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Systemic inflammatory responses following welding inhalation challenge test

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ABSTRACT

Aim: The aim of this study was to investigate inflammatory and respiratory responses to welding fume exposure in patients with suspected occupational asthma.
Methods: Sixteen patients referred to the Finnish Institute of Occupational Health underwent mild steel (MS) and stainless steel (SS) welding challenge tests, due to suspicion of OA. Platelet count, leucocytes and their differential count, hemoglobin, sensitive CRP, lipids, glucose and fibrinogen were analyzed in addition to interleukin (IL)-1β, IL-6, IL-8, TNF-α, endothelin-1, and E-selectin in plasma samples. Peak expiratory flow (PEF), forced expiratory volume in 1 min (FEV_1) and exhaled nitric oxide (NO) measurements were performed before and after the challenge test. Personal particle exposure was assessed using IOM and a mini sampler. Particle size distribution was measured by an Electric Low Pressure Impactor (ELPI).
Results: The number of leukocytes, neutrophils, and platelets increased significantly, and the hemoglobin level and number of erythrocytes decreased significantly after both the MS and SS exposure tests. Five of the patients were diagnosed with OA, and their maximum fall in FEV_1 values was 0.70 l (±0.32) 4 h after SS exposure. MS welding generated an average inhalable particle mass concentration of 31.6, and SS welding of 40.2 mg/m^3. The mean particle concentration measured inside the welding face shields by the mini sampler was 30.2 mg/m^3 and 41.7 mg/m^3, respectively.
Conclusions: Exposure to MS and SS welding fume resulted in a mild systemic inflammatory response. The particle concentration from the breathing zones correlated with the measurements inside the welding face shields.

1. Introduction

Welding is a process that joins material, usually metals or alloys, by using heat and/or compression. Welders are exposed to fumes containing different gases and particles, depending on the composition of the welding electrodes,

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welded material, and the welding method used. Welding particles include both fine (0.1–2.5 μm) and ultrafine particles (< 0.1 μm) [1].

Welding fume exposure has been associated with several adverse health outcomes such as chronic bronchitis, pneumonia, metal fume fever, lung function changes, and a possible elevated risk of lung cancer and death from ischemic heart disease [2–8]. In addition, population-based studies have shown that welders are at an almost twofold risk of developing asthma [9,10]. Moreover, other epidemiological studies have indicated that exposure to welding fumes may indeed be a direct cause of asthma [11,12]. Some case series have revealed occupational asthma (OA) in workers exposed to stainless steel welding fumes in particular [13–15].

The underlying mechanisms responsible for these cardiorespiratory effects are largely unknown. One line of research has investigated the possible association between welding fume exposure and acute systemic inflammatory responses [16–18]. The hypothesis is that short-term exposure to welding fumes may induce a local as well as systemic inflammatory reaction, which may be responsible for chronic lung and cardiovascular disease if the exposure persists for a long time [18]. In our own recent study [19], welding fumes, as well as dusts and fumes from sheet metal work, caused a slight acute inflammation during a work shift in actual workplace conditions.

The aim of the present study was to further investigate, on the basis of prior studies, whether short exposure to high concentration of welding fumes is capable of inducing acute effects on hematological, systemic inflammatory and respiratory parameters by following welding challenge test in patients with suspected OA.

2. Subjects and methods

2.1. Study subjects

The study consisted initially of 18 patients who were referred to the Finnish Institute of Occupational Health (FIOH) by pulmonologists of local central hospitals or by physicians of local occupational health units from all over Finland in 2007. Sixteen of the patients had been diagnosed with asthma previously and two patients had asthma like symptoms but not specific diagnosis of asthma; all patients were suspected of having OA caused by welding fumes. One patient was excluded from the study because his exposure tests were not performed on consecutive days, and another was excluded because he was given medication during the study which may have affected the blood results. Therefore, the final study population comprised 16 participants. They were all male, and worked as welders ($N = 7$), sheet metal workers ($N = 7$), assemblers ($N = 1$) and metal workers ($N = 1$). All of them were exposed to welding fumes in their work regardless of their occupational title. Asthma medication was discontinued before testing at FIOH.

2.2. Study protocol

Welding challenge tests were performed in a special welding chamber (6 m^3). Fifteen of the participants were exposed to mild steel (MS) (control test) and stainless steel (SS) welding fumes on consecutive days as described earlier for suspicion of OA [15]. One subject was exposed to MS welding fumes only. The manual metal arc welding (MMAW) exposure time was 30 min. During the exposure, five rods were consumed in the MS control test (OK 48.00; ESAB AB, Gothenburg, Sweden) and 11 rods in the ST welding test (OK 63.30; ESAB AB, Gothenburg, Sweden) [14].

OA was diagnosed according to European guidelines [20]. Study participants were monitored for 24 h after each challenge.

Altogether five venous blood samples (one blood sample before each of the challenge tests and one blood sample after each of the challenge tests and the fifth one on the next day after the tests) were taken from each of the subjects (Fig. 1). Baseline measurements of peak expiratory flow (PEF), forced expiratory volume in 1 min (FEV_1), and exhaled nitric oxide (NO) were performed before MS exposure, and then approximately 22 h after the MS and SS exposure. Each participant gave written informed consent and filled in a questionnaire concerning work and exposure history, smoking habits, lung and cardiovascular disease history, and medication. The study protocol was approved by the Ethics Committee of the Hospital District of Helsinki and Uusimaa.

2.3. Hematological and systemic inflammatory analyses

The concentrations of interleukin (IL)-1β, IL-6, IL-8, tumor necrosis factor alpha (TNF-α), endothelin-1, and E-Selectin in the plasma samples were determined by enzyme immunoassay (EIA) using commercial reagents: IL-1β (sensitivity 0.063 pg/ml) and TNF-α (sensitivity 0.125 pg/ml), Quantikine HS ELISA, R&D Systems Europe Ltd., Abindgon, UK; IL-6 (sensitivity 0.6 pg/ml), Peli-Pair ELISA, Sanquin, Amsterdam, the Netherlands; IL-8 (sensitivity 1.56 pg/ml), Opt EIA, BD Biosciences, Erembodegem, Belgium; endothelin-1 (sensitivity 0.68 pg/ml), QuantiGlo ELISA, R&D Systems Europe Ltd., Abindgon, UK; E-Selectin (sensitivity 20.5 pg/ml), ELISA, HyCult Biotechnology, Uden, the Netherlands).

Platelet count, leucocytes and their differential count, hemoglobin, haematocrit, sensitive C-reactive protein (CRP), lipids, glucose, and levels of fibrinogen were analyzed using established methods.

All laboratory analyses were performed blind to the exposure status of the studied participants.

2.4. Respiratory measurements

A portable, pocketsize spirometer (One Flow, STI MEDICAL, Saint-Romans, France) recorded the lung function measurements (PEF, FEV_1), and a decrease of 20% in PEF or FEV_1 from the baseline value was regarded as significant [21].

Exhaled NO was measured using a chemiluminescence gas analyzer (NIOX, Aerocrine AB, Solna, Sweden),