Chemical Pneumonitis and Acute Lung Injury Caused by Inhalation of Nickel Fumes

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Abstract

A 50-year-old man with a 30-year occupational history of welding presented with low-grade fever, fatigue and persistent dry cough. Computed tomography (CT) of the chest revealed interlobular septal thickening and bilateral non-segmental patchy ground-glass opacities except in the sub-pleural zone. He revealed that he had inhaled nickel fumes 3 days previously at work. These findings suggested a diagnosis of pneumonitis induced by inhalation of nickel fumes. Fewer reports describe pneumonitis associated with the inhalation of nickel compared with zinc fumes. Although nickel compounds are particularly pernicious among the transition metals and more toxic than zinc compounds, nickel fume inhalation rarely induces lethal acute respiratory distress syndrome. Our patient was successfully treated with corticosteroid.

Key words: nickel fumes, chemical pneumonitis, acute lung injury


Introduction

The health effects of exposure to metal fumes have been extensively studied (1). Numerous studies have evaluated the pulmonary effects of exposing workers to metal fumes (2). Respiratory effects arising in full-time welders include bronchitis, siderosis, asthma, and a possible increase in the incidence of lung cancer (1-5). Although the most frequent acute respiratory complaint of welders is metal fume fever, some reports have also described interstitial pneumonia and acute lung injury induced by inhalation of metal fumes (1, 6). Nickel fumes inhalation can cause bronchial asthma and pulmonary infiltrates with eosinophilia syndrome; however acute lung injury is very rare (7, 8). We present a patient with chemical pneumonitis and acute lung injury caused by the inhalation of nickel fumes.

Case Report

A 50-year-old man with a 30-year history of occupational welding was admitted to our hospital with low-grade fever, fatigue, persistent dry cough and grade III exertional breathlessness Fletcher-Hugh-Jones (FJH) criteria that had persisted for 3 days. A combination cold remedy taken on the fourth day had no effect and his symptoms had worsened. As fatigue progressed, he had difficulty in standing up from a seated position and performing activities requiring even minimal effort. He had a history of ureteral lithiasis. He had no known allergies to food or medications. He had a fifteen pack-year smoking history and did not consume alcohol nor use illicit drugs.

On physical examination, his body temperature, 38.3°C; respiratory rate, 32 breaths per minute; blood pressure, 143/82 mmHg; pulse rate, 102 beats per minute and oxygen saturation of 92% while breathing ambient air. No abnormal breath sounds were identified, but vesicular sounds were decreased. Skin lesions were absent. A chest X-ray upon admission revealed reticular opacities in both middle and lower lung fields (Fig. 1a). Axial chest CT showed bilateral non-segmental ground-glass opacities except in the sub-pleural zone (Fig. 1b). Based on these chest CT findings, we obtained more details of his history regarding antigen inhalation.

At that time he was a field superintendent and had walked into an area where nickel was being sprayed on metal sur-
faces via a metal-arc process, without wearing splash-proof chemical safety goggles or a face protective mask. Although he usually paid special attention to the use of personal protective equipment as part of the responsibility of his position, he had accidentally neglected these precautions on this occasion. Unfortunately, he inhaled nickel fumes when the wind shifted as he was passing by the area. Soon after inhaling nickel fumes, he developed a strong cough, but assumed based on his experience that his cough would spontaneously resolve. Two laborers working nearby had not experienced any symptoms due to adequate protection. In his industry, most welding fumes are generated using mild steel or carbon steel materials which usually contain iron and manganese, but they happened to be using nickel fumes on this occasion. He said that he had never been exposed to nickel fumes before.

Laboratory tests (Table 1) showed leukocytosis, increased serum C-reactive protein (CRP), lactic dehydrogenase (LDH) and surfactant protein A (SP-A). Arterial blood gas analysis showed hypoxemia. Differential cell counts of bronchoalveolar lavage fluid (BALF) revealed an increased ratio of neutrophils (22.0%). BAL PCR assay of choalveolar lavage fluid (BALF) revealed an increased ratio of LDH and surfactant protein A (SP-A). Arterial blood gas analysis showed hypoxemia. Differential cell counts of bronchoalveolar lavage fluid (BALF) revealed an increased ratio of neutrophils (22.0%). BAL PCR assay of choalveolar lavage fluid (BALF) revealed an increased ratio of LDH and surfactant protein A (SP-A). Arterial blood gas analysis showed hypoxemia. Differential cell counts of bronchoalveolar lavage fluid (BALF) revealed an increased ratio of neutrophils (22.0%). BAL PCR assay of choalveolar lavage fluid (BALF) revealed an increased ratio of LDH and surfactant protein A (SP-A).

Of note, the fraction of inspired oxygen (FiO2) on admission was 0.21, but it rapidly increased to 0.40 at the time of admission. Arterial blood gas analysis revealed a mixed-type respiratory failure with arterial hypoxemia (PaO2/FiO2: 480), normal pH, and metabolic acidosis (arterial pH: 7.35, HCO3−: 19.9 mmol/L). The serum C-reactive protein (CRP) level was 2.2 mg/L on admission, but it decreased to 0.5 mg/L on the 7th hospital day. There were no changes in the levels of lactic dehydrogenase (LDH) and surfactant protein A (SP-A) during hospitalization. A chest X-ray film revealed bilateral reticular opacities in the middle and lower lung fields. High-resolution chest CT (lung windowing) at first admission showed interlobular septal thickening (crazy paving) and bilateral non-segmental patchy ground-glass opacities, except in the sub-pleural zone. (Fig. 1)<br>

Figure 1. (A) Chest X ray shows bilateral reticular opacities in middle and lower lung fields. Bilateral costophrenic angles are sharply pointed. (B) High-resolution chest CT (lung windowing) at first admission shows interlobular septal thickening (crazy paving) and bilateral non-segmental patchy ground-glass opacities, except in the sub-pleural zone.

His symptoms were relieved somewhat spontaneously after admission. For treating the prolonged severe cough and dyspnea, we prescribed prednisolone (50 mg/day). Subjective symptoms and chest imaging findings remarkably improved as the levels of serum markers decreased. The prednisolone dose was tapered over a period of 1 month and discontinuation did not result in relapse. The bilateral non-segmental ground-glass opacities on chest CT improved (Fig. 3).<br>

Discussion<br>

Fumes comprise airborne particles of vapor, gas or smoke formed, for example, when a metal vaporizes into the atmosphere and then coalesces back into a solid. The inhalation of metal fumes can induce a wide range of lung pathophysiology, including airway disorders, cancer and diffuse parenchymal lung diseases (1-5). In Japan, the Ministry of Labor lists nickel carbonyl as a hazardous substance (9). The inhalation of metal fumes increases susceptibility to infectious pneumonia and induces occupational asthma. Many organizations have evaluated evidence regarding the carcinogenic effects of nickel (5, 10). The most frequent acute respiratory complaint of welders is metal fume fever (1). The condition is a self-limited, flu-like illness characterized by acute onset within 4 - 8 hr and symptoms may include thirst, dry cough, chills, fever, dyspnea, malaise, headache, and nausea. Although exposure to zinc oxide fumes is the most frequent and best-characterized cause of metal fume fever, other metal oxides including arsenic, boron, cadmium, chromium, copper, magnesium, manganese, nickel and titanium are also suggested causes (11). The toxicity of individual metals might depend on their oxidation state. Nickel is one of a large group of transition metals found in ambient air, and hence it exhibits several common oxidative states that play an important roles in catalyzing biologic oxidative reactions (12). Inhalation is the primary route of occupa-
tional exposure to nickel compounds that preferentially accumulate in the lungs and the kidneys (13). Although nickel fumes inhalation can cause bronchial asthma and pulmonary infiltrates with eosinophilia syndrome, exposure to high doses of nickel fumes causes chemical pneumonitis and pulmonary edema (7, 8). Lethal events are unusual and recovery is usually complete, but there was a report of a fatal case of acute respiratory distress syndrome due to the inhalation of nickel fumes from a metal arcing process (14). Pneumonitis induced by inhalation of metal fumes is roughly divided into chemical pneumonitis and hypersensitivity pneumonitis (9). The present case had no signs of allergic reaction on physical examination and there was no elevation of lymphocyte or eosinophil count in BALF. We
therefore diagnosed chemical pneumonitis and acute lung injury induced by inhalation of nickel fumes.

No guidelines are currently available regarding the treatment of pneumonitis induced by metal fume inhalation. Pulmonary inflammation in acute hypersensitivity pneumonitis is often reversible by removing the inhaled antigens (9). When inflammation persists even after antigens are removed, steroids are the mainstay of medical therapy. Cytokines are considered to mediate the pathological respiratory conditions associated with inhalation of metal fumes (15). The characteristic symptoms are elicited by cytokines produced in the lung as a direct response to the inhaled metal fumes. The persistent severe cough and dyspnea in the present patient were thought to be the consequence of prolonged bronchial inflammation. Metal fumes differ in both metal content and solubility (16). Studies of animal models have demonstrated that stainless steel welding fumes, which contain significant levels of nickel and chromium, induce more lung injury and inflammation, and are retained in the lungs for longer periods than mild steel welding fumes, which contain mostly iron (17). Toxicity might be associated with the content of nickel and chromium in the stainless steel welding fumes, which are absent in mild steel welding fumes. Short-term exposure of rats to stainless steel welding fumes causes significant acute lung damage and prolongs pulmonary inflammation (18). We suspect that because our patient inhaled nickel fumes, he might develop not merely fume fever, but also chemical pneumonitis and acute lung injury. We would have preferred to understand the precise chemical components of his inhaled fumes and the industrial process that he encountered, but such information was unavailable.

The characteristic chest CT findings at the first medical examination of our patient indicated a need to question him about inhaled antigens and his answers and the findings led to an early diagnosis. Early identification and management of chemical pneumonitis caused by metal fumes inhalation are important to avoid potential lethality. Of course there is no question that the use of appropriate personal protective equipment in the work environment is a necessity.

The authors state that they have no Conflict of Interest (COI).

References