Case report

Fibre glass induced synovitis

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SUMMARY Chronic synovitis developed in the dorsal extensor sheath of the hand of a 25-year-old manufacturer of fibre glass reinforced boats and surfboards. Particles found in synovial fluid aspirates were similar in morphology and elemental content to unused fibre glass and particles found in dust from the workshop floor. It was concluded that hard disc grinding required during manufacture resulted in percutaneous implantation of small glass particles, leading to chronic synovitis and effusion.

Case history

A 25-year-old boat builder developed painless swelling at the anterior aspect of the left knee in mid 1981. A diagnosis of prepatellar bursitis was made in November 1981. The swelling resolved several months later but recurred intermittently thereafter. In February 1982 he developed swelling of the dorsum of the right hand, which persisted until assessment in August 1982. He complained of pain on initial movement of the hand, but suffered no functional impairment. There was no history of significant back pain or other joint abnormality. For the preceding five years he had been working extensively with glass fibres in the manufacture of surfboards. During this period he had been troubled by nasal obstruction in spite of regular use of a mask. Several nasal polyps were removed by cautery in August 1981, and radiographic assessment in October 1981 revealed mucosal thickening in the paranasal sinuses and swelling of the nasal turbinates. He had been troubled intermittently by skin irritation, occurring predominantly in hot weather. A maculopapular rash had been observed which involved, at various times, the hands, feet, arms, legs, and trunk.

Examination in August 1982 revealed an effusion of the dorsal extensor sheath of right hand. There was a normal range of movement in all joints. 0.4 ml of clear yellow fluid of normal viscosity was aspirated

from the sheath effusion. This contained $0.13 \times 10^9/l$ white cells, 90% of which were neutrophil polymorphs.

The following investigations were normal or negative: haemoglobin, white cell count and differential count, platelet count, erythrocyte sedimentation rate, RA latex test, antinuclear antibodies, and multiple biochemical analysis.

Synovectomy of the extensor tendons sheath of the right hand was undertaken in September 1982. Before the synovectomy was done synovial fluid was aspirated and showed a cell count of $0.5 \times 10^9/l$ leucocytes with 90% neutrophil polymorphs. At operation a slightly reddened proliferative synovium was observed.

Materials and methods

Synovial fluid samples aspirated at the time of clinical evaluation and synovectomy were examined by polarised light and phase-contrast microscopy of fresh wet preparations; and by scanning electron microscopy (SEM), electron probe microscopy, transmission electron microscopy, and energy dispersive x-ray microanalysis (EDX) of glutaraldehyde-fixed samples subjected to appropriate preparative procedures. Samples of dust from the patient's workshop and unused glass fibres were examined by SEM and EDX.

Synovial tissue samples were fixed in buffered formal-saline for light microscopy, and in buffered glutaraldehyde for electron microscopy.

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Results

SYNOVIAL FLUID

Phase-contrast microscopy of wet preparations of synovial fluid revealed the presence of many needle-shaped particles estimated to be up to about $30\text{ }\mu\text{m}$ in length and $3\text{ }\mu\text{m}$ in diameter. The fibres were free in the fluid and attached to neutrophil polymorphs and mononuclear phagocytes (Fig. 1), but there was no conclusive evidence that fibres had been endocytosed and were intracytoplasmic. The fibres were not birefringent when examined by polarised light microscopy. The spatial arrangement of fibres relative to each other and synovial fluid leucocytes was unlike that seen with fibrin in synovial fluids, and no evidence of fibrin clot was seen within the fluid, which had been collected into lithium heparin tubes.

Of the numerous fibres present in the synovial fluids 25 were subjected to detailed study. The average size was $4\text{ }\mu\text{m}$ in diameter (range $2\text{--}10\text{ }\mu\text{m}$) and $20\text{ }\mu\text{m}$ in length (range $10\text{--}30\text{ }\mu\text{m}$). The majority appeared to be derived from rod-like structures with some smooth curved surfaces, some irregular surfaces, and irregular fractured ends (Figs. 2a, b). EDX analysis of the particles (Fig. 2c) showed that they all contained silicon. Most particles also showed other elements, mainly calcium, magnesium, titanium, and chlorine. Phosphorus was not detected.

The unused glass fibres were $7\text{ }\mu\text{m}$ to $13\text{ }\mu\text{m}$ in diameter and of indefinite length (Fig. 3a). These

Fig. 1 Appearance of wet smear preparation of synovial fluid examined by phase-contrast microscopy. Shows needle-shaped fibres with some adherent and free leucocytes. ($\times 500$).

Fig. 2a

Fig. 2b

Fig. 2c

Fig. 2 SEM of particles from synovial fluid showing (a) irregular surface and fractured ends ($\times 865$); (b) part of fibre having smooth rounded surface ($\times 3725$); (c) EDX spectrum of particle shown in (b) illustrating (left to right) peaks confirming presence of Si, Cl, Ca, and Ti.

fibres were composed mainly of silicon and calcium (Fig. 3b). The workshop dust contained short lengths of similar fibres (Fig. 4a) and particles having a morphology similar to the particles observed in the syno-

Fig. 3a

Fig. 3b

Fig. 3 SEM of unused glass fibre material (a) showing cylindrical structure and variations in diameter ($\times 800$); (b) EDX spectrum showing peaks confirming presence of Si (left) and Ca (right).

Fig. 4a

Fig. 4b

Fig. 4c

Fig. 4 SEM of workshop dust (a) showing short portion of cylindrical fibres ($\times 1295$); (b) part of fibre with smooth rounded surface generally similar in profile to Fig. 2b ($\times 10\,000$); (c) EDX spectrum showing peaks confirming presence of Si (left) and Ca (right).

vial fluid (Fig. 4b). EDX showed the presence of silicon, calcium, magnesium, titanium, and chlorine in this material. The ultrastructural and analytical studies, showed, therefore, that the particles in the synovial fluid had a morphology and elemental composition similar to glass fibres in the dust from the workshop.

SYNOVIAL MEMBRANE

Light microscope examination of synovial tissue excised from the extensor tendon sheath of the right hand (Fig. 5) showed villus formation, hyperplasia and hypertrophy of synoviocytes, and the presence in the subsynoviocyte connective tissues of aggregates of small lymphocytes, numerous macrophages, and occasional plasma cells and neutrophil polymorphs. Transmission electron microscopy showed that the synoviocyte proliferation comprised both type A and type B synoviocytes. No glass fibre material was identified within the synovial tissues.

Transmission electron microscopy of sections of synovial fluid cells showed that, while the cells contained large complex phagolysosomes, EDX of the phagolysosomes revealed no evidence of material derived from glass fibres.

Fig. 5 Low-power micrograph of section of synovium from tendon sheath showing villus formation, synoviocyte hyperplasia, and cellular infiltration. (Haematoxylin-eosin, $\times 100$).

Industrial aspects

Methods of manufacture. Surfboards are manufactured by application of glass-fibre reinforced resin to a central foam core. Larger products (boats, cabin roofs) are manufactured within a bivalved female mould by impregnating sheets of glass fibre with resin. Once the hardening process is complete, any trimming is done with a hard disc grinder. The cutting disc of the grinder rotates at 10 000 revolutions per minute, and sheds a dust of fine glass particles, which leave the disc at high speed.

Protective clothing and breathing devices. Glass fibres are directly irritating to the skin, and the patient usually wears clothing made of heavy cloth to cover the trunk and limbs, and (rubber) gloves when handling glass fibres. He attempts to remove glass fragments which lodge in his clothing by spraying with a jet of compressed air at pressures up to 600 kPa. The clothing is discarded when no longer suitable for further use. He wears a paper mask when cutting glass sheet or when cutting or grinding hardened resin containing glass fibre, and wears a hood with charcoal twin air filters when working with volatile reagents used in the preparation of hardened resin.

Discussion

The findings have shown that synovitis in this patient was associated with the presence in synovial fluid of particulate material derived from glass fibres. The presence of silicon in all of the particles examined, and the absence of phosphorus, was consistent with the conclusion that the particles observed in the synovial fluid were not apatite, pyrophosphate, urate, or oxalate crystals, which may be present in synovial fluid.¹ The morphology and size distribution of the synovial fluid particles, and their similarity to particles found in the workshop dust formed from the grinding of glass fibre material, indicated that they were derived from the grinding process. This conclusion is supported by studies of Assuncao and Corn,² who observed fibres of similar diameter and length following milling of glass fibres in a ball mill for varying periods.

Apart from the findings of this report, the only proved biological effects of exposure to fibre glass are irritation of the skin, conjunctiva, nasopharynx, and upper respiratory tract.³

Epidemiological studies designed to investigate the hazards of exposure to glass fibres have been fragmentary and largely directed towards studies of workers involved in the production of, rather than the use of, glass fibres.⁴⁻⁶ Both animal and human epidemiological studies suggest that glass fibres of

the type encountered in glass fibre production industries are relatively biologically inert.

Glass fibres vary considerably according to the purpose for which they are made. Glass fibre produced for thermal insulation (glass wool, rock wool) consists of small fibrous glass fragments of variable length and diameter. Glass fibres used for textile manufacture and structural reinforcement (including boat building) are produced as continuous filaments of uniform diameter.

The present case provides an example of the way in which the original fibrous material may become modified by further manufacturing processes. In this case the long continuous filament fibres used in the lay-up step of the boat building procedure have been transformed into particles of very small length which were recovered from the synovial fluid of the patient's dorsal tendon sheath, and dust from the work-shop floor. By contrast, the source material used in the lay-up step was found to consist of long glass filaments of uniform diameter. A plausible sequence of events to account for these findings is as follows: (a) glass fragments were generated when the boards and other products were trimmed with a disc grinder following setting of the resin; (b) these fragments were shed from the spinning disc at high speed; (c) a proportion of fragments were shed from the wheel at a tangent orientated toward the back of the patient's non-dominant (right) hand; (d) some fragments penetrated the skin and became associated with the dorsal tendon sheath. It is likely that titanium found on EDX analysis of particles from synovial fluid and workshop floor, but not from source material, arose from the cutting disc of the disc grinder. It seems far less likely that glass fibres were deposited in the dorsal sheath following absorption through the nasal-respiratory or oral routes.

The long-term effects of glass fibres within the synovial sheath or other body cavities and tissues are

unknown. Stanton and Wrench⁷ demonstrated development of mesotheliomas in 4 of 91 rats after intrapleural implantation of mechanically ground glass fibres with length 1–20 μm and diameter of 5 μm and in eight of 54 rats implanted with fibres of similar length and diameter 0.06–3 μm . These authors cautioned against the application of their results to man because the small size of the glass fibres used and the surgical method of application were remote from what they perceived to be likely human exposure to glass fibres. Their findings clearly acquire more potential significance in the light of the demonstration of the work-related implantation of small glass fibres within the dorsal tendon sheath of the man described in this report.

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