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The effect of Aluminum on the increasing risk of developing anemia among workers of tile production plants

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ABSTRACT

Background and aims: The aluminum-containing compounds are used as glaze in tile and ceramic production plants. It means that the workers working in these plants are in direct exposure to aluminum-containing compounds. The aim of this study was to assess the potential damages caused by aluminum among tile plant workers.

Methods: In this cross-sectional study, 60 workers whom were in direct exposure to glazing material were enrolled as case group and 112 workers whose jobs were different from the case group and who had no exposure to the chemical materials in tile plants were considered as control group. After taking fasting blood samples, it was performed cell count tests using an automated blood cell counter. Serum iron and liver function test were measured using auto analyzer. Serum aluminum measurement was done by graphite furnace atomic absorption spectrometry and ferritin was measured by ELISA.

Results: The serum aluminum level was significantly higher in the case group (7.26±2.63) than the control group (5.48±1.75) ($P<0.001$), as well as the mean hemoglobin level was lower in the case group (14.28±0.88) than the control group (15.44±1.19) ($P<0.011$). However, the mean level of iron and ferritin as well as liver tests exhibited no significant difference between two groups ($P>0.05$).

Conclusion: Occupational exposure to aluminum in tile production industries could increase the serum aluminum level but may decrease blood hemoglobin concentration, which is a predisposing factor for anemia possibly through intervening in blood iron and ferritin.

Keywords: Aluminum, Ferritin, Iron, Tile glazing, Anemia.

INTRODUCTION

The compounds which are called glaze in tile and ceramic plants are using aluminum oxide (alumina) and aluminum hydrate. The toxicity of such metals (like aluminum and zinc) in these plants has been already reported.[1] In fact; aluminum is a toxic element that has been recognized as being involved in the etiology of some diseases such as Alzheimer, Parkinson's disease, Encephalopathy, and Osteomalacia.[2] Aluminum can exert its effects through intervening in membrane lipid fluidity and iron, magnesium, and

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calcium homeostasis as well as developing oxidative stress.[2] Moreover, aluminum can enter into the body through inhalation and oral route as well as absorption of a small proportion of aluminum by gastrointestinal tract.[3] Aluminum could also be absorbed through inhalation in occupational contacts.[4]

A wide range of toxic effects of aluminum have been demonstrated such as a potential external factor for anemia symptoms in experimental animals and patients under hemodialysis.[5] Aluminum could indeed result in microcytic anemia in experimental animals. Moreover, hypochromic microcytic anemia could be attributed to aluminum among hemodialysis patients.[6] However, the data on the mechanisms of toxic aluminum effect on the red blood cells and erythropoiesis is inconsistent with this issue.[7-10] In addition, several studies have indicated that the chronic exposure to aluminum at relatively high doses could cause changes in iron metabolism.[11, 12] Some other researchers found no change in iron reserves and even reported the increase in these reserves after exposure to aluminum. For example, Vittori and colleagues observed no variation in plasma ferritin concentration, total iron binding capacity, or transferrin saturation in the mice in chronic exposure to aluminum despite noting the anemia symptoms among these animals.[13] Aluminum also seems to be effective on the metabolism of the proteins associated with iron.[14, 15] Furthermore, aluminum firmly bounds to ferritin[11] and could increase iron deposition in liver and kidney by affecting lysosomal function in these organs.[16,17] In addition, aluminum accumulation in the brain is a common characteristic of advanced neurological diseases which are prevalent in the elderly.[18] High level of aluminum is associated with neurological changes like multiple sclerosis, Parkinson's disease, and Alzheimer.[4] Prolonged occupational exposure to aluminum can accelerate the variations in senescence in the mice brain.[19]

Because of the toxicity effect of aluminum-containing compounds, the compounds which are used as glaze could impact on the level of serum aluminum and blood hemoglobin and damage liver and nervous system. Most of previous researches were studying the effect of aluminum in animals but the direct effect on human has been less assessed. Therefore, the workers who are in direct and prolonged exposure to aluminum compounds were investigated in this study. If the toxicity of this element is detected, protective measures can be considered for the workers.

METHODS

This case-control study was conducted in Clinical Biochemistry Research Center from 2012 to 2013. A total of 172 healthy men volunteers aged between 24-37 years old were selected for this study and divided into two groups: case and control. The groups were different in expositing to the tile glazing material. After the necessary coordination with the administrative director of the tile plants, the blood samples of 60 workers who were directly exposed to the glaze in the production line were taken after obtaining the informed consent forms. The samples from 112 individuals consisting of administrative personnel and the workers who were not exposed to the glazing material were also taken like the control group. The

inclusion criteria were non-smoking, having no hypertension and/or diabetes, no renal disease or other metabolic diseases; at least two years' work experience and occupational exposure for the case group.

Hemoglobin and red blood cell indices were measured using automatic cell counter (Sysmex KX-21, Japan). Liver function test were detected using an auto analyzer system (Biotecnica BT-3000, Italy). The aluminum was measured after preparation (with an equal volume of magnesium nitrate and 1% Triton X-100) by atomic absorption system (Perkin Elmer AA240z, USA) using graphite furnace and ferritin concentration that was determined by ELISA (DiaPlus Inc. commercial kit). Data were analyzed using independent t-test through SPSS software. P-value less than 0.05 was considered as significant.

RESULTS

The serum aluminum level was higher in the case group (7.26±2.63) than the control group (5.48±1.75) (P<0.001) (Table 1). The mean hemoglobin level was lower in the case group (14.28±0.88) than the control group (15.44±1.19; P=0.001). However, the mean level of iron and ferritin exhibited no significant difference between the case and control groups as well as liver tests (P>0.05). In addition, no significant difference was noted in the mean red blood cell distribution width (RDW), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and liver function tests between two groups.

Table 1: Biological characteristics of the two groups

Measurement	Case	Control	P-Value	Measurement	Case	Control	P-Value
Aluminum (µg/l)	7.26±2.63	5.48±1.75	0.001*	RDW	13.02±0.82	13±0.84	0.523
Hemoglobin (g/dl)	14.28±0.88	15.44±1.19	0.011*	Iron (mg/dl)	78.1±41.6	109.3±38.8	0.875
RBC	5.18±0.31	5.42±0.40	0.088	Ferritin (mg/dl)	67.1±50.4	55.8±53.8	0.753
HCT (%)	43.41±2.18	46.79±3.18	0.007*	ALT (U/l)	16.8±5.89	15.8±7.03	0.819
MCV(fl)	83.14±4.6	86.52±5.34	0.918	AST (U/l)	19.9±14.02	21.1±14.97	0.805
MCH	27.49±1.67	28.54±2.11	0.163	BT (mg/dl)	0.88±0.57	0.87±0.65	0.545
MCHC	32.82±0.82	32.97±2.14	0.424	BD (mg/dl)	0.22±0.08	0.23±0.08	0.531

** P<0.05 compared with control; RBC: Red blood cells count; HCT: Hematocrit; MCV: Mean corpuscular volume; MCH: Mean corpuscular hemoglobin; MCHC: Mean corpuscular hemoglobin concentration; RDW: Red Cell Distribution Width' size; ALT: Alanine Amino Transferase; AST: Aspartate Amino Transferase; BT: Total bilirubin; BD: Direct bilirubin.*

DISCUSSION

In the present study, the mean level of serum aluminum was found to be higher in the workers of the tile production plants than the control group, indicating that the occupational exposure in these plants is associated with the higher level of aluminum, which raises the likelihood of aluminum absorption through inhalation or gastrointestinal tract.

It has been well demonstrated that the workers who are exposed to the aluminum compounds could be influenced by the

toxic effect of this element.[1, 21] For example, a study on the workers of an aluminum plant concluded that the occupational exposure to the aluminum could increase absorption through air and may increase the systemic absorption. In addition, the increasing serum aluminum level was considerably higher in the individuals exposed to aluminum than the control group; the urinary albumin/ creatinine ratio increased considerably in the workers, as well.[22]

The mean hemoglobin of our participants was lower in the case group compared to the control. Although the mean hemoglobin was normal in both groups, it was lower in the case group than the control. In fact, this decrease in mean hemoglobin to the lowest normal level could be a predisposing factor for developing anemia due to the job in the tile production plants. In another study on the mice whom exposed to the aluminum citrate, hemoglobin and hematocrit decreased significantly; decreased reticulocytosis and severe inhibition of colony-forming units-erythroid (CFU-E) were also reported.[9] In a study, the decreased concentration of hemoglobin and hematocrit was reported in the mice after chronic intake of aluminum.[23] Another study which focused on the prolonged exposure to aluminum sulfate in mice, found a significant decrease in red blood cells and concentration of hemoglobin and hematocrit.[24] Although these works have been conducted in vitro and on the animals, our findings are consistent with these researches. Thus, it could be concluded that the chronic exposure to aluminum could effect on hemoglobin, red blood cells as well as the related markers in human.

Moreover, the mean level of serum iron was lower in the case group than the control, but the mean ferritin level was partially higher in the case group. Although there was no statistically significant difference in ferritin and iron level between the two groups, some biological changes were observed. For example, the decreased level of serum iron following chronic exposure to aluminum was reported in experimental animals, [9, 23, 25, 26] which is consistent with the present study. However, no effect of aluminum on iron level was reported in some studies.[27] As observed in the present study, iron was lower in the case group than the control, indicating that the relative decrease in the blood iron was observed as a result of occupational exposure to aluminum in a human group as well.

In another study, aluminum was reported to be effective on the metabolism of the proteins related to iron.[28] In another study, the Apo transferrin interaction with aluminum-ferritin was associated with iron, rather than aluminum, release which indicated that aluminum was firmly bound to the ferritin and intestinal ferritin prevented metal absorption by excreting aluminum into the lumen through mucous cells.[29] Ferritin can also detoxify the aluminum from the cells.[30] Our study revealed that the blood ferritin level was higher in the workers exposed to aluminum than the control group, which could be due to aluminum's binding to the blood ferritin. As aluminum level

increased in the blood, ferritin level could increase in the blood. Since aluminum is more likely to be firmly bound to ferritin than iron, chronic exposure to the aluminum caused the level of hemoglobin and iron to grow lower than the control group, and ferritin to grow higher than the control group.

CONCLUSION

Results in current study indicated that occupational exposure to aluminum in the tile production plants could increase serum aluminum and this high level of aluminum could in turn decrease the hemoglobin and hence, represents a predisposing factor for developing anemia through affecting the level of iron and ferritin.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests.

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