Evaluation of Oxidative Stress and Biochemical Biomarkers, and Psychological Parameters in Cement Plant Workers

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Research

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Abstract

Background

The cement industry is one of the main world industries with exposure to a wide range of hazardous chemical and physical occupational agents that can increase free radicals and cause diseases. The aim of this study was to evaluate oxidative stress, and biochemical markers and psychological parameters among cement plant workers who were exposed to variety of hazardous occupational agents.

Methods

In this cross-sectional study 40 workers exposed to cement and 40 office employees, were selected as the exposed and control group, respectively. Exposure to cement dust, silica and noise were respectively assessed using the NIOSH 0600, NIOSH 7601 and noise dosimetry methods. Oxidative stress biomarkers including malondialdehyde (MDA), superoxide dismutase (SOD), catalase (CAT), total antioxidant capacity (TAC), and biochemical parameters were measured in the serum of all participants. Depression, anxiety and stress were assessed by Depression Anxiety Stress Scales (DASS-21) questioner. Statistical analysis was performed by SPSS22 software. Independent t-test, Mann-Whitney U, Chi-square were used to evaluate the relation between variables.

Results

The results demonstrated that the level of MDA as a marker of oxidative stress was significantly higher in the exposed group.Antioxidant enzymes including SOD and CAT were significantly higher, and TAC was insignificantly lower in the exposed group. Alkaline phosphatase (ALP), aspartate transaminase (AST), depression and stress were also significantly higher in the exposure group. It seems like working in cement plants, can have hazardous effects on liver function, enzyme activity and mental health.

Introduction

The cement industry has recently grown enormously, especially in developing countries. Exposure to cement dust is known as one of the most hazardous occupational exposures in the world[1].Cement dust contains various compounds including calcium oxide (CaO), silicon dioxide(SiO_2), aluminum trioxide(Al_2O_3), iron oxide(Fe_2O_3), magnesium oxide (MgO), crystalline silica, sulfur oxide [2-5]and toxic elements such as Aluminum(Al) and Chromium (Cr) [6, 7]. Occupational exposure to cement dust has been reported to cause adverse effects such as liver, neurological, lung, heart and spleen disorders[8-11], and oxidative stress[12]. Oxidative stress is an important mediator in causing the harmful effects of some occupational stressors[13] and is defined as imbalance between the production of free radicals and the antioxidant defensive system[2, 14].

On the other hand, the cement manufacturing process also produces high noise levels which have other harmful effects on workers [15]. Exposure to harmful noise can increase metabolic activity through oxidative phosphorylation in the mitochondria, leading to the production of reactive oxygen species (ROS) and antioxidant elimination [16]. Chronic exposure to noise causes inflammation, and then oxidative stress in plasma and especially the vascular tissue, which increases the risk of cardiovascular disease, hypertension, blood viscosity, increased blood glucose, anxiety and stress [17-19].Likewise, it is believed that overproduction of free radicals leads to changes in the level of enzymatic antioxidant such as glutathione S-transferase (GST), CAT, SOD and non-enzymatic antioxidants. Enzymatic and antioxidant capacity are important markers to measure the damage caused by free radicals in vital organs[20],and MDA is one of the best indicators to measure lipid peroxidation created by oxidative stress[21].

Although various studies have been done about physiological changes, radiographic abnormalities, and clinical manifestations in workers exposed to cement dust, there are limited studies on the evaluation of oxidative stress, biochemical parameters, and mental health in workers simultaneously exposed to cement dust and noise. This current study aimed to evaluate and compare the level of plasma malondialdehyde and enzymatic antioxidants and some biochemical markers, as well as the depression, anxiety, and stress status in cement plant workers who were simultaneously exposed to cement dust, silica, and noise.

Materials And Methods

Study design

This cross-sectional study was conducted in a cement factory in the south of Iran. There were 180 workers working in different parts of this factory in which 49 workers were selected from different units of the factory through stratified random sampling. The factory included the raw material, furnace, cement production, repair, filtration, and services units. According to the population in each unit, a fraction of each unit was randomly selected. Overall 49 workers were selected from these 6 units. But 9 workers were excluded based on the inclusion and exclusion criteria.

The inclusion criteria included at least 5 years of work experience and working in fixed shifts. The exclusion criteria included, people who used food supplements or vitamins. Eventually, 40 workers were selected as the exposed group. The unexposed group were office workers, randomly selected from different administrative departments. In order to select randomly, 47 personnel codes were drawn from the complete employee list, and 40 persons who matched the inclusion and exclusion criteria entered the study.

The 40 workers in the exposed group were all exposed to silica, cement dust and >85 dB noise. The 40 office employees were not exposed to silica or cement dust and their noise exposure was less than 85dB which is the threshold recommended by the American Conference of Governmental Industrial Hygienists (ACGIH).Data were collected using a general demographic questionnaire including age, gender, work experience, disease history, smoking, tobacco consumption, drug or vitamin intake, education, and marriage.

Cement dust exposure assessment

Exposure to cement dust was measured according to the US National Institutes of Health, Method 0600 (NIOSH 0600), using a personal sampling pump (Model 224-PCXR8 SKC US). Sampling was performed by a 10 mm nylon cyclone and a 5 micrometer PVC filter during the whole shift. The pumps were calibrated before and after sampling by a digital calibrator with a flow rate of 2.2 l/min and inhalable dust density (particles with a diameter less than 5 micron) was measured. The filters were desiccated for 8 hours before and after sampling and weighed with a 0.1 mg sensitivity scale (Model AND HR-200). Cement dust exposure was calculated in milligrams per cubic meter during the work shifts and compared with the threshold limit value (TLV) as recommended by the American Conference of Governmental Industrial Hygienists (1 mg/m^3)[22].

Exposure assessment to free silica

Exposure to crystalline silica was assessed according to the US National Institute of Health and Safety (NIOSH 7601) method 7601. Sampling was performed during the work shift using a personal sampling pump (Model 224-PCXR8 manufactured by SKC USA) equipped with a 10 -mm nylon cyclone with a 37 mm-PVC filter and 5 micrometer pore size. After preparing the filters, silica was measured by a Spectrophotometer (Model Cary 60 UV-VIS, Agilent, USA) at 820 nm wavelength. The amount of silica exposure for each person was calculated in mg/m^3 and compared to the TLV- TWA recommended by the American Conference of Governmental Industrial Hygienists (0.025 mg/m^3)[22].

Noise exposure assessment

Noise exposure was assessed through a personal dosimetry method, according to the ISO9612 standard. In order to measure noise exposure, a personal calibrated TES-1354 (TES Taiwan Manufacturing Company) with a precision measurement of ±1.5% dB was attached to each worker during the entire work shift. Then, the sound equivalent level (SEL) was calculated for each worker during the work shift. The 85 dB noise level, recommended by the American Conference of Governmental Industrial Hygienists (ACGIH)was considered as the Threshold Limit Value (TLV)[22].

Blood sampling and analysis of oxidative stress biomarkers and biochemical parameters

Blood sampling was performed by a trained nurse, at 7am to 12 am, before beginning the last working shift, in the end of the week, after at least 9 hours fasting. 10 ml of blood was taken from each worker and transferred into sterile tubes. Later the samples were transferred by a cold box to the Laboratory of the Pharmacy Faculty of Shiraz University of Medical Sciences. Then the test tubes were centrifuged for 10 min at 3000 rpm to separate the serum, for chemical analysis[23].

Measuring the serum level of MDA

MDA was measured as a lipid peroxidation index. It was measured based on its reaction with thiobarbituric acid reactive substances (TBARS) using fluorimetry. Its absorption was read at 187 nm[24].

2.8. Measuring the serum level of TAC

Measuring TAC was performed by FRAP (ferric reducing ability of plasma) method. The basis of this method, is measuring the plasma's ability in reducing Fe^{+3} (ferric) to Fe^{+2} (ferrous) in the presence of a substance that is called TPTZ(2,4,6-tripyridyl-s-triazine).The complex formed by ferric and the Fe^{+2}-TPTZ is blue in acidic environments, and its maximum absorption is at 593 nm [25].

Measuring SOD activity levels

In order to measure the activity of superoxide dismutase, the SOD ZellBio GmbH (Ulm Deutschland) kit was used. This kit determines the activity of SOD in the range of 5-100 U/L with a sensitivity of 1 u/ml. SOD activity was calculated based on the amount of mass that catalyzes the decomposition of 1 μmol O^{-2} to H_2O_2 and O_2. Final SOD activity was determined by using a calorimeter at 420 nm [26].

Measuring the catalase activity levels

In order to measure the activity of the CAT (catalase enzyme), the CAT ZellBio GmbH (Ulm Deutschland) kit was used. This kit determines the amount of catalase activity in biological samples at a sensitivity of 0.5 U/mL. One catalase activity unites the amount of mass which catalyzes the decomposition of 1 μmol of H_2O_2 into water and O_2 over a period of one minute. Final catalase activity was determined using a calorimeter at 405 nm [27].

Measuring biochemical markers

In order to measure biochemical parameters including alkaline phosphatase (ALP), alanine transaminase (ALT), aspartate transaminase (AST), high density lipid (HDL), low density lipid (LDL), triglyceride (TG), total bilirubin, glucose, albumin and creatinine; standard kits and an auto analyzer system (Mindray BS-200®, China and Pars Azmun®, Tehran, Iran) were used [28, 29].

Assessment of depression, anxiety and stress

To assess the state of depression, anxiety and stress the short form of the Depression Anxiety Stress Scales (DASS-21) was used[30, 31].The DASS-21 questionnaire consists of 21 questions; each of the questions was assessed on a 4 points Likert-type scale including 0 (never), 1 (sometimes), 2 (often) and 3 (almost always). In this questionnaire, the participants indicate their response about each of the symptoms during the previous week. Each of the depression, anxiety, and stress scales consists of seven questions out of twenty-one. In order to complete the questionnaires, all individuals were interviewed face to face and every question was read for them. Because the DASS-21 questionnaire is the short form of the main DASS-42 questionnaire, the final score of each subscale (which is from 0 to 21), should be doubled and the final score of each subscale is reported from 0 to 42.

The psychometric properties of the Persian version of DASS-21 has been reported in Iran by Sahebi et al. and the Cronbach's alphas were 0.7, 0.67, and 0.49 for depression, anxiety, and stress respectively[32].

The workers were almost similar in terms of economic class and received a similar meal in the factory.

Statistical analysis

The sample size was estimated using the mean difference and standard deviations of biochemical parameters, reported in Al Salhen's study[33]. In Al Salhen's study the mean difference between biochemical parameters was high, and the calculated samples sizes were all under 10. Nevertheless, in this study 80 people were enrolled in two groups.

Data normality was tested using the Kolmogorov-Smirnov test. Descriptive statistics was used to summarize the quantitative variables, and for qualitative variables, the frequency was reported. One sample t-tests were used to compare the noise level pressure, ambient silica and cement dust levels with their permissible threshold. In order to compare the mean difference of oxidative stress biomarkers, biochemical parameters, depression, anxiety, stress/tension, noise, cement dust and silica dust between the two groups, independent t-tests and Mann-Whitney U tests were used, for normal and skewed data respectively. Chi-square was used to compare qualitative variables between the two groups.

Pearson correlation coefficients were used to assess the relation between cement dust, silica and noise exposure with oxidative stress and biochemical markers. The significance level was set at 0.05 for all of tests. Statistical analysis was performed by SPSS 22.

Results

The demographic information of the two groups is summarized in Table 1. There were no significant differences between the demographic variables in the two groups. About 60 percent of the individuals in the exposed group usually used personal protective equipment (PPE)and others did not use PPE, on their own responsibility. All participants in this study were male. The mean age of the participants was 39 ± 6.2 years, and the mean of BMI was 26.53± 3.8 kg/m^2. The mean of work experience was 13± 5.46 years.

Table 1 Demographic information of the exposed and unexposed groups.

Variable	Classification	Exposed(n=40) Frequency (%)	Unexposed(n=40) Frequency (%)		P value *
BMI** (kg/m^2)	Normal Abnormal	16(40) 24(60)	11(27.5)	29(72.5)	0.34
Age (years)	<35 35-40 >45	14(35) 20(50) 6(15)	15(37.5) 18(45)	7(17.5)	0.83
Work Experience	<10 >10	17(42.5) 23(57.5)	18(45)	22(55)	0.82
Education	Middle School Diploma Bachelor Master	4(10) 6(15) 17(42.5) 13(32.5)	7(17.5) 15(37.5) 1(2.5)	17(42.5)	0.26
Smoking	Yes No	13(32.5) 27(67.5)	10(25)	30(75)	0.45
Marital Status	Married Single	7(17.5) 33(82.5)	8(20)	32(80)	0.7
Use of personal protective equipment	Usually Sometimes Never	25(62.5) 9(22.5) 6(15)	_ _	_	_

*Chi-square

**Normal:18.5-24.9, Abnormal: <18.5 and ≥25.

Table 2 shows the amount of cement dust, silica and noise in the exposed and unexposed groups. Cement dust, free silica and noise levels were significantly higher in the exposed group. Also, the level of exposure to cement dust, silica and noise in the exposed group was higher than the Threshold Limit Values (TLV) which are 1mg/m^3,0.025mg/m^3 and 85 dB respectively.

Table 2 The amount of cement dust, silica and noise in the exposed and unexposed groups.

Variable	Noise (dB)	Cement Dust (mg/)	Free Silica (mg/)
Exposed (Mean ± SD)	98.92 ± 9.35	1.54 ± 2.30	0.086 ± 0.118
Unexposed(Mean ± SD)	49.82 ± 7.88	0.007 ± 0.008	0.001 ± 0.001
p-value	0.001*	0.001**	0.001**

Independent t-test*

Mann Whitney test**

The comparison of oxidative stress and biochemical biomarkers, depression, anxiety and stress between exposed and unexposed groups are presented in Table 3. MDA, SOD, CAT, AST and ALP were significantly higher in the exposed group.TAC was lower in the exposed group but, the difference was not significant. The scores of depression and stress were significantly higher in the exposed group.

Table 3 The comparison of oxidative stress biomarkers, biochemical parameters, depression, anxiety and stress between exposed and unexposed groups.

Variable	Exposed (Mean ± SD)	Unexposed(control) (Mean ± SD)	P value
MDA (nmol/mg protein)	0.41 ± 0.56	0.31 ± 0.07	0.001*
TAC (nmol/ml)	1.11 ± 0.37	1.22 ± 0.34	0.187*
SOD (u/ml)	416.38 ± 61.78	327.39 ± 45.39	0.001*
CAT (nmol/min/ml)	0.43 ± 0.09	0.38 ± 0.05	0.004*
ALT (IU/L)	35.17 ± 11.53	34.65 ± 10.91	0.79**
AST (IU/L)	30 ± 7.09	25 ± 5.27	0.002*
ALP (IU/L)	220.05 ± 47.20	161.87 ± 6.50	0.02*
Total Bilirubin (mg/dl)	1.63 ± 0.71	0.73 ± 0.54	0.47**
Glucose (mg/dl)	94.9 ± 12.06	92.72 ± 5.10	0.87**
Creatinine (mg/dl)	1.17 ± 0.22	1.22 ± 0.086	0.35**
Triglyceride (mg/dl)	253.75 ± 172.13	230.90 ± 115.95	0.48*
Cholesterol (mg/dl)	172.37 ± 27.44	176.37 ± 30.11	0.38*
HDL (mg/dl)	38.67 ± 9.02	40.70 ± 7.87	0.28*
LDL (mg/dl)	101.92 ± 11.40	102.12 ± 11.52	0.51*
Albumin (g/dl)	4.01 ± 0.67	4.12 ± 0.17	0.82**
Depression (max score 42)	13.25 ± 9.33	7.8 ± 7.14	0.01*
Anxiety (max score 42)	9.25 ± 8.19	6.79 ± 6.45	0.13*
Tension/Stress(max score 42)	19.65 ± 7.71	13.4 ± 9.87	0.03*

*Independent T test

**Mann Whitney test

Pearson correlations were performed to investigate the relation between cement dust, silica and noise exposure with oxidative stress and biochemical parameters. The correlations between exposure levels of harmful agents with oxidative stress and biochemical parameters are shown in Table 4.Noise pressure level was significantly correlated with MDA, SOD, CAT, AST, ALP, and glucose levels. Cement dust exposure was significantly correlated with MDA and ALP levels. The correlation between silica with MDA, SOD, depression and tension was also significant.

Table 4 The correlations between cement dust, silica, noise and oxidative stress biomarkers, biochemical parameters, depression, anxiety, tension.

Variable	Cement Dust		Noise		Silica Dust	
	Pearson Correlation coefficient	P value	Pearson Correlation coefficient	P value	Pearson Correlation coefficient	P value
MDA	0.276	0.013*	0.563	0.001*	0.291	0.009*
TAC	-0.124	0.275	-0.163	0.14	-0.123	0.275
SOD	0.117	0.117	0.617	0.001*	0.347	0.002*
CAT	0.109	0.335	0.374	0.002*	0.068	0.55
ALT	-0.003	0.980	0.045	0.698	-0.107	0.347
AST	0.172	0.12	0.314	0.005*	0.014	0.905
ALP	0.297	0.008*	0.295	0.021*	0.139	0.218
Bilirubin	-0.003	0.97	0.093	0.41	-0.036	0.753
Glucose	0.023	0.840	0.223	0.055	0.079	0.486
Creatinine	0.056	0.621	-0.11	0.33	-0.014	0.90
Triglyceride	-0.116	0.305	0.90	0.426	0.094	0.407
Cholesterol	-0.127	0.262	-0.203	0.071	-0.126	0.265
HDL	0.093	0.41	-0.114	0.314	-0.304	0.06
LDL	-0.203	0.071	-0.117	0.32	-0.207	0.065
Albumin	0.004	0.972	-0.088	0.438	0.015	0.89
Depression	0.16	0.14	0.16	0.14	0.28	0.01*
Anxiety	0.4	0.7	0.08	0.47	0.14	0.21
Tension/Stress	0.12	0.26	0.21	0.05	0.28	0.01*

* (P-value<0.05)

Discussion

The aim of this study was to evaluate the possible effects of exposure to cement dust, silica and noise on oxidative stress and biochemical biomarkers, depression, anxiety and stress among workers in a cement industry.

The results of current study showed that the level of MDA in the exposed group was significantly higher. MDA is one of the products of lipid peroxidation and is considered as a marker of damage caused by free radicals, and its increase is a sign of free radical accumulation and oxidative damage [34-36].There is evidence that the components of cement dust such as Cr, silica and Al can cause overproduction of free radicals and oxidative stress[37-39]. Other studies have also shown that cement dust increases level of MDA [12, 40, 41], and some studies have reported that exposure to noise more than the threshold limit leads to increase in MDA levels in plasma and increased oxidative stress[21, 42, 43]. There are other studies in line with the results of our study that reported an increase in plasma MDA levels in cement factory workers in comparison to unexposed individuals as well [33, 40]. But one study had different results and showed that the level of MDA was not significantly different in cement plant workers compared to their unexposed controls. However, this study did not report how much exposure the workers had received[2].These different results may be due to differences in the intensity and duration of exposure to harmful agents in the cement plant(cement dust, silica and noise), or the use of personal protective equipment.

Total Antioxidant Capacity (TAC) is an antioxidant biomarker which is measured to assess the oxidative stress status. Its increase means the overall antioxidant capacity has increased, and oxidative stress has decreased. Antioxidants reduce oxidative damage directly by reacting with free radicals and indirectly by inhibiting the activity of free radicals[44].

In the current investigation the level of TAC in the exposed group was less than unexposed group, but this difference was not significant. This slight decrease may be because of eliminating the free radicals that are generated by oxidating agents (cement dust, silica, and noise) in the exposed group[45, 46]. However, in Malekirad's study at a cement plant [2],and another similar study on workers exposed to silica, TAC levels were not significantly different in the exposed and unexposed groups[47]. The reason for the insignificant difference in the level of TAC among exposed and unexposed groups in our study and other studies could be due to the indirect effect of oxidative agents on TAC. Oxidative agents may affect TAC indirectly because the enzymatic and non-enzymatic antioxidants in the cells can counteract the effect of oxidative stress, and by restraining free radicals can prevent the effect of oxidative stress on TAC [48].

In the present study, the amounts of SOD and CAT in the exposed group were significantly higher than the non-exposed group. Similar studies have showed that SOD and CAT were higher in workers exposed to noise (77-99 dB) [49]; and among workers exposed to silica [34, 47]. Increased levels of CAT and SOD represent an increase in oxidative stress; in fact, such enzymatic antioxidants are activated in response to the overproduction of free radicals. The function of these two enzymes is related. SOD catalyzes the superoxide anion radical to O_2 and H_2O_2. CAT prevents the accumulation of H_2O_2 and cell damage by converting H_2O_2 to H_2O and O_2. Therefore, oxidative agents cause an increase in both of these enzymes, which are defensive mechanisms [50].

In our study, the amounts of AST enzyme in the exposed group were significantly higher, but still in the normal range which is about 5 to 40 units per liter of serum [51]. The serum level of AST and ALT enzymes are used to evaluate liver function. The liver is the most important organ for cleansing the body from various toxins.AST accumulates in damaged organs including the liver, skeletal muscles, heart and kidney [52, 53].Similar studies done in cement factories have shown an increase in AST levels in groups exposed to cement compared to the non-exposed groups as well[33, 40, 47].

In our finding the level of ALP enzyme in cement exposed workers was significantly higher than unexposed office employees and higher than the normal range which is about is 20 to 140 IU/L[54]. ALP is known as a cholestatic liver enzyme, and damage to bile ducts may cause its leak into blood, and increase the level of ALP in serum, and is a sign of liver dysfunction[12, 33, 52, 55, 56].Studies have suggested that the Cr in cement dust can cause liver dysfunction [57].

Depression is among the top twenty leading causes for disability around the world [58].Depression and anxiety are the most common mental disorders[59].Depression, anxiety and stress scales are common scales used to detect mental health problems [30, 60].There are few investigations about the psychiatric health of workers exposed to cement dust[61].The findings of this investigation showed that the level of depression, stress and anxiety in the exposed group were higher than unexposed office employees. Some studies have shown that exposure to noise can increase depression and stress [19, 62, 63]. In addition, other studies have shown that as oxidative stress increases, the rate of depression increases as well [64, 65]. Therefore, it is possible that exposure to the harmful agents such as cement dust, silica, and noise in cement plants can affect the mental health of workers.

Conclusion

In conclusion, our findings showed that exposure to harmful agents (probably cement dust, silica and noise) in cement plants can increase free radicals, harm liver function, deteriorate enzyme activity and cause depression and stress. Workers in cement plants should be kept away from areas with a high level of contaminants and harmful agents, and should be obliged to use PPE.

Abbreviations

ROS: Reactive oxygen species; MDA: Malondialdehyde; SOD: Superoxide dismutase; CAT: Catalase; TAC: Total antioxidant capacity; NIOSH: National Institute of Health and Safety; DASS-21: Depression Anxiety Stress Scales; ACGIH: American Conference of Governmental Industrial Hygienists; TLV: Threshold Limit Value; FRAP: Ferric reducing ability of plasma; ALP: Alkaline phosphatase; AST: aspartate transaminase; GST: glutathione S-transferase; TBARS: Thiobarbituric acid reactive substances; ALT: alanine transaminase; HDL: High density lipid; LDL: low density lipid; TG: Triglyceride; TPTZ: 2,4,6-tripyridyl-s-triazine; H_2O_2: Hydrogen peroxide

Declarations

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Authors' contributions

Darabi F, Zamanian Z, Khajehnasiri F, Keshavarzi M, and Khanjani N planned the study and study design. Darabi F, Keshavarzi M and Yosefinejad S analyzed the data. Darabi F, Keshavarzi M carried out the qualitative study. Darabi F, Keshavarzi M and Zamanian Z interpreted the data. Darabi F drafted the manuscript. Zamanian Z, Khajehnasiri F, Keshavarzi M, Khanjani N, Yosrfinejad S, Dehghani F and Nori-Abdullah M reviewed the manuscript and contributed substantially to its revision. All authors read and approved the final version of the manuscript.

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Availability of data and materials

The databases used during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Shiraz University of Medical Sciences (Ethics Code: IR.SUMS.REC.1398.386). The aim of this study was explained to all participants. Participants signed a written informed consent and voluntarily entered the study. Researchers assured the participants that their information would be kept confidential.

Consent for publication

Not applicable.

Competing interests

No conflict of interest is associated with this work.

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