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Original Research

Occupational exposure to welders' flame could predispose to macrocytic anemia in welders in Nnewi, South East Nigeria

Nancy Ibeh[1], John Aneke[2], Chide Okocha[2], Emmanuel Obeagu[3]

[1]Department of Medical Laboratory Science, College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria, [2]Department of Haematology, Nnamdi Azikiwe University Teaching Hospital, Nnewi, Anambra State, Nigeria, [3]Department of Medical Laboratory Science, Michael Okpala University, Umuahia, Abia State, Nigeria

Address for correspondence:
John Aneke, Department of Haematology, Nnamdi Azikiwe University Teaching Hospital, Nnewi, Anambra State, Nigeria.
E-mail: anekejc@ymail.com

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ABSTRACT

Background: Welders' flame is known to contain some deleterious components which could be of potential occupational health importance. **Objective:** To evaluate the effects of occupational exposure to welders' flame on hematological indices in a population of welders in Nnewi, Nigeria. **Subjects and Methods:** A total of 100 subjects were randomly selected, comprising 50 apparently healthy welders and controls, respectively. Subjects were further stratified into those that consumed alcohol and/or tobacco products and those who did not. About 3 ml of venous blood was collected from each participant and dispensed into po tassium-ethylenediaminetetraacetic acid containers for full blood count determination. This was performed using the Sysmex® automated hematology analyzer, **Model Number:** PCE 210. Results were expressed as means ± standard deviation while the student's *t*-test was used for comparison of means; *P* was significant at <0.05. **Results:** The absolute blood monocyte and eosinophil counts, mean cell volume (MCV), mean cell hemoglobin (MCH), and MCH concentration were significantly higher in welders compared with controls while the white cell, absolute neutrophil, absolute eosinophil, and platelet counts were significantly increased in study subjects with longer duration of exposure ($P < 0.05$). The packed cell volume and hemoglobin concentration were significantly lower, while the MCV was significantly higher in study subjects who consumed alcohol, compared to those who did not ($P < 0.05$). **Conclusion:** Occupational exposure to welders' flame could lead to macrocytic anemia.

KEY WORDS: Alcohol consumption, macrocytic anemia, occupational health, welders' flame

INTRODUCTION

Oxyacetylene is a mixture of oxygen and acetylene gas, used as a fuel for making hot flame that welds and cuts metals; it is the reaction of acetylene with oxygen in the welding process that produces the oxyacetylene gas. It is unstable in the pure form and is usually handled as a solution [1]. Pure acetylene is odorless, but commercial grades usually have marked odor due to impurities.

Oxyacetylene welding (oxy-fuel welding, oxy metal welding, or gas welding) refers to the processes that use fuel gases and oxygen to weld metals. Pure oxygen instead of air is used to increase the flame temperature to allow localized melting of the work piece material (e.g., steel), Acetylene (ethyne) is a hydrocarbon of the alkyne family with the chemical formula of C_2H_2. It is commonly prepared by the hydrolysis of calcium carbide, a reaction discovered by Friedrich Wöhler;

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2$$

A welder or welder operator is a tradesman who specializes in joining materials (which are commonly metals) together using flame. The welders' flame contains toxic, mutagenic compounds such as phosphine, arsine, and carbon mono oxide gases. The observed effects of prolonged exposure to this flame are attributable to the combined effects of its constituent gases; while phosphine and arsine cause oxidation of hemoglobin (Hb), red blood cell membrane fragility and ultimately hemolytic anemia, carbon mono oxide acts as Hb "poison" leading to reduced oxygen carrying capacity, hypoxia, and secondary polycythemia [2,3]. Considering

the potential health hazards associated with the welding occupation, coupled with the fact that information on this is very scarce (particularly in South-East Nigeria), this study investigated the effects of occupational oxyacetylene blowpipe gas exposure on some hematological indices of welders in South-East Nigeria.

SUBJECTS AND METHODS

Research Design

This is a cross-sectional study designed to assess the effect of exposure to welders' flame on hematological parameters. The subjects were selected using simple random sampling technique while relevant data were obtained from the participants using questionnaires.

Subject Selection

The participating subjects included consenting adult individuals whose job was primarily automobile welding with average exposure time of between 8 and 12 h of each work day. None of the study subject had any injury (such as skin or eye injury) which was related to the welding activity at the point of recruitment. Apparently, healthy nonwelders who were not on any medications capable of altering hematological parameters and who equally consented to be included in the study were recruited as controls.

Inclusion Criteria

1. Subjects between the ages of 18 and 55 years.
2. Subjects must have spent at least 1 year on the welding occupation.
3. Subjects must spend at least 8 h of work daily at the welding workshop.

Exclusion Criteria

1. Patient who use personal protective equipment (PPE), either currently or in the past.
2. Patient on treatment for any hematological condition (such as hemoglobinopathies) or on medications that are known to precipitate red cell lysis or suppress the bone marrow.
3. Patient with a current or history of jaundice or passage of coca-cola colored urine.
4. Patient, who had any symptom of ill health (particularly fever), had donated blood or received a blood transfusion in the 3 months preceding recruitment.
5. Control subjects with history of significant alcohol consumption.

Study Area

The study was conducted in Nnewi, Anambra State in South-Eastern Nigeria. The official languages spoken by the people were Igbo and English. Nnewi is the second largest city in Anambra State and it is a metropolitan city which encompasses four local government areas, Nnewi North, Nnewi South, Ekwusigo and Ihiala Local Governments; Nnewi North was the study site and comprises of four autonomous communities; Otolo, Uruagu, Umudim, and Nnewi-ichi.

Study Population

A total of 100 subjects were randomly selected for the study, comprising 50 welders who formed the study group and 50 healthy individuals who served as the control group. The study subjects were age-matched with the controls so as to remove any potential confounding effects of age on measured parameters. Subjects were further stratified into those that consumed alcohol and/or tobacco products and those who did not with a view to highlighting the influence(s) of these on occupational exposure. Significant alcohol intake was regarded as consumption of at least 280 g/week of alcohol [4].

Sample Collection

About 3 ml of blood was collected aseptically from the antecubital vein of each participant by venipuncture. The samples were then dispensed into commercially prepared potassium-ethylenediaminetetraacetic acid plastic containers and were dispatched to the laboratory where they were analyzed immediately.

Site of Analysis

The collected samples were analyzed at the Hematology Department of the Nnamdi Azikiwe University Teaching Hospital, Nnewi, a tertiary health facility in South-Eastern, Nigeria. Full blood count was done using the Sysmex® automated hematology analyzer, Model Number: PCE 210.

Statistical Analysis

The Statistical Package for Social Sciences (SPSS), version 20.0 (SPSS Inc., Chicago, IL, USA) was used for all data analyses. Results were expressed as means ± standard deviation while comparisons were made between different groups using the Students *t*-test; the level of statistical difference was set at $P < 0.05$, at 95% confidence interval.

Ethical Issues and Approval

Ethical approval was obtained from Ethical Committee of College of Health Sciences and Technology of Nnamdi Azikiwe University, Nnewi campus. Written informed consent was sought and obtained from each participant at the point of recruitment.

RESULTS

The absolute blood monocyte and eosinophil counts were significantly higher in welders (test group) compared with controls ($0.32 \pm 0.12 \times 10^9$ cells/L vs. $0.23 \pm 0.13 \times 10^9$ cells/L

and 0.39 ± 0.41 × 10^9 cells/L vs. 0.09 ± 0.06 × 10^9 cells/L, $P < 0.001$, respectively) [Table 1].

Correspondingly, the mean cell volume (MCV), mean cell hemoglobin (MCH), and MCH concentration (MCHC) were significantly higher in test groups compared with controls (90.56 ± 6.02 fL vs. 78.95 ± 6.01 fL, 27.05 ± 2.19 pg vs. 23.39 ± 2.11 pg, 30.57 ± 0.97 g/dl vs. 28.57 ± 8.22 g/dl, $P < 0.001$, respectively) [Table 1].

The white blood cell (WBC) count, absolute neutrophil, eosinophils, and platelet counts were significantly increased in study subjects with higher duration of work exposure ($P = 0.02$, 0.02, 0.01 and 0.01, respectively) [Table 2].

The packed cell volume (PCV) and Hb concentration were significantly lower, while the MCV was significantly higher in study subjects who consumed alcohol, compared with those who did not ($P = 0.02$, 0.01 and 0.02, respectively) [Table 3].

There was no statistically significant difference in the mean values of the hematological parameters of test subjects who used tobacco products compared with those of those who did not ($P > 0.05$).

Table 1: The relationships among hematological parameters in test group and control subjects

Hematological parameters	Mean±SD		*t*-test	*P*-value
	Test group	Control group		
WBC (×10^9 cells/L)	4.95±1.03	5.33±1.51	−1.455	0.15
Basophil (×10^9 cells/L)	0.00±0.02	0.00±0.01	0.581	0.56
Lymphocyte (×10^9 cells/L)	2.58±0.63	2.46±0.73	0.910	0.37
Monocyte (×10^9 cells/L)	0.32±0.12	0.23±0.13	3.668	*<0.001
Neutrophil (×10^9 cells/L)	1.72±0.58	1.89±0.57	−1. 539	0.13
Eosinophil (×10^9 cells/L)	0.39±0.41	0.09±0.06	4.938	*<0.001
RBC (×10^{12} cells/L)	5.40±0.56	5.7±1.15	−1.482	0.14
HB (g/dl)	13.28±3.23	13.96±1.20	1.408	0.16
PCV (%)	44.65±9.23	44.89±3.89	0.172	0.86
MCV (fL)	90.56±6.02	78.95±6.01	3.824	*<0.001
MCH (pg)	27.05±2.19	23.39±2.11	6.181	*<0.001
MCHC (g/dl)	30.57±0.97	28.57±8.22	-5.978	*<0.001
Platelet count (×10^9 cells/L)	238.38±67.50	222.92±71.34	1.113	0.27
MPV (μm^3)	9.04±0.67	9.12±0.73	−0.528	0.60

WBC: White blood cell count, RBC: Red blood cell count, Hb: Hemoglobin, PCV: Packed cell volume, MCV: Mean cell volume, MCH: Mean cell hemoglobin content, MCHC: Mean cell hemoglobin concentration, MPV: Mean platelet volume (μm^3); *Significant *P* values were all < 0.05, SD: Standard deviation

Table 2: Effects of duration of exposure to oxyacetylene gas on hematological parameters of test group

Hematological parameters	1-5 years *n*=35	≥6 years *n*=15	*t*-test	*P*-value
WBC (×10^9 cells/L)	4.25±1.17	5.70±0.38	−1.550	0.02*
Lymphocyte (×10^9 cells/L)	2.62±0.57	2.58±0.43	0.631	0.81
Monocyte (×10^9 cells/L)	0.33±0.10	0.23±0.12	0.791	0.20
Neutrophil (×10^9 cells/L)	1.30±0.21	1.84±0.61	4.223	0.02*
Eosinophil (×10^9 cells/L)	0.05±0.04	0.50±0.06	−1. 467	0.01*
Basophil (×10^9 cells/L)	0.00±0.00	0.01±0.04	3.988	0.05
RBC (×1012 cells/L)	5.50±0.57	5.02±0.71	−1.234	0.08
Hb (g/dl)	14.00±1.20	13.90±1.20	1.207	0.16
PCV (%)	45.15±3.62	40.89±3.55	0.165	0.17
MCV (fL)	82.55±6.73	85.05±2.59	2.675	0.19
MCH (pg)	25.63±2.42	27.33±1.47	5.272	0.09
MCHC (g/dl)	23.43±8.11	20.22±7.88	−4.937	0.32
Platelet count (×10^9 cells/L)	193.23±73.76	266.03±60.33	1.227	0.01*
MPV (μm^3)	9.13±0.52	9.01±0.50	−0.497	0.30

WBC: White blood cell count, RBC: Red blood cell count, Hb: hemoglobin, PCV: Packed cell volume, MCV: Mean cell volume, MCH: Mean cell hemoglobin content, MCHC: Mean cell hemoglobin concentration, MPV: Mean platelet volume (μm^3), *Significant *P* values were all < 0.05

DISCUSSION

Exposure to oxyacetylene gas, and (other emitted gases) in a welding process is considered a health hazard, often leading to the so-called metal fume fever, especially if safety precautions are neglected [5]. In this study, there was a statistically significant increase in the mean values of absolute monocyte and eosinophil counts, MCV, MCH, and MCHC of welders compared to those of the control group [Table 1]. Eosinophils generally remain in the circulation for about 8 h following production from the bone marrow, after which they enter the tissues. They are localized mainly in the gastrointestinal tract, skin, and lungs, but counts

Table 3: Effect of oxyacetylene gas exposure and alcohol consumption on the test group hematological parameters

Hematological parameters	Alcohol users *n*=34	Non-alcohol users *n*=16	*t*-test	*P*-value
WBC (×10^9 cells/L)	4.85±1.15	5.18±0.71	−1.048	0.30
Lymphocyte (×10^9 cells/L)	2.46±0.61	2.85±0.61	−2.116	0.04*
Monocyte (×10^9 cells/L)	0.31±0.31	0.33±0.10	−0.283	0.78
Neutrophil (×10^9 cells/L)	1.74±0.67	1.67±0.36	0.337	0.74
Eosinophil (×10^9 cells/L)	0.31±0.33	0.54±0.53	−1.816	0.08
Basophil (×10^9 cells/L)	0.01±0.02	0.00±0.00	0.980	0.33
RBC (×10^{12} cells/L)	5.30±0.52	5.62±0.58	−1.965	0.06
Hb (g/dl)	13.65±1.02	14.63±1.31	−2.867	0.01*
PCV (%)	44.03±3.46	46.74±4.23	−2.406	0.02*
MCV (fL)	90.54±6.26	83.60±5.68	−0.035	0.01*
MCH (pg)	25.99±2.34	26.18±1.92	−0.283	0.78
MCHC (g/dl)	24.06±8.28	19.40±7.40	1.918	0.06
Platelet count (×10^9 cells/L)	233.50±67.94	248.75±67.53	−0.742	0.46
MPV (μm^3)	9.04±0.77	9.05±039	−0.057	0.96

WBC: White blood cell count, RBC: Red blood cell count, Hb: Hemoglobin, PCV: Packed cell volume, MCV: Mean cell volume, MCH: Mean cell hemoglobin content, MCHC: Mean cell hemoglobin concentration, MPV: Mean platelet volume (μm^3), *Significant *P* values were all < 0.05

become markedly increased in a number of hypersensitivity and allergic reactions [6]. The observed increase in eosinophil count in test group compared to the control group may thus be related to allergic response to the components of the oxyacetylene flame. Indeed diverse welding related respiratory symptoms have long been recognized in occupational health [7]. This observation is important as these symptoms, particularly allergic rhinitis may be a prelude to more serious adverse respiratory symptoms, such as frank occupational asthma [8]. It is, therefore, very important that welders use PPE, including face masks routinely, during the course of their work in other to prevent this adverse effect.

The reason for the higher absolute monocyte count in test subjects in the study, compared with controls was not explainable from our data set, even though it is known that circulating monocytes increase significantly in the peripheral blood in various conditions associated with chronic inflammatory response [9].

The effects of arsine in humans have been shown to include damage to red blood cell membranes with subsequent hemolysis, increased plasma free Hb, and reticulocytosis [10]. In cases of severe arsine poisoning, massive hemolysis has been reported as well as life-threatening anemia and increase in serum free Hb concentration [11]. The hemolytic activity of arsine is thought to be due to oxidative stress generated through the formation of hydrogen peroxide and arsine adducts with Hb [12]. This ultimately leads to the formation of Heinz bodies and hemins which increase the fragility of red blood cell membranes and predispose to red cell fragmentation [13]. Similarly, phosphine has been shown to react chemically with hydrogen peroxide to generate reactive oxygen species (ROS) such as the hydroxyl radical. ROS cause cellular oxidative stress leading to damage of biological macromolecules which could ultimately result in cell death. The significantly higher mean values of MCV, MCH, and MCHC in test subjects compared to the control group in this study could thus be a reflection of background red cell lysis. Increase in red cell indices (with reticulocytosis) has been reported to follow hemolytic episodes [14]. The PCV and Hb concentration were not significantly different in test subjects and controls [Table 1], this is rather surprising since some degree of anemia is expected in hemolytic anemia. It is very likely that the ability of carbon mono oxide (in welders' flame) to induce hypoxia and secondary polycythemia could have blunted the development of significant anemia in study subjects. More so, anemia may not be marked in the face of red cell lysis (particularly when this is mild) if the bone marrow response is optimal [15].

Ibeh *et al*. reported significant increase in WBC in workers who were exposed to lead fumes and concluded that this was as a result of inhalation of lead fumes and subsequent inflammatory response [16]. It is likely that prolonged exposure to welders' flame triggered some degree of inflammatory reaction in our study subjects; the WBC, absolute neutrophil and eosinophil counts, as well as platelet counts, were significantly increased in subjects with higher duration of occupational exposure [Table 2]. The above markers have been shown to be increased in a number of conditions, being a component of systemic inflammatory response [17].

Test subjects who were alcohol consumers showed a significantly lower PCV and Hb concentration and higher MCV compared to those whose who did not consume alcohol [Table 3] Indeed alcohol consumption has been shown to cause bone marrow hypocellularity due to insufficient availability of vitamin B12 and/or folate for erythropoietic activities, often leading to macrocytic anemia [18]. This effect is thought to result from the inability of the ethanol irritated sticky ileal mucosa to absorb essential micronutrients (including folate/and B12), which eventually results in impaired hematopoiesis [19].

It is very important to highlight that welding activity in the study subjects involved automobile welding and occurred in the open places with very good ventilation. This is an advantage because the risk of organ damage among welders has been shown to increase significantly if work is done in confined spaces with poor ventilation [20].

CONCLUSION

A range of toxic substances including carbon monoxide, phosphine, and arsine are contained in the welders' flame and are liberated during the welding process. Occupational exposure to these chemicals in this study was associated with macrocytosis with a tendency for reduction in hematocrit to levels compatible with the diagnosis of clinical anemia, particularly in subjects who consume significant quantity of alcohol. These observations probably resulted from the oxidation of red cell membrane and Hb (by components of the welders' flame) leading to hemolysis and may equally be worsened by alcohol-induced impairment of folate/or vitamin B12 absorption in occupationally exposed individuals with significant alcohol consumption. In addition, long-term occupational exposure appears to herald the activation of systemic inflammatory response; this could represent another pathway to organ dysfunction.

RECOMMENDATIONS

To prevent injury, welders should be encouraged to wear PPEs in the form of face masks, leather gloves, protective long sleeve jackets, goggles, and welding helmets (with dark ultraviolet-filtering faceplates) to prevent the potential adverse effects of exposure to the flames. In addition, excessive alcohol consumption should be avoided so as to forestall the development of frank anemia.

REFERENCES

1. Al-Hassani F, Amin K, Lo S. Burns from acetylene gas: more than skin deep. BMJ Case Rep 2014;2014. pii: Bcr2013200007.
2. Konno T, Otsuki N, Kurahashi T, Kibe N, Tsunoda S, Iuchi Y, *et al*. Reactive oxygen species exacerbate autoimmune hemolytic anemia in New Zealand Black mice. Free Radic Biol Med 2013;65:1378-84.
3. Bonadies N, Tichelli A, Rovó A. When water does not clear the smut from the smoke. BMJ Case Rep 2013;2013. pii: Bcr2013200665.
4. World Health Organization. International Guide for Monitoring Alcohol Consumption and Related Harm. Department of Mental Health and

Substance Dependence. Geneva: WHO; 2000. Available from: http://www.whqlibdoc.who.int/hq/2000/WHO_MSD_MSB_00.4.pdf. [Last assessed on 2016 Sep 22].
5. Cain JR, Fletcher RM. Diagnosing metal fume fever – An integrated approach. Occup Med (Lond) 2010;60:398-400.
6. Al-Muhsen S, Letuve S, Vazquez-Tello A, Pureza MA, Al-Jahdali H, Bahammam AS, *et al*. Th17 cytokines induce pro-fibrotic cytokines release from human eosinophils. Respir Res 2013;14:34.
7. Subhashree AR, Shanthi B, Parameaswari PJ. The red cell distribution width as a sensitive biomarker for assessing the pulmonary function in automobile welders - A cross sectional study. J Clin Diagn Res 2013;7:89-92.
8. El-Zein M, Infante-Rivard C, Malo JL, Gautrin D. Is metal fume fever a determinant of welding related respiratory symptoms and/or increased bronchial responsiveness? A longitudinal study. Occup Environ Med 2005;62:688-94.
9. Lund H, Boysen P, Åkesson CP, Lewandowska-Sabat AM, Storset AK. Transient migration of large numbers of CD14(++) CD16(+) monocytes to the draining lymph node after onset of inflammation. Front Immunol 2016;7:322.
10. Correia N, Carvalho C, Friões F, Araújo JP, Almeida J, Azevedo A. Haemolytic anaemia secondary to arsenic poisoning: a case report. Cases J 2009;2:7768.
11. Nachman KE, Graham JP, Price LB, Silbergeld EK. Arsenic: a roadblock to potential animal waste management solutions. Environ Health Perspect 2005;113:1123-4.
12. Vahidnia A, van der Voet GB, de Wolff FA. Arsenic neurotoxicity – a review. Hum Exp Toxicol 2007;26:823-32.
13. Reimer KJ, Koch I, Cullen WR. Organoarsenicals. Distribution and transformation in the environment. Met Ions Life Sci 2010;7:165-229.
14. Zhao L, Mao ZG, Jiang H, Qin L, Huang CY, Tan B. Value of MCV/RDW combined with reticulocyte parameters in differential diagnosis of anemia diseases. Zhongguo Shi Yan Xue Ye Xue Za Zhi 2015;23:1662-6.
15. Barcellini W, Fattizzo B. Clinical applications of hemolytic markers in the differential diagnosis and management of hemolytic anemia. Dis Markers 2015;2015:635670.
16. Ibeh N, Aneke J, Okocha C, Okeke C, Nwachukwuma J. The influence of occupational lead exposure on haematological indices among petrol station Attendants and automobile mechanics in Nnewi, South-East Nigeria. J Environ Occup Sci 2016;5:1-6.
17. Luo JC, Hsu KH, Shen WS. Inflammatory responses and oxidative stress from metal fume exposure in automobile welders. J Occup Environ Med 2009;51:95-103.
18. Huang Z, Shi J, Shao Y, Nie N, Zhang J, Li X, *et al*. Clinical profile of megaloblastic anemia in China: a single center experience from MegA-1710 program over two decades. Ann Hematol 2016;95:827-8.
19. Prior PL, Vaz MJ, Ramos AC, Galduróz JC. Influence of microelement concentration on the intensity of alcohol withdrawal syndrome. Alcohol Alcohol 2015;50:152-6.
20. Golbabaei F, Seyedsomea M, Ghahri A, Shirkhanloo H, Khadem M, Hassani H, *et al*. Assessment of welders exposure to carcinogen metals from manual metal arc welding in gas transmission pipelines, Iran. Iran J Public Health 2012;41:61-70.

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