ORIGINAL ARTICLE *Turkish Respiratory Journal* 2006; 7(2): 52-55

Occupational and Environmental Lung Diseases

High-resolution Computed Tomography Findings in Arc-welders

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Abstract

Background: Welding work is associated with exposure to various fumes and gases that are potentially harmful to the respiratory system. **Objective:** To describe high-resolution computed tomography (HRCT) findings in arc-welders. **Materials and Methods:** The study involved 36 arc-welders and 26 officers as the control group. Arc-welders with a history of 2-to-30 years' exposure and control subjects underwent HRCT scanning. The welders were grouped according to their smoking habits (smokers, n=14; non-smokers, n=22). HRCT findings of both groups were compared. **Results:** Predominant HRCT findings in the arc-welders were poorly-defined centrilobular micronodules (31/36, 86.1%) and branching linear structures (17/36, 47.2%). Poorly-defined centrilobular micronodules were found in 12 (85.7%) patients in the smokers subgroup, and 19 (86.4%) patients in the non-smokers subgroup. The branching linear structures were found in 7 (50.0%) patients in the smokers subgroup, and 10 (45.5%) patients in the non-smokers subgroup. Ground-glass pattern was not observed in either of the two subgroups. Moreover, no difference was found in CT abnormalities between these two subgroups. In the control group, poorly-defined centrilobular micronodules were found in 14 (53.8%) subjects, but branching linear structures and ground-glass pattern were not observed. Differences in CT abnormalities were significant between arc-welders and controls (p=0.005). There was no significant relationship between pulmonary function tests and spread of micronodules (FEV_1% r=-0.10, p=0.6; FVC% r =-0.08, p=0.6) and welding duration (FEV_1% r =-0.09, p=0.6; FVC% r =-0.21, p=0.2). **Conclusion:** Poorly-defined centrilobular micronodules and branching linear structures were the most frequently seen HRCT abnormalities in arc-welders. Occurrence of these similar findings less frequently and intensely in non-smoker control subjects requires the investigation of other potentially causative inhalants.

Keywords: arc-welders, high-resolution computed tomography, welding fumes

Received: June 20, 2006 Accepted: July 06, 2006

INTRODUCTION

Welding refers to any process of joining pieces of metal at joint faces that have been made soft or liquid by heat and/or pressure [1]. Welding work is associated with exposure to various fumes and gases that are potentially harmful to the respiratory system [2]. Inhaled gases from welding fumes may vary depending on the method employed and the materials used. The chemical properties of welding fumes can be quite complex. Most welding materials are alloy mixtures of metals, commonly iron, manganese, chromium, and nickel [3]. Much of the fume created from welding is made up of particles less than 1μm in aerodynamic diameter, giving them a high probability of being deposited in terminal bronchioles or alveoli, where rapid clearance by the mucociliary system is not effective [1]. Welders' pneumoconiosis, which is caused by inhalation of iron oxide fumes, is known as welders' siderosis [1,4,5]. Although the thin-section computed tomography (CT) findings of welders' pneumoconiosis had been well described [4-6], the studies comparing those of a control group with the high-resolution computed tomography (HRCT) findings of welders are scarce. The purpose of this study was to describe the HRCT findings of arc-welders and compare with normal controls.

METHODS

The study was carried out on arc-welders (n=36) performing welding operations in the industrial area of Kırıkkale city and a non-smoker control group (n=26). All the welders were men and their work shift was 8 hrs/day, 6 days/week. A history of exposure to welding fumes was available for 36 individuals, its duration ranging from 2 to 30 years. All subjects in the control group were officers who attended the hospital for a check-up. Chronic respiratory symptoms were recorded using the Modified British Medical Research Council questionnaire on respiratory symptoms [7]. It included the usual questions about cough, phlegm, shortness of breath, wheezing, and chest tightness. Detailed occupational history, the presence or not of protective device, and smoking habits of all the welders were recorded. The welders were grouped according to their smoking habits (smokers, n=14; non-smokers, n=22). Lung-function testing was performed in all welders and controls with a portable spirometer (MIR Spirobank, Italy) according to the recommendation of the American

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Table 1. Characteristics of welders and control subjects*

	Welders (n=36)	Controls (n=26)	P value
Age (year)	41.67±12.71	46.92±6.66	NS
FEV_1/FVC	84.70±10.70	87.50±12.03	NS
$FEV_1\%$	105.61±18.54	112.43±26.84	NS
FVC %	104.07±20.24	107.62±20.93	NS
FEF_{25-75}	91.02±28.10	112.26±44.41	0.03

*Data are given as mean± SD, NS: Not significant.

Thoracic Society [8]. Forced expiratory volume in one second (FEV_1), forced vital capacity (FVC), peak expiratory flow (PEF) and 25%–75% forced expiratory flow (FEF_{25-75}) were measured, and the best value of three maneuvers was expressed as a percentage of the predicted value.

High-resolution computed tomography (HRCT)

All subjects in both the welder and control groups underwent thin-section CT, performed using a Picker SeleCT (Haifa, Israel) in high-resolution mode according to the method of Mayo and colleagues [9]. The matrix size was 512x512 and the scanning time 2.1s. The patients were examined in the supine position during full deep inspiration, with their arms held over their heads. Images were recorded at a window width of 1,600 HU and at a window level of -600 HU. Section cuts of 1.5 mm thickness at 10 mm increments were obtained throughout the lungs. HRCT scans were assessed independently by two pneumologists and two radiologists, and final conclusions were reached by consensus. Findings were classified as poorly-defined centrilobular micronodules, branching linear structures, or ground-glass attenuation. Poorly-defined centrilobular micronodules were defined as those showing fuzzy centrilobular round opacity no greater than 7 mm in diameter, and 2-3 mm apart from the interlobular septae or pleural surface [10]; branching linear structures as poorly-defined X- or Y-shaped centrilobular densities which did not taper peripherally as normal bronchovascular structures; and ground-glass attenuation as poorly-defined opacity greater than 7 mm in diameter which did not obliterate the parenchymal architecture. In each subject, the predominant pattern as well as its vertical and horizontal distribution was analyzed. Vertical distribution referred to whether the findings were observed predominantly in the upper lung zone (above the carina) or the lower (below the carina). Horizontal distribution referred to whether they were noted predominantly in the peripheral lung zone (less than 3 cm from the parietal pleura) or the central (more than 3 cm from the parietal pleura) [5].

Statistical Analysis

Data were analyzed using the SPSS version 9.0. Data were expressed as mean ± SD. For comparisons of continuous variables a Student's t-test was performed. The chi-square test (or Fisher's exact test when appropriate) was used for testing differences between groups. A p value less than 0.05 was considered statistically significant.

Table 2. HRCT findings in welders and control subjects

	Welders n:36 (%)	Control n:26 (%)	OR	95%CI	P value*
Centrilobular micronodules	31 (86.1)	14 (53.8)			0.005
Upper zones	18 (50.0)	4 (15.4)	5.5	1.5 to 19.1	0.005
Lower zones	27 (75.0)	12 (46.2)	3.5	1.1 to 10.2	0.02
Central distribution	26 (72.2)	8 (30.8)	5.8	1.9 to 17.6	0.001
Peripheral distribution	24 (66.7)	8 (30.8)	4.5	1.5 to 13.2	0.005
Branching linear structures	17 (47.2)	0			0.0001
Upper zones	5 (13.9)	0	0.5	0.4 to 0.6	0.04
Lower zones	15 (41.7)	0	0.4	0.3 to 0.6	0.0001
Central distribution	0	0			NS
Peripheral distribution	17 (42.2)	0	0.4	0.3 to 0.5	0.0001
Ground-glass attenuation	0	0			
Upper zones	0	0			
Lower zones	0	0			
Central distribution	0	0			
Peripheral distribution	0	0			
Emphysema	1	1	NS		

*Statistical significance for the comparison between welders and control subjects, NS: Not significant.

Table 3. HRCT findings of smoking and nonsmoking welders

	Welders		
	Smokers n: 14 (%)	Nonsmokers n: 22 (%)	p value
Centrilobular micronodules	12 (85.7)	19 (86.4)	NS
Branching linear structures	7 (50.0)	10 (45.5)	NS
Ground-glass attenuation	0	0	NS

NS: Not significant.

RESULTS

This study involved welders (n=36) and officers (n=26) as a control group. All welders and control subjects were men and their mean ages were 41.6±12.7 and 46.9±6.6 years, respectively. The range of duration of exposure to welding fumes in the arc-welders group was 2-30 years (mean 14.69.±7.49 years). The welders were grouped according to their smoking habits (smokers, n=14; nonsmokers, n=22). The range of smoking in the smokers group was 10-26 pack-years (mean 13.8 pack-years). All subjects in the control group were lifelong non-smokers. Only seven welders used a mask during the work shift. Descriptive characteristics of the subjects analyzed are shown in Table 1.

Cronbach's alpha of concordance of four different readers was 0.79.

Predominant HRCT findings in the arc-welders were poorly-defined centrilobular micronodules (31/36, 86.1%) and branching linear structures (17/36, 47.2%). In the control group, poorly-defined centrilobular micronodules were found in 14 (53.8%) patients; branching linear structures and ground-glass pattern were not observed. A significant difference was found between CT abnormalities of arc-welders and those of controls (p=0.005) (Table 2).

In the smokers subgroup, poorly-defined micronodules were found in 12 (85.7%) patients and branching linear structures in 7 (50.0%) patients. In the non-smokers subgroup, poorly-defined micronodules were found in 19 (86.4%) patients and branching linear structures in 10 (45.5%) patients. Ground-glass pattern was not observed in the smoker and non-smoker subgroups. No significant difference was found between CT abnormalities of the two subgroups (p>0.05) (Table 3).

Other nonspecific HRCT findings in welders included pleural thickening (n=8), bronchial dilatation or wall thickening (n=8), subpleural lines (n=3), localized bronchiectasis (n=2), localized stable tuberculous lesions (n=2), subpleural nodules (n=2), localized emphysema (n=1), calcified hilar lymphadenopathy (n=1), calcified nodules (n=1), and fibrotic linear bands (n=1).

Table 4. Intercorrelation between pulmonary function tests, spread of micronodules, and welding duration in welders

	FEV1% (r)	p	FVC% (r)	p
Spread of micronodules	-0.10	0.6	-0.08	0.6
Welding duration	-0.09	0.6	-0.21	0.2

r: Pearson's correlation.

We found no significant relationship between pulmonary function tests and spread of micronodules (FEV_1% r=-0.10, p=0.6; FVC% r =-0.08, p=0.6) and welding duration (FEV_1% r =-0.09, p=0.6; FVC% r =-0.21, p=0.2) in welders (Table 4).

DISCUSSION

In this study, predominant HRCT findings in arc-welders were poorly-defined centrilobular micronodules and branching linear structure diffusely distributed in the lung. Ground-glass pattern was not observed in either of the groups. Emphysema was observed in one case in each group. The case with emphysema in welders belonged to the subgroup of smokers. The occurrence of poorly-defined centrilobular micronodules in the control group as well suggests that the pathogenesis of the lesions in this group may be different from that in the welders. However, the occurrence of these structures in welders more diffusely and intensely shows the causal relationship between fumes and CT findings. As poorly-defined centrilobular micronodules may occur due to other reasons, the investigation of their possible causes will clarify this issue. Radiologic evaluation may be performed according to the ILO International Radiological Classification of Pneumoconiosis, but our scores were also seen as appropriate according to previous publications.

This iron oxide pneumoconiosis in welders is known as welders' siderosis [1]. Siderosis is a radiological disorder which manifests itself by the presence of small, very radio-dense opacities with uniform distribution throughout the lungs [11]. These nodular densities are due to deposition of minute iron oxide particles in the perivascular and peribronchial lymphatics. These inert particles lie in these lymphatics and the lymphoid tissues of the lung without causing local fibrosis of the pulmonary parenchyma. When the exposure to the fumes is discontinued, this particulate matter may be removed with eventual clearing of the roentgenographic densities in the lungs [12]. Pure siderosis is not associated with respiratory symptoms or functional impairment, and does not predispose to tuberculosis [11].

In a previous study by Akira [6], ill-defined centrilobular micronodules were identified in thin- section CT in 71% (15 of 21) of arc-welders and were described to reflect

the deposition of minute iron oxide particles along perivascular and peribronchial lymphatic vessels. Another study by Han et al. [5] also reported that ill-defined centrilobular micronodules are frequently observed findings in thin-section CT in welders' pneumoconiosis. They thought that these findings can be explained by the presence of pigmented macrophages in air spaces and interstitium close to the center of the acinus, with occasional fibrosis around pigmented deposits in these areas, which was demonstrated by previous studies. In addition, they detected positive thin-section CT findings in 14% (6 of 43) of subjects in their smoker control group, the predominant findings being poorly-defined micronodules in four, branching linear structures in one, and ground-glass attenuation in one subject. These and the present findings appear similar to those of smoker's lung [13]. However, the findings in our study were thought to represent the effects of exposure to welding and were not the results of smoking because there was no difference between the smoking and nonsmoking subgroups of welders. In addition, the presence of pathologic findings in the non-smoking control group in the present study suggests that inhalants other than welder smoke may cause similar findings. Furthermore, in detailed anamnesis of control subjects with similar pathologic findings, we could not detect any smoke inhalation that may have caused these HRCT findings. However, it should be realized that similar findings may occur due to various causes and this issue should be further investigated in wider populations.

In conclusion, predominant thin-section CT findings in the arc-welders are poorly-defined centrilobular micronodules and branching linear structure diffusely distributed in the lung. Occurrence of similar CT findings, less intensely and frequently in the non-smoker control group, requires the investigation of other inhalants that may cause these findings.

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