eosinophilic cytoplasm, and bizarre mitotic figures.

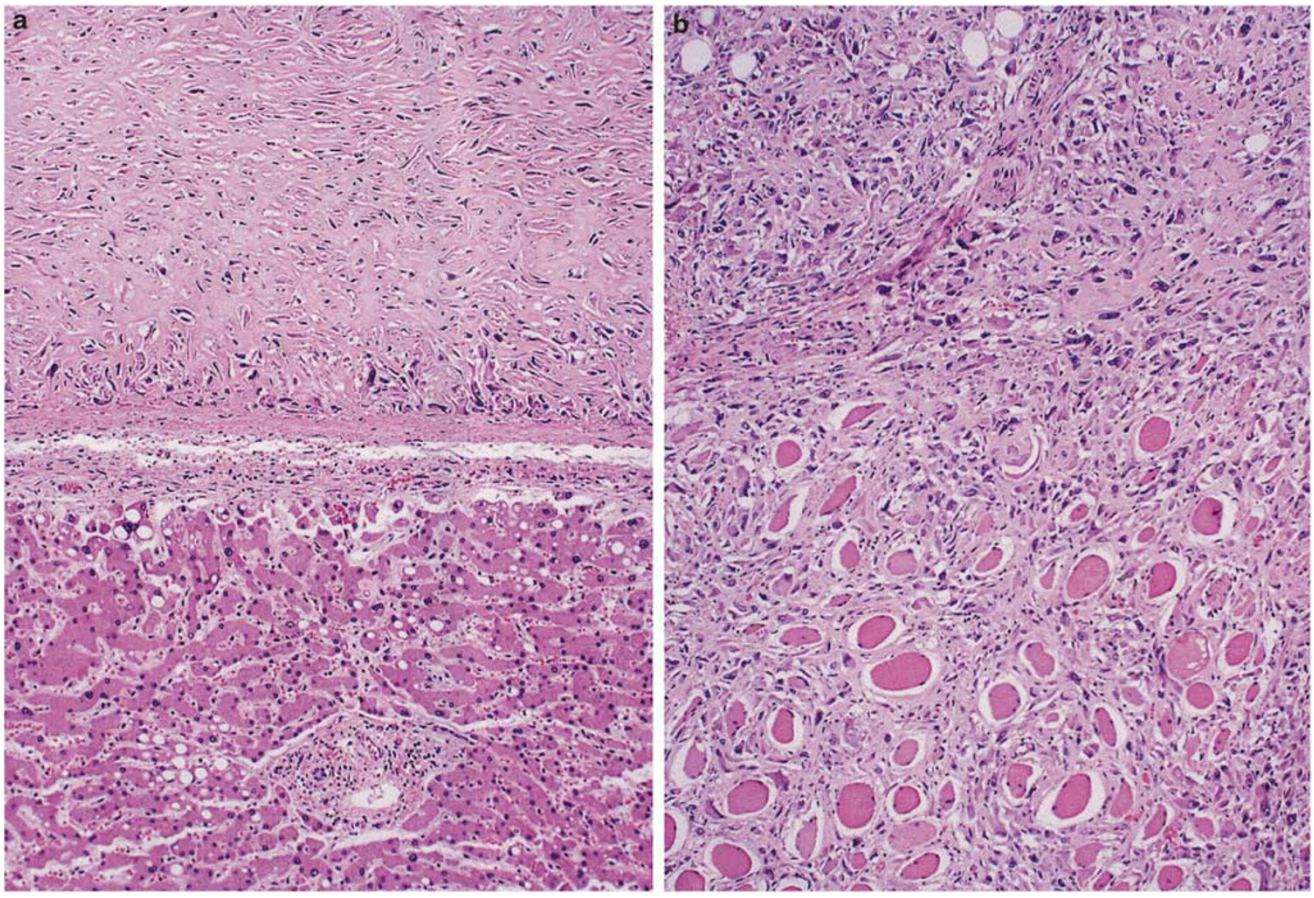

Figure 3 Hematoxylin and eosin-stained sections (medium power) of a case of peritoneal desmoplastic mesothelioma. (**a**) This tumor involved the dome of the liver and (**b**) invaded surrounding adipose and skeletal muscle tissue.

Table 2 Sarcomatoid mesothelioma: immunohistochemical findings

Marker/antibody	*Number of immunoreactive cases/total cases (%)*	*Remarks*
Cytokeratins	261/280 (93%)	One equivocal result
Vimentin	101/111 (91%)	
Calretinin	12/39 (31%)	Usually focal labeling of <10% of tumor cells

were detected in our controls). Amosite concentrations were significantly higher in the sarcomatoid group ($P=0.03$). For non-commercial amphibole fibers, the median fiber count in the sarcomatoid malignant mesothelioma patients was 4180 (range <470 to 455 000) *versus* 2540 for non-sarcomatoid malignant mesotheliomas (range 26–286 000). Non-commercial amphibole concentrations were not significantly different between the two groups ($P>0.05$). The reference population had a mean non-commercial asbestos fiber count of <600 (range <170 to 2540). The median chrysotile asbestos fiber count was only slightly higher in patients with sarcomatoid tumors at 1450 (range <470 to 14 200) *versus* other malignant mesothelioma histologies at 1100 (range <120 to 197 000) ($P>0.7$) and the reference population (median of <600, range <100 to 1000).

Survival data were available for 260/326 (80%) patients in this study (Figure 5), with follow-up ranging from 1 to 22 months after diagnosis. At 2 months after diagnosis, approximately 70% of patients were alive, but at 4 months the survival rate dropped sharply to 50%, and to 30% at 6 months. Only 10% of patients were alive after 1 year, and 5% after 18 months.

Discussion

Sarcomatoid mesothelioma is defined by the absence of epithelial elements in the biopsy material or <10% of epithelial tissue.[14] For the purposes of our study, we excluded any case with an identifiable epithelial component. It is the least common of the three main types and accounts for roughly 10% of pleural malignant mesotheliomas, with a reported range of approximately 7–22%.[14–17] Interestingly, an origin of sarcomatoid malignant mesothelioma

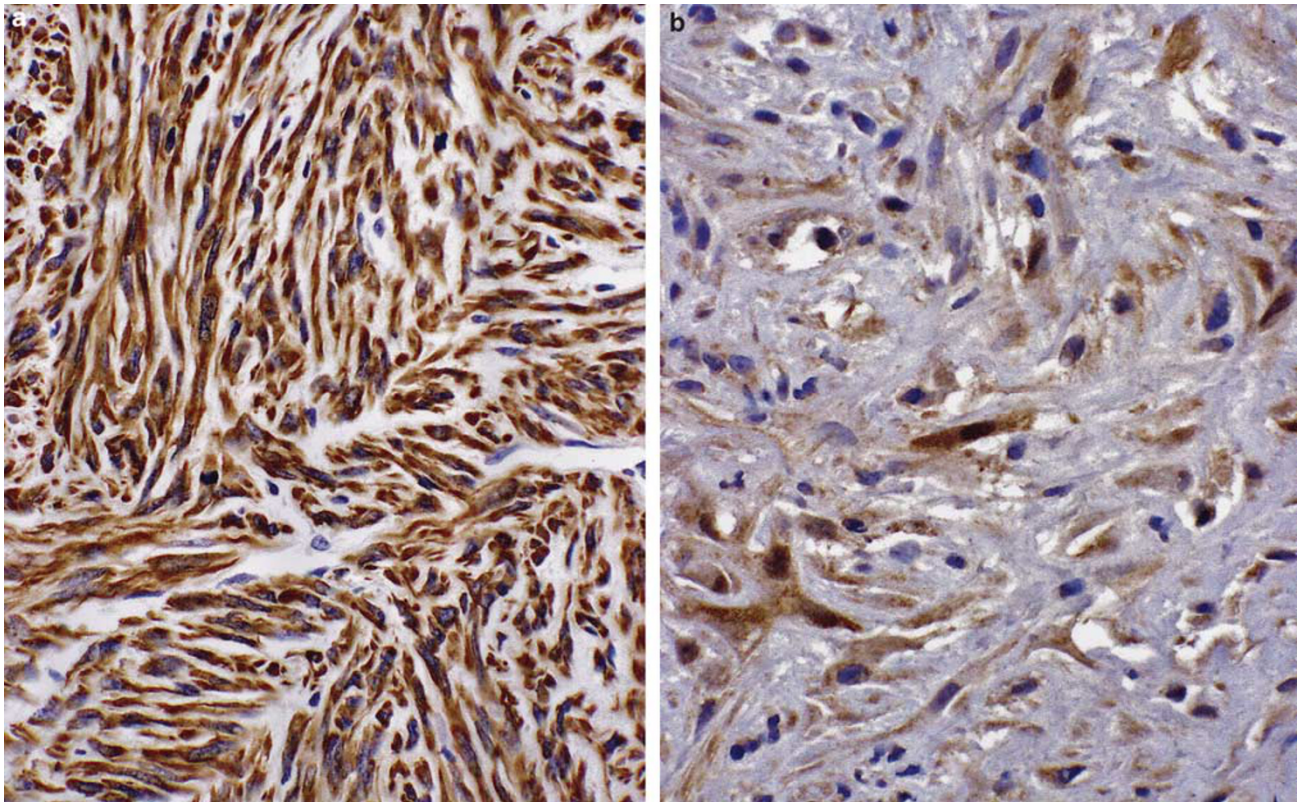

Figure 4 Immunohistochemical staining for cytokeratins and calretinin in sarcomatoid malignant mesothelioma (high power). (**a**) Immunohistochemical staining for cytokeratins (CKs) showing strong and diffuse cytoplasmic immunoreactivity in tumor cells. (**b**) Anti-calretinin immunostain showing focal cytoplasmic and nuclear immunoreactivity.

Table 3 Associated pathologic findings in patients with sarcomatoid mesothelioma

Pathologic finding	*Number of cases with finding/total cases examined (%)*
Pleural plaques	144/182 (79%)
Histological asbestosis	34/127 (27%)
Elevated asbestos content in lung tissue	57/61 (93%)

outside of the pleura is rare; only 2% of the cases in the present study arose in the peritoneum, and there were no cases arising in the pericardium or tunica vaginalis testis. The proportion of peritoneal sarcomatoid malignant mesotheliomas in our study closely approximates the number of peritoneal sarcomatoid malignant mesotheliomas reported in published data.[11,18] Only 4% of the sarcomatoid malignant mesotheliomas in this series occurred in women when compared with 10% of other histological types.

Histologically, sarcomatoid malignant mesothelioma may resemble a soft tissue malignant fibrous histiocytoma or fibrosarcoma, and some show extreme nuclear pleomorphism and resemble the pleomorphic variant of malignant fibrous histiocytoma.[6,19] In addition, sarcomatoid malignant mesotheliomas may show leiomyoid features,[20] and heterologous elements, such as chondrosarcomatous or osteosarcomatous differentiation, or both, occur rarely.[16,17,21,22] This variation in histological appearance invites confusion with soft tissue tumors, including leiomyosarcoma, synovial sarcoma, chondrosarcoma, and osteosarcoma.[22] Thorough histological examination of the tumors comprising this series revealed a desmoplastic component in a substantial proportion (34%). Desmoplastic malignant mesothelioma typically represents a subtype of sarcomatoid malignant mesothelioma and represents approximately 2–10% of mesotheliomas, although desmoplastic areas may sometimes be present in epithelial and biphasic malignant mesotheliomas.[15,23–25] Macroscopically, the tissue is firm and rubbery, and sometimes described as 'woody' in consistency. These tumors are characterized by a deceptively 'bland' appearance, raising a differential diagnosis of benign fibrous pleuritis or pleural plaque.[8,26]

It is worth noting at this point that the role of immunohistochemistry is more limited for sarcomatoid malignant mesotheliomas than for epithelial mesotheliomas, because staining for mesothelial markers is less often positive than in epithelial malignant mesotheliomas.[6] For example, in this

Table 4 Asbestos fiber analysis in 61 cases of sarcomatoid mesotheliomas

Tumor histology and fiber counts	*Asbestos bodies*[a] *(LM)*	*Commercial amphibole asbestos (A+C)*[b] *(s.e.m.)*	*Non-commercial asbestos (TAA)*[b] *(s.e.m.)*	*Chrysotile (s.e.m.)*
Sarcomatoid				
Median	1640	15 600	4180	1450
Range	<3 to 436 000	<280 to 494 000	<470to 455 000	<470 to 14 200
Other				
Median	348	6640	2540	1100
Range	<0.2 to 1 600 000	120–11 900 000	26–286 000	<120 to 197 000
Reference				
Median	2.9	<600	<600	<600
Range	0.2–22	<100 to <2540	<170 to 2540	<100 to 1000

LM, light microscopy; s.e.m., scanning electron microscopy; A+C, amosite+crocidolite; TAA, tremolite+anthophyllite+actinolite.
[a]AB count/g wet lung.
[b]Uncoated fiber counts are numbers/g wet lung.

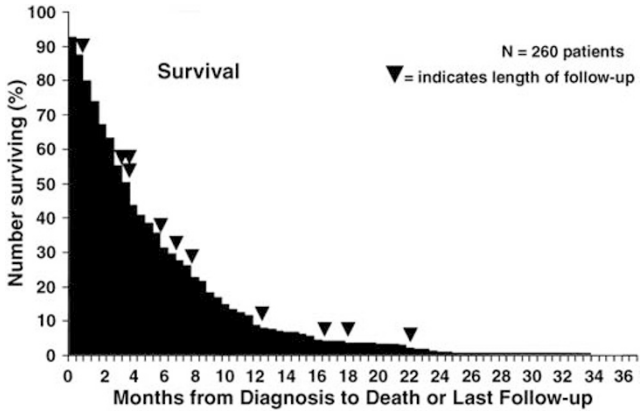

Figure 5 Survival curve: sarcomatoid mesothelioma. Patient survival data were available for 260 patients with a follow-up available up to 22 months. The mean survival was 3.5 months and the 1-year survival rate is approximately 10%.

series of sarcomatoid malignant mesotheliomass, only 31% showed positive labeling for calretinin—widely regarded as the most specific and reliable marker for mesothelial differentiation in epithelioid malignant mesotheliomas—and the staining was usually focal with predominantly cytoplasmic and occasional nuclear reactivity. One study reported from the United Kingdom showed positive calretinin labeling in 39%, whereas Doglioni *et al*[28] reported positive calretinin staining in all 44 mesotheliomas studied, but their series included only three sarcomatoid malignant mesotheliomas.[27] Lucas *et al*[29] reported that 70% of their sarcomatoid malignant mesotheliomas stained for calretinin and thrombomodulin (10 cases), but they commented that the sarcomatoid component of malignant mesotheliomas showed decreased expression of mesothelial epitopes. In our limited experience, expression of other mesothelial markers, such as CK5/6 or thrombomodulin, is uncommon, and Attanoos *et al*[27] found detectable CK5/6 expression in only 29% of their cases of sarcomatoid malignant mesotheliomas. One of the more common reasons for professional referral of sarcomatoid malignant mesotheliomas to us is that the referring pathologist is confronted with a sarcomatoid tumor thought to be a malignant mesothelioma on clinical and radiological grounds, but the mesothelial markers such as calretinin are negative—a result that is the rule rather than the exception for sarcomatoid malignant mesothelioma. Podoplanin has recently been suggested as a useful marker in this setting.[30] We are analyzing the usefulness of these antibodies, but our current experience with WT1, podoplanin, and CK5/6 is too limited to report.

CK expression is more frequently positive, and sarcomatoid malignant mesotheliomas usually stain for either CK8/18 or pan-CKs with antibodies such as CAM5.2 and AE1/AE3, respectively.[6,27] In the present study, the majority of tumors were immunoreactive with CK antibodies (93%), with only one equivocal result. This result differs from the study reported by Lucas *et al*[29] who found that 7 out of 10 sarcomatoid malignant mesotheliomas were immunoreactive with pan-CK antibodies, but other studies have also shown the utility of CK immunohistochemistry in the diagnosis of sarcomatoid malignant mesotheliomas.[31,32] Importantly, CK-negative tumors do occur (about 8%); Attanoos *et al*[27] reported absence of CK staining using AE1/AE3 in seven cases of sarcomatoid malignant mesothelioma out of a total of 31 cases (23%).[14,27] Lucas *et al*[29] reported three CK non-reactive sarcomatoid malignant mesotheliomas that were all immunoreactive for thrombomodulin, and one was reactive for smooth muscle actin. We have noted cases of sarcomatoid malignant mesotheliomas staining negatively with AE1/AE3 but positively with CAM5.2 (and *vice versa*). In our experience, only rare cases fail to stain

Table 5 Criteria for differential diagnosis of sarcomatoid pleural tumors

	Sarcomatoid mesothelioma	*Sarcomatoid carcinoma*	*Monophasic synovial sarcoma*	*Malignant solitary fibrous tumor*
Gross distribution, clinical	Pleural-based tumor, confluent, diffusely infiltrating. Very rarely localized. Usually in males of >50 years	Usually more localized deposits, rarely generalized. Frequently peripheral (often apical) lung mass	Any site but usually relatively circumscribed. Rarely more generalized, often in younger age (40–50 years)	Usually fairly localized, in younger age (30–50 years)
Immunohistochemistry	CK^+ (usually)	CK^+, other carcinoma-related markers may also be positive	CK^+ (focal) $CD99^+$ $BCL2^+$ (rarely calretinin$^+$)	CK^-, $C34^+$ $Bcl2^+$ $CD99^+$
Other	Electron microscopy rarely contributory	Electron microscopy rarely contributory	t(X;18)	Characteristic histological appearances in benign areas

for CKs when a cocktail is used, which includes AE1/AE3, CAM5.2, and MNF.116. The reasons for sarcomatoid mesotheliomas staining negatively for CKs include too narrow a coverage of keratin types, poor tissue fixation/preservation (hence the role for vimentin, which is sensitive to fixation), failure to use epitope retrieval techniques, sampling error for a small biopsy specimen (keratin staining in many sarcomatoid mesotheliomas is patchy and 'clonal'), and finally, a truly keratin-negative tumor. We accept the criteria for diagnosis of CK-negative malignant mesothelioma that have been suggested in the literature and include the typical anatomical distribution, and the exclusion of primary pulmonary or soft tissue sarcomas.[6]

When dealing with suspected sarcomatoid malignant mesotheliomas and especially desmoplastic tumors, CK immunohistochemistry is often extremely useful for showing invasion of extrapleural tissue such as subpleural adipose tissue. In our experience, *bona fide* invasion of chest wall soft tissues (eg, adipose tissue) by CK-positive spindle cells is virtually diagnostic of malignancy when dealing with a pleura-based and confluent fibrous lesion of the pleura, and it occurs very infrequently with fibrous pleuritis.[6,33]

The combination of positive CK expression and calretinin seems to be highly characteristic of sarcomatoid malignant mesothelioma, but CK and calretinin immunohistochemistry cannot always discriminate between malignant mesothelioma *versus* synovial sarcomas and spindle-cell carcinomas.[8,20,27,32,34–36] In cases in which CK staining is negative, the gross distribution of tumor and absence of any history of an antecedent primary soft tissue sarcoma or intrapulmonary mass lesion with radiological features of a primary lung carcinoma may aid in making the diagnosis.[37–39] In this context, we advise extreme caution in making a diagnosis of sarcomatoid malignant mesothelioma in a patient with a mass present within the lung parenchyma, especially for apical masses, which frequently involve the pleura secondarily.

In the case of synovial sarcoma, molecular demonstration of the translocation t(X;18) aids in the diagnosis of these neoplasms.[14,40–42] In addition, synovial sarcomas typically present as a more localized mass and in a younger age group.[14,42,43] The most important distinguishing features between these sarcomatoid pleural lesions are summarized in Table 5.

The role of electron microscopy is limited in making the diagnosis of sarcomatoid mesothelioma. Sarcomatoid mesotheliomas may on occasion show microvilli and increased number of intracytoplasmic intermediate filaments, but more commonly the ultrastructural features are indistinguishable from those of soft tissue fibrosarcoma or malignant fibrous histiocytoma, and comprise only a population of fibroblastoid, myofibroblastoid, and fibrohistiocytic cells.[6,15,16,26,44]

The asbestos content in the 61 cases of sarcomatoid mesothelioma that we analyzed was considerably higher than in the 235 cases of epithelial and biphasic types analyzed during the same time period. The median asbestos bodies count, as determined using light microscopy, was nearly five times higher than that for the other histological types. However, there was considerable overlap between the two groups, and hence the nonparametric testing did not show a statistically significant difference. Higher values were also observed for commercial amphibole fibers (amosite or crocidolite), non-commercial amphiboles (tremolite, actinolite or anthophyllite), and chrysotile, and the most common fiber type identified was amosite. However, because of extensive overlapping of values, only the amosite concentration was significantly higher in the sarcomatoid group. The asbestos content exceeded that of our reference population in 93% of sarcomatoid mesotheliomas. Robinson *et al*[45] have also reported a higher asbestos content in the sarcomatoid variant when compared with other histological types.

Sarcomatoid mesotheliomas are associated with a particularly poor prognosis, as shown by our data and reported by others.[45] The survival was similar for desmoplastic and pure sarcomatoid variants. In contrast, epithelioid pleural mesotheliomas are typically associated with a survival of 12–24 months

after diagnosis; for example, in a study of 1605 cases in the German Mesothelioma Register, Neumann *et al*[4] recorded a survival time of 16.9 months for epithelioid malignant mesotheliomas, compared with 13.1 months for biphasic tumors and 5.5 months for the sarcomatoid subtype. Consequently, in many medical centers, patients with sarcomatoid mesothelioma are not considered to be candidates for extrapleural pneumonectomy.[5,21,25]

Disclosure/conflict of interest

The authors declare no conflict of interest.

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