

Abnormalities in pulmonary function after brief exposure to toxic metal fumes

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A 26-year-old welder became ill after exposure to zinc and cadmium fumes at work. His initial clinical course was consistent with that of metal fume fever, but persistence of symptoms and signs beyond the usual duration in this condition led to suspicion of a toxic pulmonary reaction to cadmium. The finding of high percentages of both metals in the urine confirmed this diagnosis. Pulmonary function tests showed restriction of lung volumes, with increased elastic recoil and reduced diffusion, but no evidence of airways obstruction. Chest roentgenograms indicated central pulmonary edema, which cleared in 6 days. Follow-up assessment 2 years later showed incomplete improvement of the restrictive ventilatory defect.

Un soudeur de 26 ans est tombé malade après avoir été exposé à des vapeurs de zinc et de cadmium au cours de son travail. L'évolution clinique immédiate a été semblable à celle d'une fièvre provoquée par les vapeurs de métal, mais la persistance des symptômes et des manifestations au delà de la durée normale de cette affection ont fait soupçonner une intoxication pulmonaire au cadmium. La découverte de pourcentages élevés des deux métaux dans l'urine a confirmé ce diagnostic. Les tests de la fonction pulmonaire ont révélé une diminution du volume pulmonaire, avec une augmentation de la dilatation et de l'élasticité, et une diminution de la diffusion, mais aucun signe d'obstruction des voies respiratoires. Les radiographies pulmonaires ont indiqué un oedème pulmonaire central qui s'est résolu en 6 jours. Une évaluation subséquente survenant 2 ans plus tard a montré une amélioration complète du trouble ventilatoire.

Welders most commonly present to emergency rooms with ophthalmologic problems due to "flash burns". Respiratory problems, which are less frequently seen, include symptoms of bronchitis due to high

ozone concentrations (6 to 9 parts per million) produced by high-temperature arc welding.¹ Oxides of nitrogen can also be produced; they irritate the entire respiratory tract.² However, the most common respiratory problem is metal fume fever. The initial symptoms of metal fume fever, a disease of acute onset, include thirst and a metallic taste in the mouth. Chills, fever, myalgia and fatigue occur 4 to 8 hours later. These symptoms are self-limited and disappear within 36 hours.³

We present the case of a welder who worked with a silver solder containing zinc and cadmium, and had a prolonged respiratory illness, during which pulmonary function studies were performed.

Case report

A 26-year-old man with 9 years' experience as an oxyacetylene welder presented to an emergency room with a hacking cough. Several days earlier he had started a new job after not having worked for 3 months.

On the first day, after soldering brass pieces together into beds for several hours without head protection he noted tightness in his chest; by the end of the day a dry, forceful cough had developed. That evening he had increased shortness of breath at rest, shaking chills and a choking sensation when he tried to take a deep breath. He noted slight hemoptysis the following day. He smoked a package of cigarettes a day, kept no pets, and had not been exposed to other metal fumes.

The dry cough, chills and shortness of breath persisted in spite of the use of an antibiotic and a cough suppressant prescribed by a physician, and he went to the emergency room 4 days after the cough's onset.

The blood pressure was 130/80 mm Hg, pulse rate 125 beats/min and temperature 37.5°C. Breath sounds were decreased at the lung bases and rales were heard in both axillae. A sample of arterial blood drawn while the patient was breathing room air yielded the following values: pH 7.46, partial pressure of carbon dioxide 27 mm Hg and partial pressure of oxygen 70 mm Hg. Chest roentgenograms taken at the time of admission and before discharge are shown in Figs. 1A

and 1B. Urinalysis gave normal results and there was no evidence of renal tubular acidosis or aminoaciduria.

During the next 3 days the cough subsided and the patient felt better without treatment.

Pulmonary function tests done the day after admission (Table I) showed reduced lung volumes (measured plethysmographically) and impaired diffusing capacity of carbon monoxide (measured by the single-breath method). Most of the improvement in total lung capacity, vital capacity and diffusing capacity of carbon monoxide occurred in the first week. The improvement in both the restriction of lung volumes and the diffusion impairment during the next 2 years is shown in Table I. The maximum expiratory flow was high during the illness, consistent with elevated elastic recoil of the lung, as was found by direct measurement with an esophageal balloon on the seventh hospital day (Fig. 2A). When the elastic recoil pressures were plotted against lung volume as a percentage of the patient's observed total lung capacity (Fig. 2B), the curve was within the normal range. There was no evidence of airways obstruction: airways resistance and specific airways conductance were normal, and the relation between the elastic recoil of the lung and the maximum expiratory flow measured at the same lung volume were within the normal range.

Testing of the urine for trace metals, done on the 10th hospital day, showed concentrations of 40 mg/dL for zinc and 1.5 mg/dL for cadmium. Three months after admission his urine contained 0.18 mg/dL of zinc and 0.53 µg/dL of cadmium. Concentrations of both metals were measured by atomic absorption spectrophotometry.

Analysis of the solder (Table II) revealed substantial percentages of zinc and cadmium.

Discussion

The initial clinical course of this patient was consistent with that of metal fume fever. His respiratory problem began on the first day of his new job. The high concentration of zinc in the urine was consistent with a degree of exposure sufficient to have produced metal fume fever. However, metal fume fever is self-limiting, lasting at most 48 hours;⁴

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this patient's symptoms did not begin to abate until 5 days after exposure. Since workers do not usually present to physicians with metal fume fever because its short course is known to them, and because of the apparent benignity of the disease, the true incidence of metal fume fever cannot be estimated.^{4,5} Thus, an additional process was suspected in this patient. The elevated concentration of cadmium in the urine 15 days after exposure, the protracted clinical course and the results of analysis of the solder suggested an additional diagnosis of acute toxic pulmonary reaction to cadmium.

In the past the industrial firing or welding of cadmium-plated material produced cadmium poisoning. Recently solders containing cadmium mixed in various proportions with other metals have become a source of poisoning. These solders are hazardous chiefly because most workers are unaware of the potential toxicity of cadmium and therefore take no precautions.⁵ The hazard with cadmium is particularly great because this metal has a significant vapour pressure at its melting point (320°C); hence a concentration of 50 000 times the safe limit can easily be produced when cadmium is melted. The reported incidence of accidental acute pneumonitis caused by exposure to cadmium vapour is very low; fewer than 100 cases have been reported so far.

The initial chest roentgenogram in our patient demonstrated the first stage of the acute pulmonary toxic reaction, in which edema and hemorrhage are extensive. During the healing phase of interstitial pneumonitis the lung volumes improved. However, the persistent, long-term restrictive ventilatory defect indicates that some interstitial pulmonary fibrosis, not apparent roentgenographically, did evolve.

We are aware of only two previous reports of pulmonary function following acute cadmium pneumonitis. Beton and colleagues⁶ reported the forced expiratory volume in 1 second, vital capacity and maximum voluntary ventilation for three people exposed briefly to cadmium; in two of these patients the vital capacity improved over a 4-month period. Townshend⁷ found that the vital capacity and steady-state diffusing capacity of carbon monoxide were reduced in one patient and improved

over 3 years' follow-up, but the vital capacity never surpassed 78% of the normal predicted value after 4 years' follow-up. In neither report was there evidence of airways obstruction. In our patient the elastic recoil pressures were elevated when com-

pared with lung volumes expressed as a percentage of the normal predicted values, but were normal when compared with lung volumes expressed as a percentage of the observed total lung capacity. This suggests that there is a two-compartment system in

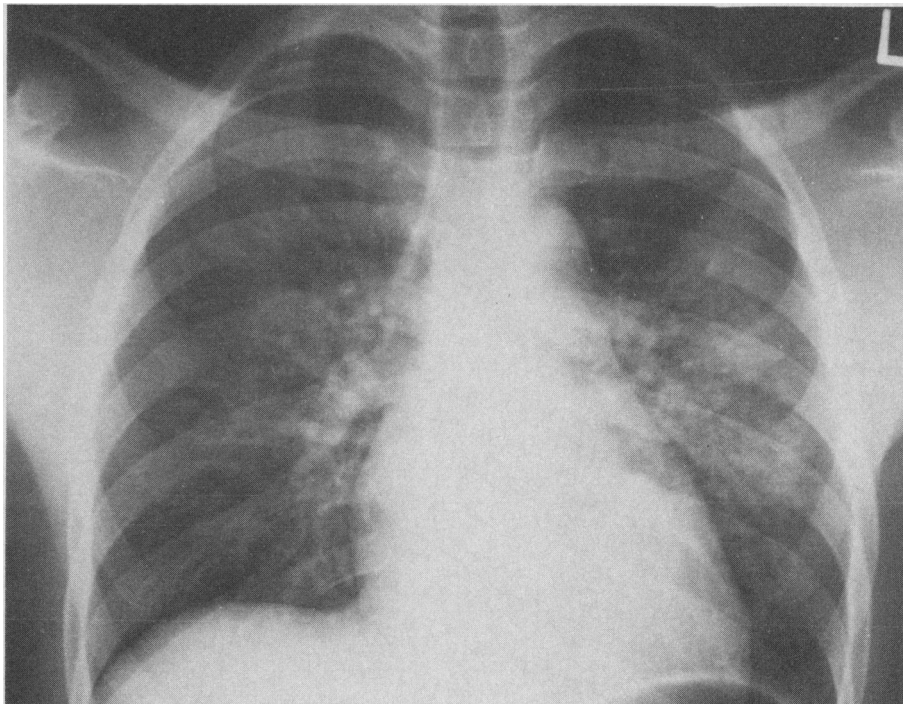


FIG. 1A—At time of admission, typical pattern of pulmonary edema with small heart.

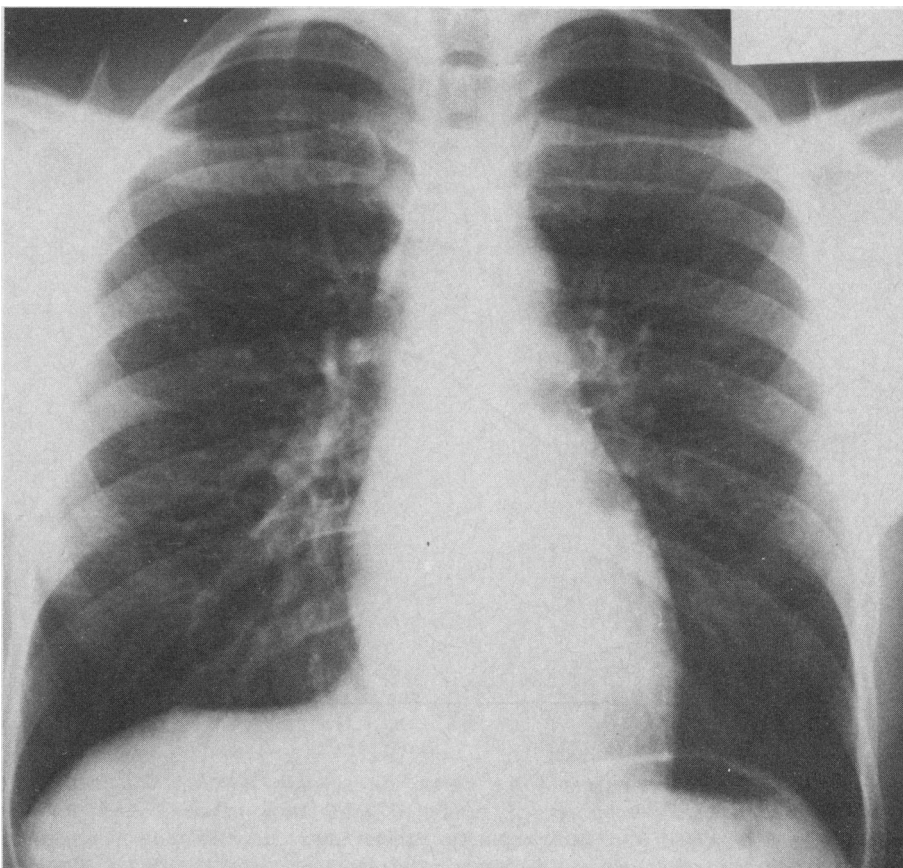


FIG. 1B—Before discharge 6 days later, complete clearing of pulmonary edema.

Table I—Results of pulmonary function tests done on three occasions in man with toxic pulmonary reaction to cadmium

Variable	Observed values (and % of normal predicted values)		
	Day after admission to hospital	Six weeks later	Almost 2 years after admission
Total lung capacity, L	3.4 (46)	5.5 (74)	5.6 (78)
Functional residual capacity, L	2.4 (59)	3.0 (75)	2.9 (72)
Vital capacity (VC), L	1.8 (32)	4.1 (76)	4.4 (83)
Residual volume, L	1.7 (87)	1.4 (70)	1.2 (60)
Forced expiratory volume in 1 second, L	1.6 (36)	3.9 (89)	3.9 (93)
Maximum expiratory flow at 50% VC, L/s	2.7 (50)	7.6 (141)	7.4 (140)
Maximum expiratory flow at 50% VC, VC/s	1.5 (150)	1.4 (141)	1.4 (137)
Airway resistance, cm H ₂ O/L/s	1.5 (89)	0.9 (71)	0.9 (64)
Diffusing capacity of carbon monoxide,* mL/min/mm Hg	13.7 (52)	27.8 (85)	24.9 (73)

*Measured by single-breath method.

Table II—Approximate content of metals in silver solder used by patient

Metal	%
Silver	55
Copper	20
Zinc	18
Cadmium	6
Tin	1

which parts of the parenchyma have normal compliance and parts are totally noncompliant; the latter are responsible for the restriction of lung volumes. This pattern was previously reported by Gibson and Pride⁸ in patients with fibrosing alveolitis.

This case is the first in which more extensive pulmonary function tests were performed following brief exposure to cadmium fumes; therefore, we cannot compare our results with those in previous reports, except for the reduced vital capacity and diffusing capacity and the absence of airways obstruction.

This patient will require long-term monitoring for possible early pulmonary deterioration. He has been advised to stop smoking, but we believe there is no need for him to stop working as a welder unless proper ventilation or respiratory protection is not available. There are as yet no long-term follow-up reports of workers similarly exposed to cadmium in whom lung function recovered rapidly. Whether these patients will have accelerated functional deterioration remains unknown.

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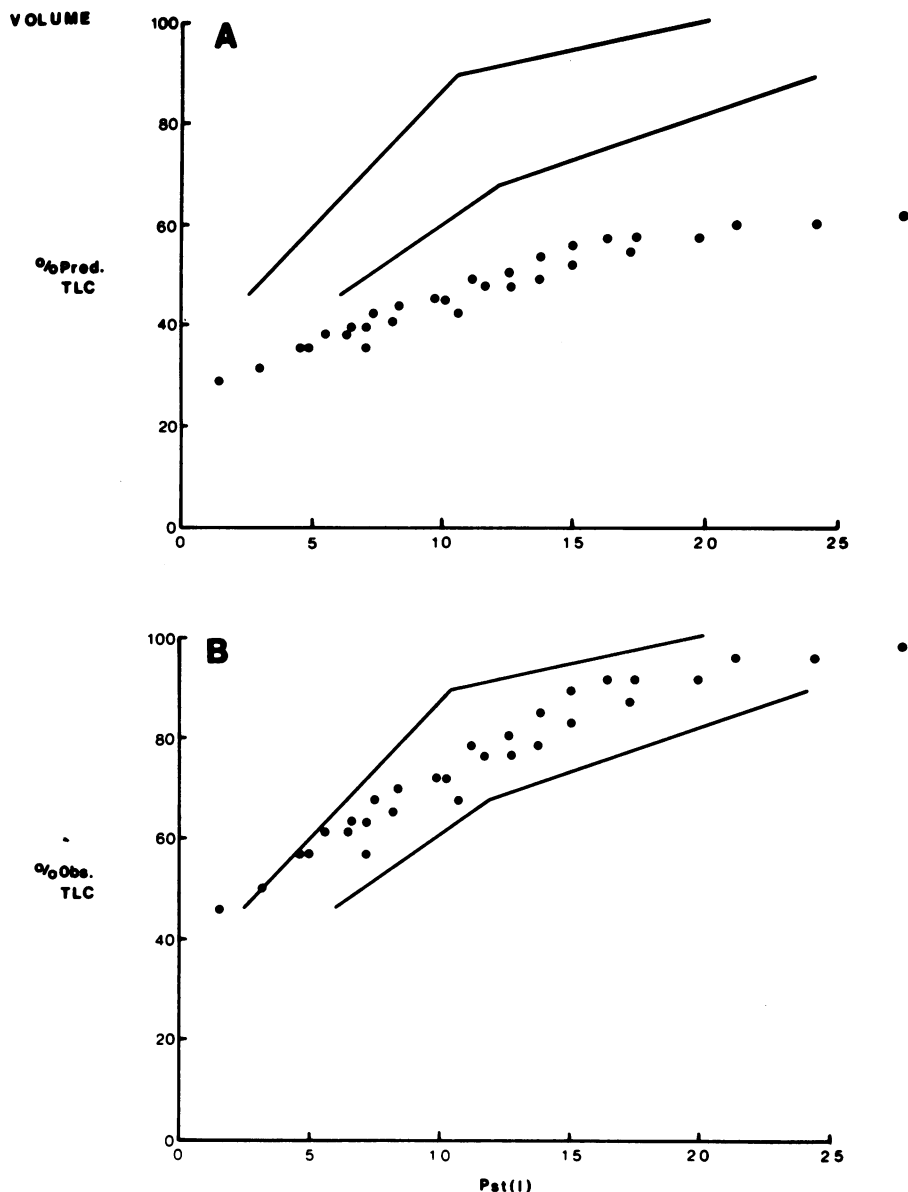


FIG. 2—Expiratory pressure-volume curve, on seventh hospital day, showing lung volume as (A) percentage of predicted total lung capacity and as (B) percentage of observed total lung capacity, against static transpulmonary pressure in centimetres of water. Spaces between solid lines represent predicted normal range for patient's age.