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MEDICAL SCIENCES / DAHİLİ TIP BİLİMLERİ

Evaluation of Radiological Abnormalities in Workers Exposed to Heavy Metals and Solvents: A Single-Center Study

Ağır Metal ve Solventlere Maruz Kalan Çalışanlarda Radyolojik Anormalliklerin Değerlendirilmesi: Tek Merkezli Bir Çalışma

Hakan Baş[1], Leyli Can Aynal[2], Özgür Akkale[3], Abdulsamet Sandal[4]

[1]Ankara Gazi Mustafa Kemal Environmental and Occupational Diseases Hospital, Clinic of Radiology, Ankara, Türkiye
[2]Ankara Gazi Mustafa Kemal Environmental and Occupational Diseases Hospital, Clinic of Neurology, Ankara, Türkiye
[3]Ankara Gazi Mustafa Kemal Environmental and Occupational Diseases Hospital, Clinic of Internal Medicine, Ankara, Türkiye
[4]Ankara Gazi Mustafa Kemal Environmental and Occupational Diseases Hospital, Clinic of Occupational Diseases, Ankara, Türkiye

Abstract

Objectives: Heavy metal and solvent exposure is an important occupational hazard that causes serious health problems in industrial workers. This study aimed to evaluate radiological abnormalities in patients diagnosed with occupational heavy metal and solvent toxicity.

Materials and Methods: Retrospectively, 962 male patients between the ages of 18 and 64 who were diagnosed with heavy metal and solvent toxicity between 2018 and 2020 were examined. Radiological evaluations were performed with posterior-anterior chest radiography, high-resolution computed tomography of the thorax, abdominal radiography and abdominal ultrasonography. Abnormal findings were systematically recorded and analyzed.

Results: Emphysema was detected in 29.6% of the patients, hepatosteatosis in 58.1% and osteoporosis in 14.2%. These rates are higher than the rates in the general population. Additionally, 10.2% of patients had a reticulonodular pattern suggestive of pneumoconiosis, while 6.1% had gallbladder polyps.

Conclusion: This study demonstrates severe pulmonary, hepatic, and skeletal abnormalities in workers exposed to heavy metals and solvents. The findings highlight the need for stricter occupational safety regulations, preventive strategies, and regular health screenings for workers at risk. Future studies should focus on prospective studies that include both male and female individuals to understand the long-term effects of these toxic exposures.

Keywords: Occupational exposures, heavy metals, solvents, radiology, fatty liver

Öz

Amaç: Ağır metal ve solvent maruziyeti, endüstriyel çalışanlarda ciddi sağlık sorunlarına yol açan önemli bir mesleki tehlikedir. Bu çalışmada, mesleki ağır metal ve solvent toksisitesi tanısı alan hastalarda radyolojik anormalliklerin değerlendirilmesi amaçlanmıştır.

Gereç ve Yöntem: Retrospektif olarak 2018-2020 yılları arasında ağır metal ve solvent toksisitesi tanısı alan 18-64 yaş arası 962 erkek hasta incelendi. Radyolojik değerlendirmeler posterior-anterior akciğer grafisi, toraksın yüksek çözünürlüklü bilgisayarlı tomografisi, abdominal radyografi ve abdominal ultrasonografi ile gerçekleştirildi. Anormal bulgular sistematik olarak kaydedildi ve analiz edildi.

Bulgular: Hastaların %29,6'sında amfizem, %58,1'inde hepatosteatoz ve %14,2'sinde osteoporoz tespit edilmiştir. Bu oranlar, genel popülasyondaki oranlarından daha yüksektir. Ek olarak, hastaların %10.2'sinde pnömokonyozu işaret eden retikülonodüler patern saptanmış, %6,1'inde ise safra kesesi polipleri bulunmuştur.

Sonuç: Bu çalışma, ağır metallere ve çözücülere maruz kalan çalışanlarda ciddi pulmoner, hepatik ve iskelet sistemi anormalliklerini ortaya koymaktadır. Bulgular, risk altındaki çalışanlar için daha katı iş güvenliği düzenlemeleri, önleyici stratejiler ve düzenli sağlık taramalarına olan

Address for Correspondence/Yazışma Adresi: Hakan Baş
Ankara Gazi Mustafa Kemal Environmental and Occupational Diseases Hospital, Clinic of Radiology, Ankara, Türkiye
E-mail: hakanbas7@outlook.com **ORCID ID:** orcid.org/0000-0001-8641-843X
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ihtiyacı vurgulamaktadır. Gelecekteki çalışmalar, bu toksik maruziyetlerin uzun vadeli etkilerini anlamak için hem erkek hem de kadın bireyleri içeren prospektif araştırmalara odaklanmalıdır.

Anahtar Kelimeler: Mesleki maruziyetler, ağır metaller, solventler, radyoloji, karaciğer yağlanması

Introduction

The rapid development of technology and industrial activities has resulted in a concerning rise in the occurrence of heavy-metal and solvent toxicities, posing significant risks to worker health and safety. Exposure to toxic heavy metals, such as arsenic, cadmium, nickel, mercury, chromium, zinc, lead, and various solvents during industrial processes, such as paint and metal alloy production, can have immediate and long-term health implications (1). Chronic exposure to these substances can result in severe cardiovascular disorders, lung damage, liver damage, peripheral-central neuronal damage, kidney damage, cancer, and diabetes. The toxic effects of heavy metals and solvents are attributed to the production of reactive oxygen species. Chronic heavy metal and solvent toxicity occupational exposure occurs through direct contact, smoke inhalation, and inhalation of aerosols and microparticles. Toxic substances that can be measured in serum in the early stages accumulate in the lungs, kidneys, liver, and central and peripheral nervous systems even after exposure is stopped. The cellular oxidative stress they create here and the important redox enzymes in the oxidative defense mechanism are also affected, adversely affecting cellular energy production and use. Thus, irreversible cell and related organ damage can occur with known apoptosis and necrosis mechanisms. They can cause many disorders such as accelerated atherosclerosis and endothelial damage in the cardiovascular system, damage to alveoli in the lungs, peripheral polyneuropathies, neurodegenerative changes in the central nervous system, tubular necrosis in the kidneys, fatty liver, steatohepatitis, cirrhosis, and hepatocellular cancer (2-9). Exposure to heavy metals and solvents during industrial processes can lead to serious health complications. Despite the known risks, limited research focuses on the radiological manifestations of these toxic exposures. Therefore, this study aims to systematically evaluate radiological abnormalities in affected patients.

Materials and Methods

This study was conducted retrospectively and received approval from the Clinical Research Ethics Committee of the University of Health Sciences Türkiye, Keçiören Training and Research Hospital. from the ethics committee (decision no.: 2012-KAEK-15/2264, date: 23.03.2021) We enlisted the participants who made reference to our institution within 2018 and 2020.

Participants

Patients received outpatient examinations or inpatient diagnosis and treatment at our institution.

The Inclusion Criteria

a) Being aged between 18 and 64

b) Diagnosed with occupational heavy metal or solvent toxicity

The Exclusion Criteria

a) Being under the age of 18 or over the age of 65

b) Patients with missing radiological examinations

Data Sources

Demographic, clinical, and occupational information collected during the research population's hospital admissions, laboratory, and radiology examinations was retrospectively assessed. Radiology records were reviewed for patients with heavy metal or solvent poisoning. The records included posterior-anterior chest X-rays, thorax high-resolution computed tomography (HRCT), direct abdominal radiography, and abdominal ultrasonography. Abnormal radiological findings were recorded. All patients underwent clinical and radiological evaluations to exclude alternative diagnoses, including active or past tuberculosis, interstitial lung disease, and rheumatologic conditions, before attributing findings to occupational heavy metal exposure.

Statistical Analysis

The statistical analysis was conducted using SPSS version 22.0. Continuous variables were represented using the mean value plus or minus the standard deviation, while categorical variables were presented as counts and percentages.

Results

The data of 984 patients admitted with occupational heavy metal and solvent poisoning were evaluated retrospectively. Of the 984 patients, 962 met the study inclusion criteria. Twenty-two patients were excluded from the study due to incomplete radiological examinations. The flowchart is shown in Figure 1.

All the patients were male. The average age is 379± years. Of the 962 patients, 961 (99.8%) were present with lead, 75 (7.8%) with solvent, 625 (64.9%) with manganese, 230 (23.9%) with cadmium, 9 (1%) with chromium, 78 (8.1%) with nickel, 80 (8.3%) with arsenic, 21 (2.2%) with mercury, 73 (7.6%) with

antimony, 31 (3.2%) with molybdenum, 21 (2.2%) with cobalt, 7 (0.7%) with polyaromatic hydrocarbon, 2 (0.2%) with thallium and 7 (0.7%) with zinc.

Smoking was reported in 65.3% (n=628) of patients, and alcohol consumption in 24.5% (n=236). Occupational distribution indicated that 48.5% (n=466) of the patients worked in battery production and recycling facilities, 28.6% (n=275) in ore mining operations, and 22.9% (n=221) in other industries, including paint and metal processing. Patients with comorbidities included 18.6% (n=179) with diabetes and 12.9% (n=124) with hypertension. No history of active or past tuberculosis, nor significant rheumatologic or pulmonary diseases, was identified in the cohort.

Exposure duration varied across the study population. A larger proportion of patients (54.2%, n=521) had been exposed for less than 5 years, 33.6% (n=323) for 5-10 years, and 12.2% (n=118) for more than 10 years.

Morbidity due to occupational heavy metal or solvent exposure and radiological findings of these patients are shown in Table 1. Morbidities such as pneumoconiosis, osteoporosis and hepatosteatosis diagnosed in this study population were derived from clinical notes of hospital-affiliated multidisciplinary occupational diseases health board as being due to chronic occupational exposure to heavy metals and solvents. Pneumoconiosis and osteoporosis were identified in 108 (11.2%) and 136 (14.2%) individuals, respectively. The average age of patients with osteoporosis was 32.5±10.2 years. The most prevalent abnormalities on abdominal ultrasonography were hepatomegaly (254, 26.4%), hepatosteatosis (560, 58.1%), and gallbladder polyps (58, 6.1%).

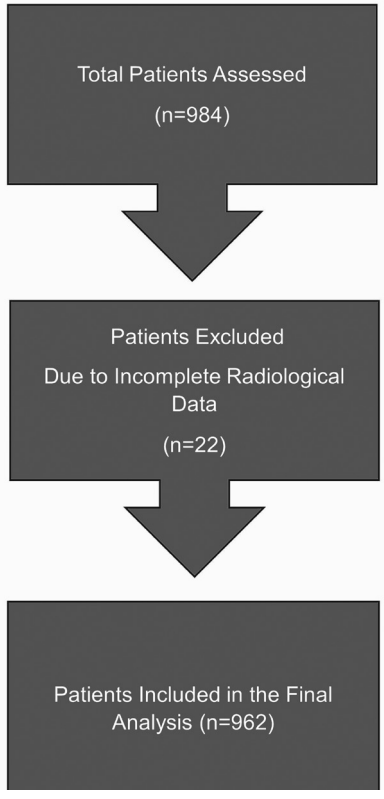

Figure 1: The flowchart of the study

Discussion

Our study examines radiological anomalies in patients with occupational heavy metal and solvent toxicity, revealing some differences from findings in the general population. It emphasizes the effects of persistent exposure to toxicants on several organ systems, particularly the respiratory and hepatic systems.

Clinically, 11.2% of the study population had a diagnosis of pneumoconiosis. Chest X-ray findings revealed a reticulonodular pattern in 10.2% of patients, while HRCT identified pulmonary nodules in only 1.1% of cases. This highlights a significant discrepancy. The relatively high prevalence of reticulonodular patterns observed on chest X-rays may be attributed to the low specificity of this imaging modality, as it can detect non-specific changes that are not necessarily related to pneumoconiosis or occupational exposure. Furthermore, the absence of comprehensive studies evaluating the prevalence of reticulonodular patterns in the general population adds to the complexity of interpreting these findings. This limitation makes it challenging to definitively attribute these patterns to occupational exposure. Future studies incorporating HRCT and larger control groups are necessary to improve our understanding of the diagnostic accuracy and specificity of these imaging modalities in the context of occupational lung diseases (10).

HRCT findings, such as apical fibrosis, were evaluated alongside patients' clinical histories. The absence of active or past tuberculosis, interstitial lung disease, or other significant pulmonary conditions was confirmed during the diagnostic process, supporting the attribution of findings and comorbidities to occupational heavy metal exposure. HRCT scans provided further information on lung findings. While emphysema was observed in 29.6% of the study population, determining whether this finding is predominantly attributable to occupational heavy metal exposure or smoking is challenging. The high smoking rate among participants (65.3%) suggests that both factors may have contributed, acting either independently or synergistically. Future studies with detailed exposure assessments and smoking-independent control groups are needed to clarify the primary drivers of emphysema in this population.

Radiology plays a crucial role in diagnosing pulmonary pathologies in workers exposed to heavy metals and solvents, as these exposures can lead to various occupational lung

diseases. The imaging features of these diseases are often complex and require a comprehensive understanding of the patient's occupational history and exposure details to interpret radiographic accurately and CT findings (11,12). HRCT is particularly effective in identifying parenchymal, airway, and pleural abnormalities associated with these conditions, surpassing traditional chest radiography in diagnostic accuracy (13). Exposure to heavy metals such as cadmium, manganese, and nickel can result in acute conditions like chemical pneumonitis and pulmonary edema, as well as chronic diseases

Table 1: Morbidity due to occupational heavy metal or solvent exposure and radiological findings of the patients*

		n, (%)
Morbidities	Cerebrovascular disease	2 (0.2)
	Hypertrophic cardiomyopathy	9 (1.0)
	Pneumoconiosis	108 (11.2)
	Osteoporosis	136 (14.2)
Chest X-ray findings	Reticulonodular pattern	98 (10.2)
	Solitary nodule	24 (2.5)
	Cardiothoracic index >0.5	12 (1.3)
	Pericardial fat pad	22 (2.3)
	Prominent aortic knob	47 (4.9)
	Hilar enlargement	3 (0.3)
	Elevated diaphragm	4 (0.5)
Abdomen X-ray findings	Phlebolith	6 (0.6)
HRCT findings	Fibrosis	14 (1.5)
	Apical fibrosis	21 (2.2)
	Vascular variations	3 (0.3)
	Nodule	11 (1.1)
	Respiratory bronchiolitis	42 (4.3)
	Bronchial wall thickening	30 (3.1)
	Mucus impaction	18 (1.8)
	Atelectasis	14 (1.5)
	Vertebral degeneration	264 (27.4)
	Cardiomegaly	69 (7.2)
	Aortic atherosclerosis	3 (0.3)
	Emphysema	285 (29.6)
	Diaphragm elevation	8 (0.8)
Abdominal US findings	Hepatomegaly	254 (26.4)
	Hepatosteatosis	560 (58.1)
	Area separated by fat	22 (2.3)
	Gallstone	10 (0.1)
	Gallbladder polyp	58 (6.1)
	Splenomegaly	15 (1.6)
	Accessory spleen	11 (1.1)
	Kidney stone	40 (4.1)
	Renal cyst	31 (3.2)
	Increased renal parenchyma echogenicity	8 (0.8)
	Hydronephrosis	7 (0.7)
	Pyelonephritis sequela	9 (0.9)

*An individual may present with more than one morbidity or finding
HRCT: High-resolution computed tomography, US: Ultrasound

such as emphysema and pulmonary fibrosis (14). For instance, cadmium exposure is linked to emphysema, while cobalt exposure can lead to hard metal lung disease characterized by interstitial pneumonitis. Additionally, certain metals like arsenic, chromium, and nickel are recognized lung carcinogens, contributing to a significant proportion of occupational lung cancer cases (14). The accurate diagnosis of these conditions is critical, as misdiagnosis can lead to irreversible health outcomes, underscoring the importance of radiologists and clinicians being adept at recognizing both common and uncommon imaging features of occupational lung diseases (11).

Abdominal ultrasonography revealed a high prevalence of hepatosteatosis (58.1%) in the study population, which significantly exceeded the prevalence reported in the general population, which ranges from 20% to 30% depending on risk factors such as obesity and diabetes (15). This high prevalence in our study population highlights the hepatotoxic potential of heavy metals and solvents, as the liver is the primary detoxification organ exposed to these toxins (15). This high prevalence in our study population highlights the hepatotoxic potential of heavy metals and solvents, as the liver is the primary detoxification organ exposed to these toxins. Chronic exposure to heavy metals can disrupt lipid metabolism and promote oxidative stress, leading to fat accumulation in hepatic cells (16).

Gallbladder polyps were detected in 6.1% of patients, a remarkable finding considering their relatively low prevalence in the general population (17). In the context of heavy metal and solvent exposure, the formation of gallbladder polyps may be related to chronic inflammation and cellular proliferation driven by toxic insults to the biliary epithelium. These processes may lead to the development of benign neoplastic growths. Follow-up, perhaps over many years, is needed to understand the proportion of these polyps progressing to malignancy. Figure 2 displays an ultrasonographic image of numerous polyps in the gallbladder of a patient who has lead poisoning.

Exposure to heavy metals and solvents has been linked to an increased risk of osteoporosis, as evidenced by multiple studies. Heavy metals such as cadmium and lead have been shown to negatively impact bone mineral density (BMD), contributing to conditions like osteopenia and osteoporosis. A systematic review and meta-analysis found that cadmium exposure significantly increased the risk of these conditions, particularly in older adults and men, while lead exposure was more pronounced in men (18). Additionally, a study using data from the National Health and Nutritional Examination Surveys highlighted a strong positive relationship between blood cadmium levels and the prevalence of osteoporosis (19). The molecular mechanisms underlying these effects involve the deregulation of detoxifying enzymes, as seen in osteoporotic patients with elevated plasma levels of heavy metals like copper and lead, which correlate with altered gene expression patterns (20). Furthermore, environmental pollutants, including heavy metals and solvents, have been identified as modifiable risk factors for osteoporosis, emphasizing the need for improved environmental policies to mitigate these risks (21). The prevalence of osteoporosis (14.2%) in this relatively young cohort (mean age 32.5 years) is of particular concern. Osteoporosis is commonly seen in older adults and postmenopausal women, but in our study it appears to be directly linked to toxic exposure. Heavy metals such as lead and cadmium can interfere with bone metabolism by disrupting calcium homeostasis and promoting osteoclast activity while inhibiting osteoblast function (22). It may result in decreased BMD and increased fracture risk, as evidenced by the high incidence of osteoporosis among exposed workers.

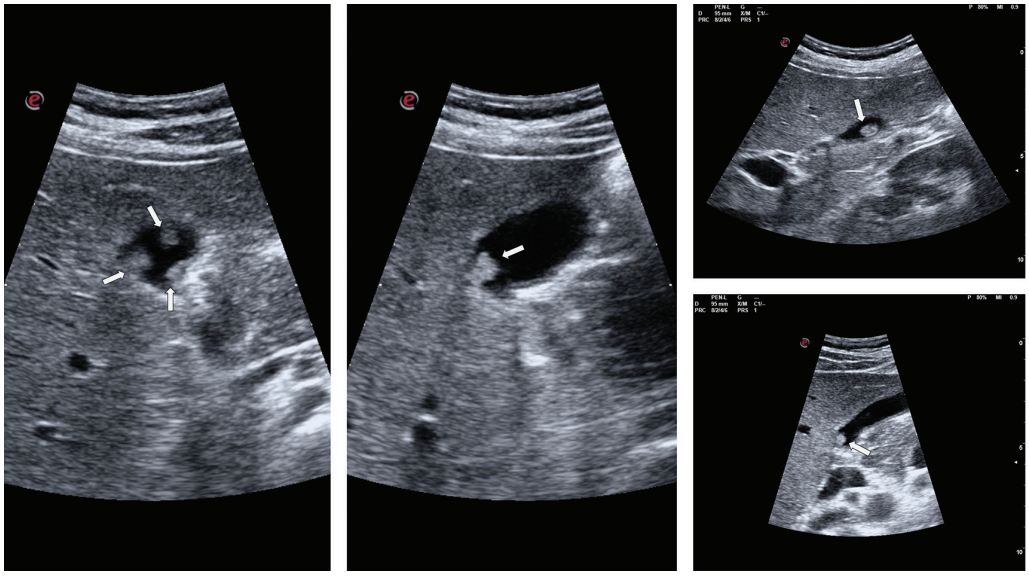

Figure 2: Ultrasound images of gallbladder polyps. These images show polyps in the lumen of the gallbladder in different lead-exposed workers (arrows)

A notable aspect of our study is that all patients were male. This gender homogeneity likely reflects the workforce's demographic makeup in traditionally male-dominated industries with high exposure to heavy metals and solvents. However, this introduces a potential bias and limits the generalizability of our findings to female workers, who may experience different health effects from similar exposures. Women may have different physiological responses to toxic exposures, influenced by factors such as hormonal differences and changing body fat composition that may affect the distribution and storage of toxicants. Future research should aim to include female workers to provide a more comprehensive understanding of occupational health risks associated with heavy metal and solvent exposure.

Study Limitations

The study had several limitations. The study's retrospective nature may have introduced biases regarding the completeness and accuracy of the recorded data. Some relevant clinical or exposure details may not have been adequately documented. Furthermore, the fact that the study was conducted at a single center may limit the generalizability of the findings to other populations or geographic areas. The study did not provide longitudinal follow-up, which would have been valuable in understanding the progression and long-term outcomes of the identified radiological abnormalities.

Conclusion

In conclusion, our study demonstrates significant radiological abnormalities among workers exposed to heavy metals and solvents, revealing substantial impacts on pulmonary, hepatic, and skeletal systems. These findings emphasize the critical need for targeted preventive strategies and comprehensive occupational health measures to protect workers in high-risk industries. The observed abnormalities underline the importance of early detection and systematic health evaluations to mitigate the health consequences of prolonged toxic exposures. The study's retrospective design, single-center focus, and lack of longitudinal follow-up are notable limitations that may affect the generalizability and depth of the findings. Future research should prioritize prospective, multi-center studies with diverse populations, including both male and female workers, to provide a more nuanced understanding of these exposures' effects. Additionally, integrating long-term follow-up and well-matched control groups will be essential to delineate the direct impacts of occupational exposure from other contributing factors.

Ethics

Ethics Committee Approval: This study was conducted retrospectively and received approval from the Clinical Research Ethics Committee of the University of Health Sciences Türkiye, Keçiören Training and Research Hospital (decision no.: 2012-KAEK-15/2264, date: 23.03.2021).

Informed Consent: Informed consent was not obtained since it was a retrospective study.

Footnotes

Authorship Contributions

Surgical and Medical Practies: H.B., A.S., Concept: H.B., L.C.A., Ö.A., A.S., Design: H.B., L.C.A., Ö.A., Data Collection and Processing: H.B., L.C.A., A.S., Analysis or Interpretation: H.B., L.C.A., Literature Search: H.B., Ö.A., A.S., Writing: H.B.

Conflict of Interest: According to the authors, there are no conflicts of interest related to this study.

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