



A breathless builder

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Case report

The patient was a 30-year-old male mason whose work frequently involved cutting and grinding brick and cement with powered tools. He was an active smoker (1–1.5 packs per day). He had worked in building construction since the age of 14 yrs, as a labourer then as a mason and had been a mason for the previous 13 years. He reported frequent exposure to cement and brick dust while removing stone floors with a jackhammer. From 8–2 months prior to presentation, he had been employed repairing exterior brick on three large apartment buildings (figure 1). This required cutting through brick and mortar with a powered, high-speed demolition saw and grinding mortar from between bricks with a powered

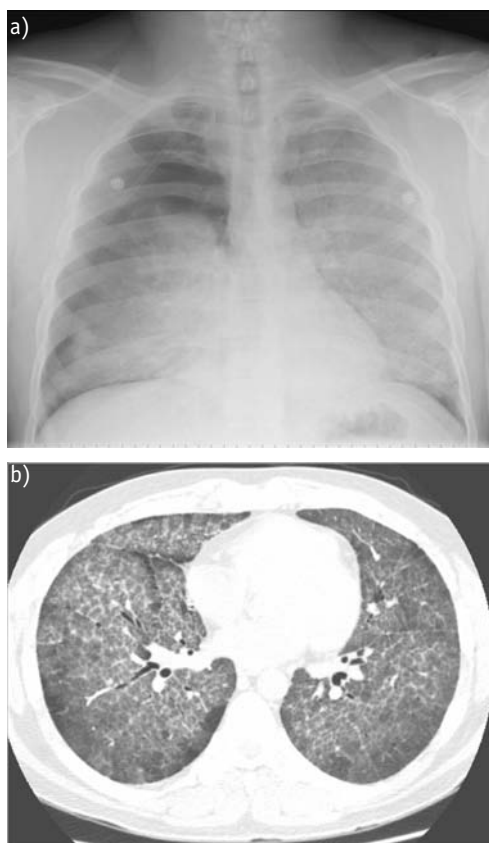
hand-grinder, a common task known as "tuck-pointing" (figure 2), while intermittently using a disposable particle mask. After completing this job, he felt well for ~2 months and then gradually began to develop a nonproductive cough, dyspnoea on exertion and an 11 kg weight loss without fever. Serial pulmonary function testing showed restriction and a marked reduction in diffusing capacity. Chest computed tomography (CT) showed bilateral diffuse infiltrates. A purified protein derivative test was negative. Bronchoalveolar lavage fluid was mucoid, and culture was negative. A transbronchial biopsy was nondiagnostic and the post-bronchoscopy chest film showed a very small right apical pneumothorax. An HIV test was negative.



Figure 1
 Brick apartment building whose exterior was renovated by the patient.



Figure 2
 Mason performing "tuck-pointing" on a brick building exterior, using a handheld powered mortar grinder, similar to that used by our patient. Field testing of air levels of dust in similar circumstances indicates that the particle mask shown in the figure may not be adequate to protect against the high levels of dust generated. Photograph courtesy of the National Institute for Occupational Safety and Health.

**Figure 3**

a) Chest radiograph on emergent presentation, with large right pneumothorax and bilateral diffuse infiltrates. b) Chest CT prior to lung biopsy, showing bilateral and diffuse alveolar filling.

There was no evidence of silicotic nodules on biopsy. Stains and cultures of lung tissue for organisms were negative and a granulocyte macrophage-colony stimulating factor (GM-CSF) antibody test was negative.

Additional examination of lung tissue demonstrated macules of mixed opaque and birefringent dust associated with a mild degree of peribronchiolar and interstitial fibrosis (figure 5a). Much of the dust was strongly birefringent, typical of silicates, while a smaller amount of dust was weakly birefringent, consistent with crystalline silica (figure 5b).

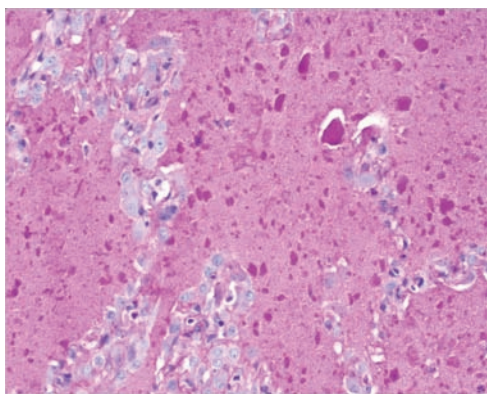
Scanning electron microscopy (SEM) of the lung tissue *in situ* in paraffin block (using variable pressure SEM to allow examination of non-conductive samples) identified individual particles within macrophages in the lung tissue, and allowed energy-dispersive X-ray spectroscopy (EDS) analysis of their elemental content. This qualitative analysis showed numerous particles composed primarily of a mixture of aluminium silicates (found in standard red brick) and lesser amounts of silica (found in mortar; figure 6).

There were rare particles of iron, titanium, iron with chromium and cerium. This was sufficient for a diagnosis of mixed dust pneumoconiosis in addition to alveolar proteinosis [1]. The patient's employer was notified and given information on the prevention of dust exposure in construction and the case was reported to the Occupational Lung Disease Registry of the state health department.

Three days later, the patient developed acute rightsided chest pain requiring urgent evaluation. An initial physical examination revealed cyanosis without clubbing and faint inspiratory rales at the left base. Oxygen saturation was 80% on room air. The patient had a large rightsided pneumothorax with bilateral diffuse airspace disease (figure 3a).

After insertion of a chest tube, he continued to have high oxygen requirements. Chest CT showed diffuse ground-glass opacities with an upper lobe predominance (figure 3b).

Video-assisted thoracoscopic surgery (VATS) biopsy of the right upper lobe showed pulmonary alveolar proteinosis (PAP; figure 4).



Treatment

For treatment of alveolar proteinosis, a left lung lavage was performed under general anaesthesia with a double lumen endotracheal tube using the method described by KAO *et al.* [2] with retrieval of ~20 L of milky-appearing lavage fluid. The lavage fluid progressively cleared with each aliquot.

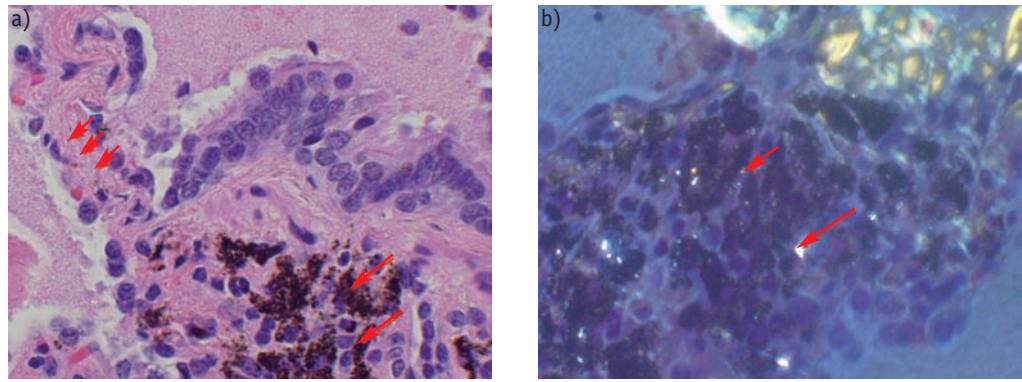
The procedure was uneventful with no oxygen desaturations noted. Unexpectedly, oxygenation worsened several hours postlavage, resulting in ~1 week of mechanical ventilation without a significant improvement in oxygenation. The patient was extubated and eventually discharged on 6 L per min continuous oxygen, with a referral for lung transplantation. After several weeks at home he spontaneously experienced a second right pneumothorax, requiring rehospitalisation and chest tube drainage. Three months after the initial whole lung lavage, as part of his transplant evaluation, a repeat whole lung lavage was performed (this time bilateral)

Figure 4

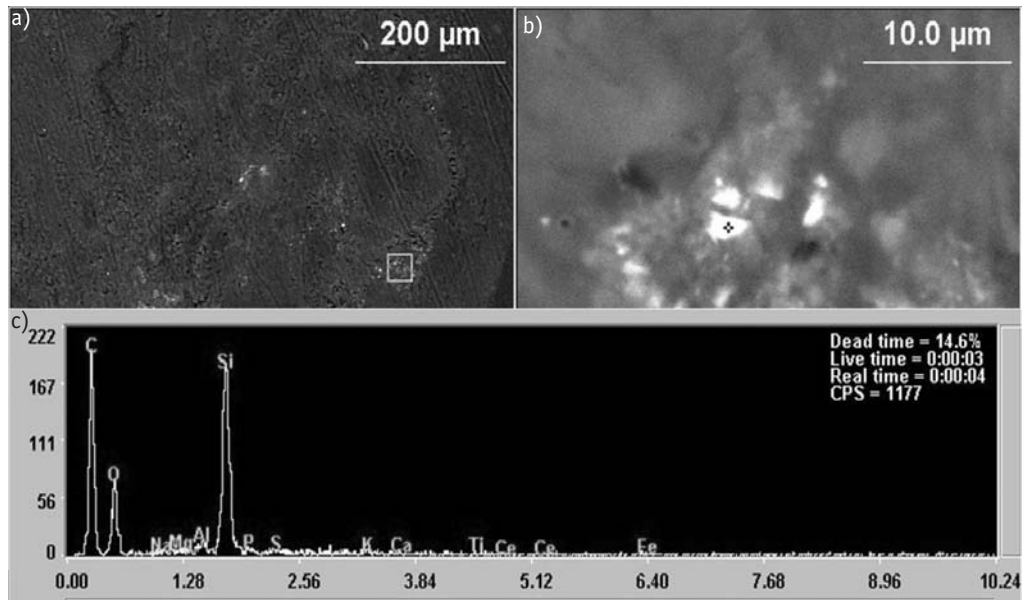
Periodic acid Schiff stain of VATS biopsy showing alveolar filling with proteinaceous material (alveolar proteinosis). Alveolar walls in this view show little or no cellular infiltrate.

Figure 5

a) Additional views of VATS biopsy material show dust-filled macrophages (arrows) with mild peribronchiolar and interstitial fibrosis (arrowheads). b) Polarised light microscopy of lung biopsy shows detail of one dust macule, with strongly birefringent dust, typical for silicates (arrow), and weakly birefringent particles, typical for crystalline silica (arrowhead). In addition to alveolar proteinosis, the biopsy fulfilled pathological criteria for mixed dust pneumoconiosis.

**Figure 6**

SEM (backscattered electron images). EDS analysis shows particles in macrophages as noted by light microscopy, including many particles too small to be visible by light microscopy. These were composed of a mixture of aluminium silicates, iron with chromium (steel) and silica (shown above). The white box (a) is enlarged in b. The blue cursor located over individual particles indicates the location from which the EDS spectrum (c) was collected.



complicated by a third rightsided pneumothorax requiring tube thoracostomy. However, oxygenation improved markedly and immediately, to the degree that he needed no supplemental oxygen at rest, regained weight and markedly increased his activity level, though still requiring oxygen with exertion. A repeat chest CT showed reduction in the alveolar filling process after the second whole lung lavage.

Discussion

PAP may be the following: congenital, due to mutations in surfactant or GM-CSF genes; secondary to haematologic cancers, immunosuppression or dust; or acquired (idiopathic), which is in some cases an autoimmune process targeting GM-CSF [3]. Weight loss and susceptibility to recurrent infections are clinical characteristics. The development of PAP is a well-described complication of severe silicosis termed acute silicosis or silicoproteinosis. Acute silicosis was described in 1900 by BETTS [4] in a case series of 30 fatalities of males working in a single mineral ore crushing mill whose mean age at death was 30

years. It was further defined by subsequent authors [5, 6]. In a review of 34 cases, PRAKASH *et al.* [7] noted alveolar proteinosis as a non-specific response to a variety of injuries including exposure to dusts, chemicals or infections, commenting that its uncommon occurrence suggests individual susceptibility as an important factor in its aetiology [7, 8]. Alveolar proteinosis has been reproduced in a rat model by instillation of silica dust into the lungs [9]. The high prevalence of current or past smoking suggests that smoking, which involves chronic inhalational exposures to very small combustion particles, may be a risk factor [3, 10].

Before the availability of lung transplantation, silicoproteinosis had been described as having a uniformly fatal course [11, 12].

The current patient presented with the clinical picture of silicoproteinosis, but in the context of mixed dust exposure with prominent alveolar proteinosis and less prominent mixed dust fibrosis rather than silicosis. Mixed dust pneumoconiosis is caused by inhalation of a mixture of silica and nonsilica dust, including coal, talc,

and/or other silicates. It has recently been defined pathologically as "pneumoconiosis showing dust macules or mixed-dust fibrotic nodules, with or without silicotic nodules, in an individual with a history of exposure to mixed dust" [1]. It is distinguished from silicosis by the predominance of mixed dust fibrotic lesions over silicotic nodules.

Review of a material safety data sheet indicates that standard red brick is made almost entirely of aluminium silicate. Mortar is usually a mixture of calcium silicates, aluminium silicates, iron and silica sand. Measurement of respirable silica dust exposure in circumstances similar to this patient's exceeded the US Occupational Safety & Health Administration permissible exposure limit by a factor of >10 in all samples, rendering the negative pressure respirators in use inadequate [13]. The mechanical action of powered tools on silica may create small, freshly fractured particles which are more reactive in the lungs due to the formation of free radicals [14]. These workplace studies have focused on respirable crystalline silica, which is best recognised as a hazard to lung health, without emphasising the hazards of nonsilica mineral dust.

The pathological findings of mixed dust pneumoconiosis in the current patient were subtle compared with the dramatic alveolar proteinosis, and without recognition of the significance of his occupational history, additional studies of lung dust content might not have been pursued.

Whole lung lavage has previously been used to reduce the dust burden in pneumoconiosis, but its long-term efficacy has not been subject to controlled trials [15, 16]. Lavage has been reported previously in a patient with extensive mixed dust pneumoconiosis without alveolar proteinosis, producing a dramatic return of pigmented dust and symptomatic improvement, but little change in lung function [17].

Alveolar proteinosis is often but not always responsive to whole lung lavage, which has been described as a stop-gap therapy for a condition that needs definitive treatment of the underlying process [18]. The current patient's adverse response to initial unilateral lung lavage, followed by a good though partial response to bilateral lung lavage 3 months later, suggests that the timing of the procedure may be important to outcome. This experience suggests that in some instances lavage performed later, rather than earlier, in the clinical course of alveolar proteinosis may be more effective, at least in the context of an acute response to mixed dust pneumoconiosis.

Conclusion

This patient's occupational exposure is well recognised as hazardous, and is experienced by thousands of masons and allied construction workers each year in the USA alone. Such exposures, if uncontrolled over time, would be expected to contribute to the gradual development of mixed dust pneumoconiosis and silicosis over the working life of many of these construction workers, as seen in the mild interstitial changes of figure 5a. One approach to preventing over-exposure to dust during the tuck-pointing process, through ventilation of the handheld grinder, has been evaluated [19]. Because of the extremely widespread use of the tuck-pointing process in brick building maintenance now and in the foreseeable future, efforts to reduce dust levels are essential to prevention of chronic lung disease. The acute and progressive alveolar proteinosis experienced by the current patient suggests the possibility of an underlying susceptibility to this condition, with the alveolar proteinosis response having been triggered by an acute massive dust exposure superimposed upon previous chronic dust exposure.

References

1. Honma K, Abraham JL, Chiyotani K, et al. Proposed criteria for mixed-dust pneumoconiosis: definition, descriptions, and guidelines for pathologic diagnosis and clinical correlation. *Hum Pathol* 2004; 35: 1515-1523.
2. Kao D, Wasserman K, Costley D, Benfield JR. Advances in the treatment of pulmonary alveolar proteinosis. *Am Rev Respir Dis* 1975; 111: 361-363.
3. Trapnell BC, Whitsett JA, Nakata K. Pulmonary alveolar proteinosis. *N Engl J Med* 2003; 349: 2527-2539.
4. Betts W. Chalicosis pulmonum or chronic interstitial pneumonia induced by stone dust. *JAMA* 1900; 34: 70-74.
5. Buechner HA, Ansari A. Acute silico-proteinosis. A new pathologic variant of acute silicosis in sandblasters, characterized by histologic features resembling alveolar proteinosis. *Dis Chest* 1969; 55: 274-278.
6. Chapman E. Acute silicosis. *JAMA* 1932; 98: 1439-1441.
7. Prakash UB, Barham SS, Carpenter HA, Dines DE, Marsh HM. Pulmonary alveolar phospholipoproteinosis: experience with 34 cases and a review. *Mayo Clin Proc* 1987; 62: 499-518.
8. Abraham JL, McEuen DD. Inorganic particulates associated with pulmonary alveolar proteinosis: SEM and X-ray microanalysis results. *Appl Path* 1986; 4: 138-146.
9. Friemann J, Pott F, Wilk KB, et al. Pulmonary alveolar proteinosis in rats after administration of quartz: its possible role in morphogenesis of lung cancer. *J Cancer Res Clin Oncol* 1994; 120: 348-353.
10. Goldstein LS, Kavuru MS, Curtis-McCarthy P, Christie HA, Farver C, Stoller JK. Pulmonary alveolar proteinosis: clinical features and outcomes. *Chest* 1998; 114: 1357-1362.
11. Banks DE. Acute Silicosis. In: Merchant JA, ed. *Occupational Respiratory Diseases*. Washington, US Department of Health and Human Services, 1986; pp. 239-241.
12. Davis GS. Silica. In: P. Harber, ed. *Occupational and Environmental Respiratory Disease*. 1st Edn. St Louis, Mosby, 1995; pp. 373-383.
13. Nash NT, Williams DR. Occupational exposure to crystalline silica during tuckpointing and the use of engineering controls. *Appl Occup Environ Hyg* 2000; 15: 8-10.
14. Vallyathan V, Shi XL, Dalal NS, Irr W, Castranova V. Generation of free radicals from freshly fractured silica dust. Potential role in acute silica-induced lung injury. *Am Rev Respir Dis* 1988; 138: 1213-1219.
15. Liang WP, Chen CY. Clinical evaluation of massive whole lung lavage for treatment of coal workers pneumoconiosis. *He Bei: Liao Yang (J Hebei Convalescence)* 1992; 1: 1-9.
16. Wilt JL, Banks DE, Weissman DN, et al. Reduction of lung dust burden in pneumoconiosis by whole-lung lavage. *J Occup Environ Med* 1996; 38: 619-624.
17. Mason GR, Abraham JL, Hoffman L, Cole S, Lippmann M, Wasserman K. Treatment of mixed-dust pneumoconiosis with whole lung lavage. *Am Rev Respir Dis* 1982; 126: 1102-1107.
18. Kavuru MS, Popovich M. Therapeutic whole lung lavage: a stop-gap therapy for alveolar proteinosis. *Chest* 2002; 122: 1123-1124.
19. Heitbrink W, Collingwood S. Protecting tuckpointing workers from silica dust: draft recommendations for a ventilated grinder. *Electronic Library of Construction Occupational Safety and Health* 2005. www.cdc.gov/elcosh/docs/d0600/d000683/d000683.html. Date last modified: January 2005. Date last accessed: April 3, 2007.