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REVIEW

Occupational hypersensitivity pneumonitis: A preventable cause of interstitial lung disease

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ABSTRACT

Occupational hypersensitivity pneumonitis: A preventable cause of interstitial lung disease

Hypersensitivity pneumonitis (HP) is an immune-mediated interstitial lung disease caused by repeated inhalation of organic or chemical antigens, commonly in occupational settings. Although often less severe than other respiratory diseases, HP can progress to irreversible pulmonary fibrosis if not diagnosed early. Diagnosis involves a detailed occupational history, high-resolution computed tomography, pulmonary function tests, bronchoalveolar lavage, and immunologic assays. High-risk occupations include farming, bird breeding, poultry processing, wood and textile work, mushroom and compost handling, and healthcare. Notably, exposure to metalworking fluids (MWFs), previously considered rare, has become a prominent cause of HP. MWFs may contain bacteria, fungi, mycobacteria, and dissolved metals, triggering immune-mediated lung inflammation. Preventive strategies—early recognition, antigen avoidance, and workplace monitoring—are key. Systemic corticosteroids may help in acute stages, but long-term prognosis depends on exposure duration and timely intervention.

Key words: Hypersensitivity pneumonitis; occupational hypersensitivity pneumonitis; metalworking fluids; interstitial lung disease

ÖZ

Mesleki hipersensitivite pnömonisi: Önlenebilir bir interstisyel akciğer hastalığı nedeni

Hipersensitivite pnömonisi (HP), tekrarlayan organik veya kimyasal antijen inhalasyonuna bağlı gelişen immün aracılı interstisyel akciğer hastalığıdır ve özellikle mesleki ortamlarda sık görülür. Çoğunlukla HP, diğer solunum yolu hastalıklarına kıyasla daha hafif seyreder ancak erken tanı konulmadığında geri dönüşüzlüğü pulmoner fibrozise ilerleyebilir. Tanı, ayrıntılı mesleki öykü, yüksek çözünürlüklü bilgisayarlı tomografi, solunum fonksiyon testleri, bronkoalveolar lavaj ve immünolojik değerlendirmeleri içerir. Yüksek riskli meslekler arasında tarım, kanatlı hayvan yetiştiriciliği, tavuk işleme, ahşap ve tekstil işleri, mantar ve kompost işlemleri ile sağlık sektörü yer almaktadır. Son yıllarda, daha önce nadir görülen metal işleme sıvılarına (MWF) maruziyet, HP'nin önemli bir nedeni olarak öne çıkmıştır. MWF'ler bakteri, mantar, mikobakteri ve

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çözünmüş metaller içerebilir ve bu durum immün aracılı akciğer inflamasyonunu tetikleyebilir. Önleyici stratejiler arasında erken tanı, antijen maruziyetinin önlenmesi ve işyeri ortamının izlenmesi bulunur. Akut evrede sistemik kortikosteroidler faydalı olabilir ancak uzun dönem prognoz, maruziyet süresi ve zamanında müdahaleye bağlıdır. Bu derleme, mesleki HP'nin tanı ve önlenebilirliğine dikkat çekerek hem klinik farkındalığı artırmayı hem de iş sağlığı uygulamalarını geliştirmeyi amaçlamaktadır.

Anahtar kelimeler: Aşırı duyarlılık pnömonisi; mesleki aşırı duyarlılık pnömonisi; metal işleme sıvıları; interstisyel akciğer hastalığı

INTRODUCTION

Hypersensitivity pneumonitis (HP), formerly known as extrinsic allergic alveolitis, is an immune-mediated interstitial lung disease (ILD) resulting from repeated inhalation of environmental antigens, most commonly organic dusts, animal proteins, or certain chemicals. These antigens trigger an abnormal immune response in sensitized individuals, leading to inflammation of the alveoli, bronchioles, and interstitial lung tissue (1). The underlying immunological mechanism involves a combination of Type III (immune complex-mediated) and Type IV (delayed-type) hypersensitivity reactions, leading to alveolar and interstitial inflammation (2).

HP can occur in both occupational and non-occupational settings, and early detection and antigen avoidance are critical to prevent irreversible lung damage (3). It is the third most common ILD after idiopathic pulmonary fibrosis (IPF) and connective tissue diseases. Clinical presentation varies depending on the type of exposure, the duration of exposure, and the patient's immune status (4). While acute symptomatic exposures are mainly reversible, chronic exposure with insidious symptoms may result in progressive pulmonary fibrosis and permanent respiratory impairment (3). Since the disease develops in a small proportion of individuals exposed to the same antigen, it is thought that there is a genetic predisposition to the disease (4).

The estimated incidence of HP is reported to be 1.3-1.9 per 100.000 population and is more frequently observed in female patients and non-smokers (5). The prevalence of HP is higher among individuals who have quit smoking compared to the general population (6). Differentiating HP from IPF can sometimes be challenging. Notably, HP has different epidemiological characteristics compared to IPF, which predominantly affects male patients and smokers. In studies involving large patient cohorts, the mean age at diagnosis for HP is reported to be 52 years, suggesting that HP tends to affect younger individuals than IPF (5).

Clinical presentations of HP and other ILDs can be similar. When characteristic imaging features are inconclusive, a detailed exposure history is crucial in

supporting the diagnosis of HP. More than 200 antigens have been identified in association with HP, with the most common exposures encountered in clinical practice being occupational, hobby-related or environmental (7). Individuals involved in bird feeding, cheese, coffee, or mushroom processing - as well as farmers, furhandlers, and malt workers - represent the most frequently affected groups (8). Despite the importance of exposure history in clinical diagnosis, a causative antigen cannot be determined in approximately 50-60% of the patients (9). This limitation underscores the critical role of radiological evaluation and highlights the need for a multidisciplinary approach, with close collaboration among clinicians, radiologists, and pathologists.

In this narrative review, we aimed to discuss the clinical, radiological, and pathological features of HP, outline its diagnostic and therapeutic approaches, and emphasize the importance of recognizing and preventing occupational forms of the disease. Additionally, we aimed to highlight the occupational etiology of HP with particular emphasis on emerging risk factors and the use of novel metalworking fluids (MWF).

Etiology

Exposure to organic substances and the development of HP have been documented across a wide range of occupations. In addition to the antigenic properties of causative substances—such as solubility and particle size—the individual's genetic predisposition, as well as the dose, intensity, and duration of exposure, are believed to contribute to both the development and prognosis of the disease. Chemicals associated with occupational HP tend to be more lipophilic, more likely to cross-link with proteins, and pose a higher asthma risk compared to those causing occupational asthma (10). While organic chemical compounds are less commonly implicated, substances like isocyanates and anhydrides are notable examples. Although isocyanates are not inherently antigenic, they can bind to host proteins to form haptens. They are widely used in the large-scale production of polyurethane polymers, foams, paints, and plastics. Additionally, some microorganisms such as *Mycobacterium immunogenum*—which can colonize contaminated

MWF—have been associated with HP in automotive and metalworking environments. As work practices evolve, while some occupational causes of HP have declined, new agents and risks continue to emerge. Clinicians must remain vigilant and stay informed about newly identified triggers to aid in accurate diagnosis. Table 1 summarizes the causative antigens associated with certain occupational groups. Sporadic cases of HP have been reported in various occupational settings, including office workers exposed to contaminated humidifiers and ventilation systems, lifeguards at public swimming pools, and workers in polyurethane foam manufacturing for the automotive industry (10,11).

The true prevalence of occupational HP in the general population remains unclear, as available data are largely derived from occupation-specific, geographically and temporally limited studies. Farmer's lung, one of the most common forms, is reported to affect

0.4-7% of the farmers (12), with estimates rising to 9% in humid regions and falling below 2% in drier areas (13). Using the 2018 national population of 82,003,882 reported by the Turkish Statistical Institute (TÜİK) and previously reported annual prevalence estimates for hypersensitivity pneumonitis, the estimated number of HP cases in Türkiye ranges from approximately 1.370 to 2.222 cases per year (14). These figures may underestimate the true burden due to factors such as the high number of unregistered child agricultural workers and the widespread domestic keeping of birds and pigeons, both of which increase exposure risk. In Türkiye, most HP-related studies are limited to case series. A few focus on specific occupational groups, including agricultural workers, mushroom growers, malt workers, and hazelnut leaf collectors (14,15). While others emphasize domestic exposures, particularly among bird and pigeon keepers (15).

Table 1. Examples of occupations and responsible antigens implicated in hypersensitivity pneumonitis (10,11)

Occupation	Responsible antigens
Agriculture and animal husbandry	Thermophilic actinomycetes, <i>Lichtheimia corymbifera</i> , <i>Sitophilus granarius</i> proteins, phytase, and subtilisin enzymes
Spa workers and those exposed to humidifiers and cold vapor	<i>Mycobacterium avium</i> complex, nontuberculous mycobacteria, <i>Klebsiella oxytoca</i> , Thermophilic actinomycetes, <i>Alternaria alternata</i> , <i>Rhodotorula</i>
Caring for birds and poultry	Serum and feather proteins
Veterinary, laboratory workers, pharmaceutical manufacturing	Protein and secretions, mouse serum proteins, penicillin and cephalosporins
Grain and flour processing and loading	<i>Sporobolomyces</i> , <i>Aspergillus fumigatus</i> , <i>Aspergillus clavatus</i> , <i>Sitophilus granarius</i> , insect pathogens
Timber processing, construction, wood stripping, paper manufacturing, and masonry fabrication	<i>Alternaria alternata</i> , pine proteins, mold colonization
Plastics production, paint manufacturing, electronics industry, and other chemicals	Isocyanate, acid anhydrides, aerosolized or gas-phase organic chemicals
Textile workers (may not include full forms for HP)	Cotton gin dust, upholstery fabric and nylon velvet (flock), silk proteins
Metalworking	<i>Acinetobacter</i> , <i>Ochrobactrum</i> , <i>Mycobacterium immunogenum</i> (associated with metalworking fluids), cobalt, zinc, zirconium
Fertilizer production	<i>Streptomyces albus</i> , Thermophilic actinomycetes
Detergent production	<i>Bacillus subtilis</i> enzymes
Tobacco and malt production	<i>Aspergillus</i> spp.
Nutrient production	<i>Penicillium verrucosum</i> , <i>Penicillium camemberti</i> , <i>Penicillium roqueforti</i> (cheese), <i>Cryptostroma corticale</i> (flower, plant), <i>Penicillium citreonigrum</i> (moss), <i>Botrytis cinerea</i> (wine), paprika slicers (paprika), Shiitaki, Bunashimeji, Pleurotus, Pholiota, Shimeji, Agaricus (fungus), carmine enzyme, almond protein, soy and malt proteins, larmine protein
Underwater workers	Alginate (algae) protein, pearl protein, mollusk shell protein
Dental prosthesis fabrication	Acrylate compounds, zinc, zirconium

Clinical findings

Although symptoms may occasionally develop within weeks of antigen exposure, they more commonly arise after months or even years of continuous or intermittent exposure (6). This latency period varies depending on the triggering agent, averaging around 9 years in cases of bird fancier's lung and 5 years in mushroom worker's lung (16). Clinical features typically include dyspnea, cough, and mid-inspiratory rhonchi, along with less common symptoms such as weight loss, flu-like illness, chest tightness, and wheezing. Symptom onset may be acute, insidious, or recurrent (6). In advanced or delayed cases, digital clubbing and cor pulmonale may also be present.

HP was previously classified as acute, subacute, or chronic, but the 2019 guidelines reclassified it into two forms: Non-fibrotic (purely inflammatory) and fibrotic (mixed inflammatory-fibrotic or pure fibrotic) (17). This updated classification offers a more objective and clinically relevant framework. However, distinguishing between these forms—particularly fibrotic HP and IPF—can be challenging. Classification should therefore rely on predominant clinical and radiological findings. Female, non-smoking patients with known exposure and younger age should be evaluated for HP using high-resolution computed tomography (HRCT), bronchoalveolar lavage (BAL), and lymphocyte analysis. In contrast, male patients over 60 years with no identifiable exposure history should be assessed for IPF via HRCT, with multidisciplinary discussion recommended for accurate diagnosis (17,18).

Pathological findings

Most patients with HP exhibit a combination of four key histopathologic features: i) cellular bronchiolitis surrounding the small airways, ii) diffuse chronic interstitial inflammation predominantly composed of lymphocytes and plasma cells, iii) poorly formed non-necrotizing granulomas, sometimes with giant cells, iv) scattered areas of organizing pneumonia (19). These lesions are usually peribronchiolar in distribution and may progress to obliterative bronchiolitis. In some patients with an insidious disease course, emphysema may be prominent.

Fibrosis, when present, usually shows one of three patterns: i) irregular peribronchiolar fibrosis, ii) patchy subpleural fibrosis with architectural distortion similar to usual interstitial pneumonia, or iii) uniform

fibrosis without distortion similar to non-specific interstitial pneumonia (NSIP). Distinguishing fibrotic HP from idiopathic NSIP or other ILDs can be particularly challenging (20). A cellular variant of NSIP may also be seen, characterized by temporally homogeneous lymphoplasmacytic infiltration, predominantly in a peribronchial distribution.

Radiological findings

Chest radiography

The contribution of chest radiography to the diagnosis of HP is limited but can be beneficial in the differential diagnosis. In non-fibrotic HP, imaging abnormalities may include numerous small (<5 mm), ill-defined nodules with relative sparing of the apices and lung bases. Patchy or diffuse ground-glass opacities, sometimes resembling pulmonary edema, may also be present, along with occasional areas of consolidation. Fine reticular patterns can be seen, and the zonal distribution of findings is often variable. When fibrosis develops, chest x-ray may reveal a reticular pattern and honeycombing, often with upper lobe predominance. Associated volume loss is frequently observed in the upper lobes. Additionally, cardiac enlargement may be present due to cor pulmonale (21).

High-resolution computed tomography

HRCT plays a central role in the diagnosis and classification of HP, helping to differentiate between non-fibrotic and fibrotic forms based on characteristic imaging patterns. HRCT can detect radiologic abnormalities in 88-92% of the affected patients (22).

In cases with non-fibrotic HP, HRCT typically reveals inflammatory changes without evidence of fibrosis or architectural distortion. Common findings include ground-glass opacities, centrilobular ground-glass nodules, and air trapping. Ground-glass opacities are usually bilateral and symmetrical, though they may appear patchy, with a predilection for the middle and lower lung zones or peribronchovascular regions (Figure 1). Centrilobular nodules—often with a central lucency representing the bronchiolar lumen—are a hallmark feature. These nodules are diffusely distributed on axial images and may predominantly affect the upper to middle lung zones in the craniocaudal plane. A higher number of centrilobular nodules is associated with greater diagnostic confidence (23). Air trapping is particularly evident on expiratory HRCT scans and is indicative of small airway involvement.

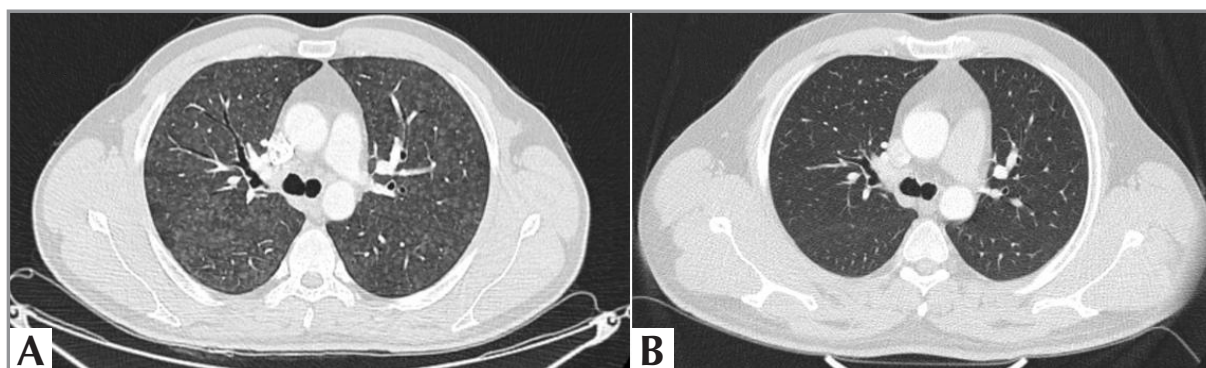


Figure 1. A patient who had worked as a welder for 14 years in the industrial kitchen production sector, specializing in stainless steel processing, presented with acute dyspnea and cough in the setting of occupational exposure to metal dust and welding fumes. HRCT demonstrated diffuse centrilobular ground-glass nodules (A). The nodules resolved two weeks after cessation of work and treatment with prednisone (B).

This finding often contributes to the appearance of a mosaic attenuation pattern, which reflects regional heterogeneity in ventilation and perfusion (24,25).

Fibrotic HP cases exhibit a combination of inflammatory and fibrotic features, reflecting a more chronic disease course. HRCT findings commonly include reticulation and traction bronchiectasis which may have an upper or mid-lung predominance. Honeycombing may be present, though usually less extensive than in IPF, and often involves the upper lobes. Volume loss, particularly in the upper lobes, is also a frequent finding. Despite the presence of fibrosis, features such as air trapping and mosaic attenuation often persist, especially on expiratory imaging. A characteristic sign in fibrotic HP is the so-called “headcheese sign” or newly named “three density sign”—a patchwork of ground-glass opacities, air trapping, and normal lung parenchyma—highlighting the mixed inflammatory and fibrotic nature of the disease (Figure 2) (21,26).

Diagnosis

The diagnostic evaluation of HP begins with clinical suspicion and the identification of a potential causative antigen. In patients suspected of having HP, it is essential to obtain a detailed clinical history, with particular attention to the type, intensity, and timing of exposures in relation to symptom onset. The use of structured questionnaires, adapted to the local environmental and occupational context, is recommended to improve the sensitivity of exposure detection. When occupational exposure is suspected, consultation with an occupational health physician may provide valuable insights. In non-occupational cases, such as suspected mold-related HP, an environmental

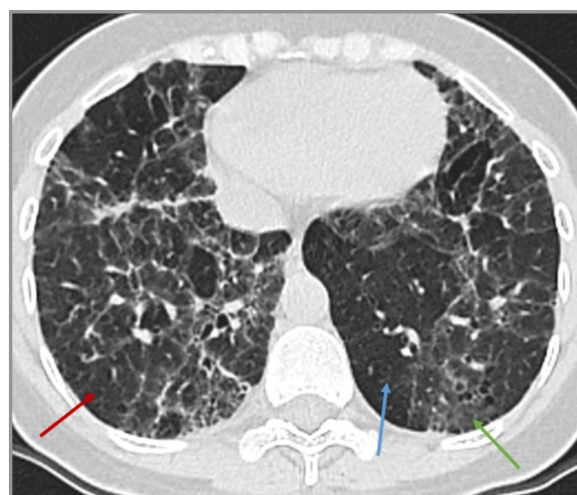


Figure 2. Three-density sign in a patient with fibrotic hypersensitivity pneumonitis. The green arrow indicates ground-glass opacity, the blue arrow denotes areas of air trapping, and the red arrow highlights regions of normal, spared parenchyma.

assessment of the patient’s home may be warranted. Despite thorough evaluation, the causative antigen often remains unidentified. Although most patients with HP exhibit serum precipitating antibodies against the implicated antigen, these antibodies lack specificity, as they may also be present in asymptomatic individuals with similar exposures. Furthermore, their absence does not exclude the diagnosis. Therefore, the diagnosis of HP relies on the integration of clinical features, pulmonary function testing, immunological assessments, BAL analysis, and radiological findings (Figure 3). Pulmonary function tests typically demonstrate a restrictive pattern with a reduced diffusing capacity for carbon monoxide. BAL fluid

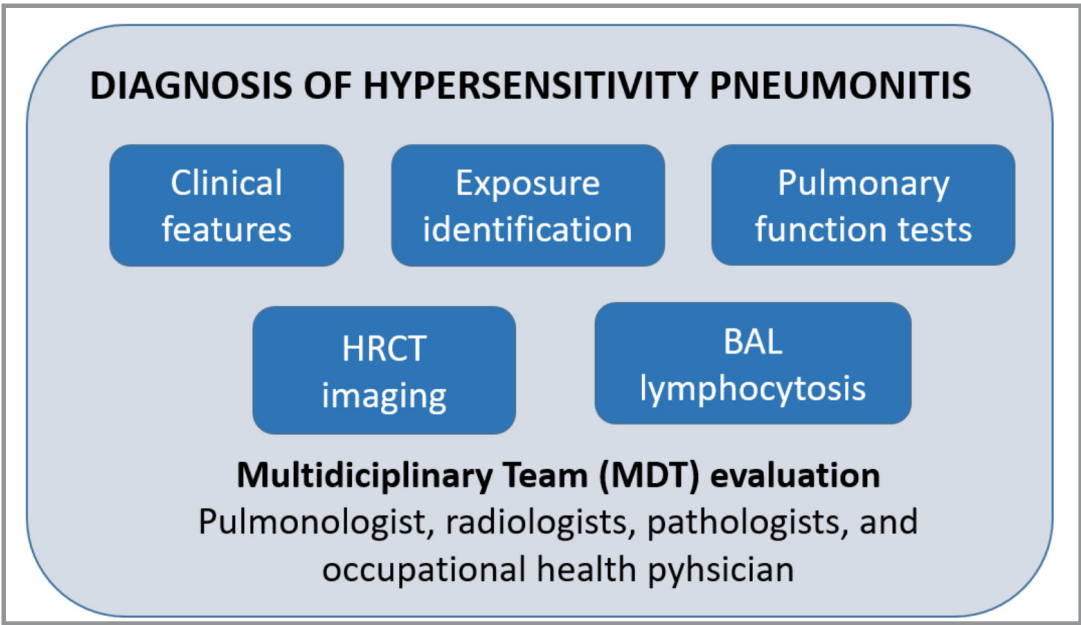


Figure 3. Diagnostic evaluation of hypersensitivity pneumonitis.
HRCT: High-resolution computed tomography, BAL: Bronchoalveolar lavage.

analysis usually shows lymphocytosis, and detection of specific IgG antibodies to suspected antigens can provide supportive evidence. In cases where non-invasive methods are inconclusive, lung biopsy may be necessary, revealing features such as poorly formed non-necrotizing granulomas and interstitial lymphocytic inflammation. Ultimately, a multidisciplinary team discussion involving pulmonologists, radiologists, and pathologists is essential for integrating all clinical, radiological, and pathological information to establish a confident diagnosis (27).

Assessment of occupational factors

The relationship between occupational exposure and the development of HP - referred to as occupational HP - has been well-documented, emphasizing the importance of accurate epidemiological data. A study involving 50.000 farmers and their spouses in the United States found that approximately 2% of the farmers and 0.2% of their spouses had a doctor-diagnosed history of farmer's lung (28). According to official statistics, the incidence of all occupational diseases, including HP, in Türkiye has remained relatively low over the last 20 years, at around % 0.006 (29). However, to obtain more accurate epidemiological data in our country, comprehensive and well-structured studies are necessary.

Many occupations carry a risk for the development of HP. These occupations, which involve exposure to plant, animal, and chemical agents, constitute a continually expanding list. It is crucial for healthcare providers to be familiar with these occupational risks and to thoroughly review the work histories of patients presenting with compatible symptoms. Moreover, a detailed occupational history can lead to the identification of previously unrecognized high-risk occupations. Diagnosing HP through comprehensive evaluation does not only facilitate appropriate treatment for the affected individual but also contributes to the prevention of disease among other exposed workers. Early diagnosis and timely intervention are essential to halt disease progression and improve patient outcomes (30).

The ongoing identification of new types of HP is closely linked to changes in agricultural and industrial practices, as well as the increasing diversification of products and services. For example, "machine operator lung" is associated with *Pseudomonas* exposure in cooling water, and HP cases have been recognized in workers within the automotive parts manufacturing industry. Given the complexity of keeping track of numerous high-risk exposures, it is practical to classify HP subtypes into five primary antigen groups as outlined in Table 2 (31).

Table 2. Representative HP types categorized by major antigen classes (31)		
Antigen class	Specific antigen	HP type
Bacteria	Saccharopolyspora rectivirgula	Farmer's lung
Fungi	Trichosporon cutaneum	Summer HP
Mycobacteria	Mycobacterium avium intracellulare	Jacuzzi lung
Proteins	Altered pigeon serum	Pigeon feeder lung
Chemical products	MDI	MDI HP
HP: Hypersensitivity pneumonitis, MDI: Diphenylmethane diisocyanate.		

The frequency of HP is influenced by workplace conditions and risk factors associated with the responsible agent, such as antigen concentration, intensity and duration of exposure, water solubility of the antigen, particle size, and use of respiratory system personal protective equipment. However, the observation that not all individuals working under the same conditions develop the disease suggests the presence of personal predisposing factors. HP typically arises from inhalation exposure to a wide range of primarily organic or low-molecular-weight chemical agents. These agents trigger an immunologically mediated inflammatory response, which, if present, can lead to progressive lung damage. Despite the terminology “hypersensitivity” or “allergic” in its name, HP is not considered an atopic disease and does not involve IgE-mediated reactions or eosinophilic inflammation (32). Unlike many other lung diseases, 80-95% of HP cases occur in non-smokers. Although the reason for this association remains unclear, it is not a strong enough factor to exclude the diagnosis of HP in a patient who do smoke. On the other hand, smoking has been linked to the development of the chronic form of HP and is associated with a worse prognosis (33). Cigarette smoking exerts variable and complex effects on the efficacy of several commonly used diagnostic tests for HP. In workers who smoke, the effects of smoking can complicate the diagnosis of HP (34).

In occupational HP, differential diagnosis from other ILDs is essential. Hard metal pneumoconiosis, caused by inhalation of cobalt and tungsten carbide dust, can closely resemble occupational HP both clinically and radiologically (35). This rare but serious condition—seen in industries such as tool manufacturing, metal grinding, and diamond polishing — differs from classic pneumoconioses (e.g., silicosis) by involving an immune-mediated response rather than simple dust deposition. Cobalt exposure triggers lung inflammation and subsequent fibrosis, often associated with giant cell interstitial pneumonia, which is characterized

by the presence of large, multinucleated cells within lung tissue (36). Clinically, patients present with progressive dyspnea, dry cough, and fatigue. If exposure persists, the disease may progress to chronic respiratory failure; however, early diagnosis and cessation of exposure can halt its progression.

Novel Agents

Nanomaterials

Inhalation of nanosilica, silver nanomaterials, and carbon nanotubes—commonly used in cosmetics, pharmaceuticals, printer toner, paints, food products, polishes, electronics, optoelectronics, cancer therapies, deoxyribonucleic acid (DNA) transfection, and enzyme immobilization—can lead to pulmonary inflammation, myocardial ischemic injury, increased blood viscosity, DNA damage, pulmonary fibrosis, and pleural and pericardial effusions (37).

Indium-tin oxide, commonly used in liquid crystal display screens, has been associated with the development ILD or pulmonary alveolar proteinosis (38). “Flavor worker’s lung”, a form of constrictive bronchiolitis, is characterized by concentric submucosal fibrosis in the terminal and respiratory bronchioles, often extending to peribronchial tissue. This condition is associated with exposure to the ketone diacetyl (2,3-butanedione), a butter-flavoring agent commonly used in microwave popcorn production (39). Similarly, “Flockworkers’ lung” associated with the inhalation of “flock” fibers used in synthetic textile manufacturing, leads to lymphoid bronchiolitis and peribronchiolitis, characterized by prominent lymphoid hyperplasia within the lung tissue (40).

Metalworking fluids

The adverse effects of MWF, which are increasingly used in metalworking processes, have become more pronounced on employee health. Numerous studies have shown that these substances pose significant health risks when not properly managed and con-

Table 3. Classification of metalworking fluids (43)			
Oil based (Immiscible with water)		Water based (Miscible with water)	
Pure oils (%100 fat)	Soluble oils (%60-90 fat)	Semi-synthetic Liquids (%2-30 fat)	Synthetic liquids (%0 fat)
Mineral oils Animal fats Vegetable oils	Mineral oil + Emul- sifier	Soluble oils + Synthetic oils	Water + Organic chemicals

trolled (41,42). Considering the complex chemical structures of MWFs, it is essential to understand the specific properties of the fluid being used when evaluating its impact on worker health. The choice of an MWF base depends on the kind of the production process and the material worked. Oil-based fluids are applied when good lubrication is favoured. Water-based fluids are used when it is essential to reduce the temperature of the materials and wear products by heat dissipation outside of the friction zone. Metalworking oils are composed using animal, vegetable or synthetic oils as a base (Table 3) (43). If risk assessments and associated process controls are not adequately implemented, fundamental occupational health and safety concerns may arise, primarily due to employees’ direct exposure to the fluids or indirect exposure to their vapors (44).

MWFs used in the industry are applied in two ways: either mixed with water or used unmixed. These fluids, which are extensively employed in computer numerical control machines, are pumped through pipes to the workpiece and then return to the reservoir for storage at the end of the operation. During this circulation, oils from the machine components mix with the fluid in the reservoir, while particles such as metal shavings and dust accumulate, complicating fluid maintenance (45). The tendency of MWFs to lose their properties over time and undergo biological degradation, coupled with the health risks posed to employees exposed to this fluids, underscores the necessity of implementing both technical and organizational measures. In order to effectively control the degradation process, key parameters such as concentration, pH, and bacterial content should be regularly monitored. In addition to the biological degradation of MWFs, their potential to become significant pollutants in the working environment—either through heating during use or evaporation under ambient conditions—must be carefully considered in risk assessment studies. It is also essential to consider factors that could contribute to occupational diseases,

particularly the long-term effects that may result from prolonged exposure to these fluids (45,46).

MWFs are essential for addressing the challenges encountered during machining processes. These fluids help reduce the high temperatures (350-1000°C) generated by heat during cutting, while also minimizing friction at the tool-chip interface through lubrication. This not only supports the removal of chips from the operation area but also extends tool life and enhances product quality. The two primary functions of MWFs—lubrication and cooling—are achieved through various combinations of water-based cooling and oil-based lubrication properties, along with anticorrosive, emulsifying, and additive properties. In applications where lubrication is more important than cooling, pure oils mixed with additives are preferred. These MWFs, also known as cutting oils, are typically mineral oils. Additives such as lard, beaver oil, sulfur, and chloride can be added to into these mineral oils. Additive-free mineral oils are generally used for machining metals with high machinability, such as aluminum and magnesium, and sulfur-containing free-cutting steels. Oils with additives are preferred for heavy-duty operations such as screw cutting, gear manufacturing, and hole drilling. However, additive-containing oils are less commonly used due to their higher cost, increased risk of ignition, and potential adverse effects on human health. Although pure water was historically the first cooling fluid employed, it is no longer preferred today because of its poor lubrication properties and corrosive effects. The main components of modern MWFs include mineral oils, vegetable oils, synthetic oils, and a variety of additives such as bactericides and fungicides. Among MWFs, soluble oils, semi-synthetic oils, and synthetic oils are emulsified with water for use. Additionally, all types of MWFs may contain additives such as stabilizers, biocides, diluents, dyes, and odorants (44-46).

Briefly, exposure to MWFs, which was relatively uncommon before 2000, is now the most frequently recognized cause of occupational HP. Various sub-

stances present in MWFs—including bacteria, mycobacteria, fungi, biocides, emulsifiers, reodorants, and dissolved metals such as chromium and cobalt—may contribute to disease development. Multiple factors likely drive different outbreaks. Although immunological reactions to mycobacteria growing in MWFs have been reported, the exact role of these fluids in disease pathogenesis remains unclear. Numerous outbreaks have been identified in facilities using standard sumps in large industrial settings. Since microbial contamination of MWFs is inevitable during use, reducing aerosol inhalation—particularly through reengineering to eliminate recirculation—should be a primary focus of disease prevention (45).

Treatment

The termination of contact with the causative agent is the most critical step both for protecting against HP and for ensuring effective treatment. If the responsible agent is present in the workplace, eliminating exposure is the primary intervention that significantly influences the course of the disease. Personal and environmental occupational safety measures, such as wearing protective masks and ensuring adequate ventilation, must be implemented. Establishing healthy workplace conditions across all occupations is essential to uphold the fundamental right to a healthy life (47).

Although corticosteroids can lead to significant regression of symptoms and improvement in severe pathophysiological disturbances in the acute and subacute forms of HP, studies have shown that corticosteroid therapy does not alter long-term outcomes. While there is some variation in clinical practice, it is generally recommended that treatment with prednisone be initiated at a dose of 40–60 mg/day for two weeks, followed by a gradual dose reduction and discontinuation within 2–4 weeks. Overall, treatment should not typically exceed six months. In patients requiring long-term steroid therapy, immunosuppressive agents such as mycophenolate mofetil or azathioprine may be used as alternatives to minimize steroid-related side effects. In cases where fibrosis is present—evidenced by findings such as honeycombing and traction bronchiectasis on HRCT—the prognosis is poor. In cases with progressive massive fibrosis, anti-fibrotic therapy (nintedanib, pirfenidone) can be considered. Supportive care, including oxygen therapy for hypoxemia and pulmonary rehabilitation to improve respiratory function and quality of life, is also essential. In advanced cases with irreversible

lung damage, lung transplantation may be an option. Early diagnosis and prompt removal from antigen exposure are crucial to preventing progression to chronic, fibrotic lung disease. Therefore, avoidance of antigen exposure remains the most effective strategy for primary, secondary, and tertiary prevention (3).

Prevention

Early diagnosis of HP is vital, as complete avoidance of the culprit antigen can lead to full or partial recovery in the early stages and help maintain disease stability in later stages. If exposure continues, HP can progress to chronic forms with poorer outcomes. Occupational physician plays a key role in assessing the risks of HP in the workplace and must establish appropriate health surveillance programs. Following a thorough workplace risk assessment, appropriate interventions should be implemented to prevent exposure to hazardous agents, primarily through primary prevention strategies. These include eliminating the causative agent altogether or substituting it with a non-hazardous or less hazardous alternative. Additionally, engineering controls and the use of personal protective equipment should be employed to further minimize exposure (48). Preventive measures should be implemented in the workplace, and their effectiveness should be periodically evaluated through retrospective assessments. As part of secondary prevention, employees at risk should be identified, and appropriate tests should be conducted to facilitate the early diagnosis of HP. The aim is to identify and treat affected individuals at an early stage to prevent progression. Periodic medical examinations, including radiological imaging and pulmonary function tests, should be carried out at intervals determined by the occupational physician to ensure ongoing monitoring and early detection of any disease progression.

Affected workers should be informed about other comorbidities and lifestyle factors that may exacerbate disease progression of the disease, and their follow-up and treatment plans should be tailored accordingly. For instance, educating workers about the detrimental effects of smoking, emphasizing the importance of smoking cessation, and providing appropriate support are essential. Moreover, training employees about the disease and raising awareness are crucial components of prevention, as is instructing them to seek immediate medical attention if symptoms occur. Tertiary prevention involves managing the disease and its complications, offering rehabilitation, and ensuring compensation for workers

with permanent disabilities. One of the most critical responsibilities of chest physicians is to conduct a detailed occupational history in any case where HP is suspected (49). Asking questions such as, “Do you think your work is causing your disease?” — along with evaluating symptom patterns in relation to work and vacation periods and identifying potential workplace exposures — is crucial for the accurate assessment and diagnosis of occupational diseases. Some studies have shown that highly antigenic proteins can be transported home on an individual’s clothing, potentially causing disease in family members through “take-home” exposure. Therefore, it is important not only to assess the patient but also to inquire about the occupations and activities of other household members. A comprehensive evaluation should include details about previous jobs, hobbies, secondary employment, the home environment, potential environmental exposures near the home, and other factors that may be relevant to the differential diagnosis, such as feeding birds at home (48,49).

CONCLUSION

Although occupational HP is often regarded as a less severe condition among occupational respiratory diseases both globally and in our country, some cases with subtle, insidious symptoms may go unrecognized for years and eventually present with advanced pulmonary fibrosis due to prolonged, low-level exposure. However, with early diagnosis and appropriate preventive measures, disease progression can be halted, and patients may achieve full or partial recovery. Emerging triggers—particularly MWFs—are increasingly recognized as significant contributors due to their biological and chemical components, underscoring the need for stringent workplace safety measures. Crucially, occupational diseases are largely preventable, and regular health surveillance of at-risk workers is essential. To enhance prevention and management, it is imperative to raise physician awareness, develop a national diagnostic guidelines, establish a robust occupational disease reporting system, and implement comprehensive policies, legal frameworks, and standards that prioritize not only diagnosis and compensation but also proactive disease prevention.

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CONFLICT of INTEREST

The author declare that they have no conflict of interest.

AUTHORSHIP CONTRIBUTIONS

Concept/Design: TD, DK

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