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ECG changes in workers with lead intoxication

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Abstract

A significant number of studies have proven that occupational lead exposure increases the risk of cardiovascular disease. However, evidence regarding the potential effects of lead on the cardiac conduction system is sparse and inconclusive. We planned a descriptive study examining the relationship between occupational lead exposure and electrocardiogram (ECG). We investigated 48 patients, 46 males (95.8%) and two females (4.2%), who were hospitalized in Ankara Occupational and Environmental Diseases Hospital Hospital in 2022 due to lead intoxication, measured blood lead and examined ECG in this study. Descriptive and multivariable analyses were performed. The lead level was determined as 50.00±7.07 in women and 37.80±13.28 µg/L in men. No permanent significant relationship was detected between gender and lead level ($p>0.05$). No significant relationship was found between lead level and heart rhythm ($p>0.05$). It was determined that there was no significant correlation between the patients' lead levels and ECG results (ventricular rate, PR interval, QRS complex, QT and QTc) ($p>0.05$). Our study concluded that abnormal ECG results may also occur in occupational lead exposure but they were not related to toxic blood lead levels.

Keywords: Lead exposure, occupational disease, electrocardiogram

Introduction

Lead is widely found in the environment due to its extensive industrial use, making it a significant environmental toxin that adversely affects human health [1]. Exposure to lead can lead to various health issues, including problems with the nervous system, blood, digestive system, and heart in humans and animals [2]. Research has shown that lead exposure can contribute to heart-related issues, with chronic exposure to even low levels of lead being linked to high blood pressure in both humans and animals [3]. Other heart-related issues from lead exposure include changes in heart rhythm, issues with heart muscle contraction, and a higher risk of heart rhythm problems due to certain stress hormones [3,4].

Exposure to lead is a critical factor in the onset of cardiovascular diseases and various other health issues in humans, including atherosclerosis, pain conditions, and high blood pressure. This is due to its effects, such as blocking the repair of blood vessels, hindering the formation of new blood vessels, promoting oxidative stress and inflammation, and deactivating nitric oxide (NO) [5]. The lead ion, known as $Pb2+$, shares similar properties with $Ca2+$, which allows it to interfere with various bodily processes that rely on signalling and the movement of divalent cations through channels [6].

A study on 775 men from the Normative Aging Study found that low-level lead exposure, mainly measured in bones, is linked to heart conduction issues. Higher bone lead levels correlated with longer QT and QRS intervals on electrocardiograms (ECGs), mainly in men under 65, and increased the risk of intraventricular and atrioventricular blocks, depending on age. This suggests that even low-level cumulative lead exposure may impair heart electrical activity, with no significant association found between blood lead levels and ECG outcomes [1]. The research investigated the impact of lead exposure on heart electrical activity over eight years in 498 men initially free from ECG abnormalities in the veterans affairs (VA) Normative Aging Study. Higher baseline lead levels in the tibia were linked to an increased likelihood of QT prolongation and longer QT and JT intervals at later ECG tests. Additionally, these men experienced greater enlargements in QT and QRS intervals over

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time, even after adjusting for other factors. Lead in the patella was also related to longer QT and JT intervals, but blood lead levels showed no significant association. The findings indicate that even low-level, cumulative lead exposure can negatively affect the heart's electrical conduction system over time [7]. Lead's interference with calcium disrupts calcium levels and affects the functioning of calcium channels in heart cells, further diminishing their ability to contract effectively. These effects are indirectly evidenced by the prolonged QT interval observed in ECG readings [8]. Another study investigated the effect of lead exposure on ECG changes in workers, finding that higher lead levels, significantly above 35 µg/dl, were linked to prolonged QT intervals, which could elevate arrhythmia risk. It suggests regular ECG checks for lead-exposed workers [9]. Our study examined ECG changes in foundry workers with high lead levels.

Material and Methods

A total of 48 patients, 46 males (95.8%) and two females (4.2%), hospitalized in Ankara Occupational and Environmental Diseases Hospital between 1 January and 31 December 2022 due to lead intoxication, were included in the study. Ethics committee permission was obtained from Gazi University.

The study was descriptive, and the files of the patients who were hospitalized due to lead intoxication were evaluated retrospectively. All individuals working in the foundry who were followed up due to lead intoxication between the dates of the study were included in the research. Employees with known cardiovascular disease, hypertension and diabetes were not included in the study. Foundry workers who agreed to participate in the study, did not meet the exclusion criteria, and had a blood lead level of 15 µg/L or above were included. Workers were exposed to lead eight hours a day and forty hours a week. Blood samples and ECG were taken at the end of an eight-hour shift. In the study, workers with blood lead levels of 15 µg/L and above were diagnosed with lead intoxication. Gender, blood lead levels at admission, and ECG were evaluated. ECGs of the patients were performed with a standard 25 mm/second rate and 10 mm/millivolt amplitude. Heart rate, QRS duration, PR, QT, and QTc interval were calculated from the ECGs.

Statistical Analysis

The analysis and quality control computerized via SPSS 26.0 programme the data of the study was performed. In descriptive findings, continuous variables were summarized as mean, standard deviation, minimum, maximum, and median; categorical variables were summarized as number and percentage values. The conformity of the variables to normal distribution was evaluated by visual (histogram and probability graphs) and Kolmogorov-Simirnov tests. Continuous variables not conforming to normal distribution were evaluated by Mann Whitney U test and Kruskal Wallis Variance analysis according to categorical variables. The Spearman Correlation test was used to analyze continuous variables that did not fit the normal distribution. Statistical significance was accepted as $p<0.05$.

Results

The blood lead level of the patients was between 15-62 µg/L (38.31±13.27). When the electrocardiograms of the patients were evaluated, 42 (89.3%) had sinus rhythm, three (6.4%) had sinus arrhythmia, and two (4.3%) had atrial rhythm. Mean ventricular rate was 70.38±12.22 BPM (min=51, max=101), PR interval 158.04±31.17 ms (min=122, max=330), QRS complex 94.33±11.60 ms (min=79, max=134), QT 383.83±29.07 ms (min=326, max=452), QTc 401.00±24.12 ms (min=300, max=445) (Table 1).

Table 1. Data on patients' ECG measurements and lead levels

Parameters	Mean±SD	Min-Max	Median
Ventricular rate (BPM)	70.38±12.22	51-101	67
PR interval (ms)	158.04±31.17	122-330	154
QRS (ms)	94.33±11.60	79-134	92.50
QT (ms)	383.83±29.07	326-452	384
QTc (ms)	401±24.12	300-445	402.50
Lead level (µg/L)	38.31±13.27	15-62	40

The lead level was determined as 50.00±7.07 in women and 37.80±13.28 µg/L in men. There was no persistently significant relationship between gender and lead level ($p>0.05$). Lead level; Sinus rhythm was determined as 37.50±13.19, sinus arrhythmia as 36.67±16.04, and atrial rhythm as 55.00±0.00. There was no significant relationship between lead level and cardiac rhythm ($p>0.05$) (Table 2).

Table 2. Evaluation of lead level according to gender and cardiac rhythm

	Lead level (µg/L)			p
	Mean±SD	Min-Max	Median	
Female	50.00±7.07	45-55	50	0.215
Male	37.80±13.28	15-62	39	
Sinus rhythm	37.50±13.19	15-62	39	
Sinus arrhythmia	36.67±16.04	20-52	38	0.133
Atrial rhythm	55.00±0.00	55-55	55	

It was determined that there was no significant correlation between the patients' lead levels and ventricular rate, PR interval, QRS complex, QT and QTc ($p>0.05$) (Table 3).

Table 3. Correlation of ECG findings and lead level

Parameters		Lead level (µg/L)
Ventricular rate (BPM)	**r**	-0.065
	p	0.659
PR interval (ms)	**r**	-0.130
	p	0.379
QRS (ms)	**r**	0.164
	p	0.265
QT (ms)	**r**	0.130
	p	0.378
QTc (ms)	**r**	0.164
	p	0.266

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Discussion

Lead exposure can cause many health problems in workers, including cardiovascular system diseases. When looking at the studies conducted in this field, data on employees with and without lead exposure were generally evaluated.

Cardiovascular disease is a leading cause of death and a major contributor to the burden of disease worldwide [10]. Environmental toxicants, including lead and other metals, are potentially preventable exposures. These exposures may explain interpopulation differences in cardiovascular disease rates [11,12]. Lead exposure is known to be associated with cardiovascular outcomes, but the contribution of lead to cardiovascular disease is still not fully understood. In the literature, it has been reported that the average heart rate in workers with lead exposure was 70.9±10.4, 72.8±12.1, 71.8±11.6, 67.1±10.9, and the average heart rate in workers with lead intoxication was 70.27±9.74 and 75.45±8.9, respectively [9,13-17]. In our study, the average heart rate was determined as 70.38±12.22, and in this respect, it is compatible with the previous studies data. In the study conducted by Yu et al., baseline ECG recordings in workers were compared two years after exposure, and it was determined that the heart rate of workers after exposure was higher than at the beginning [18]. Different results were obtained in case-control studies conducted to determine the effect of lead exposure on heart rate. In some studies, it has been reported that workers who are exposed to lead are similar to those who are not [9,14,16]. On the other hand, in some studies, it has been reported that the heart rate is higher in exposed workers, and in some, it is lower [19]. Additionally, Böckelmann et al., reported that workers with higher lead exposure had lower heart rates than those with lower exposure [15]. In the study of Poreba et al., it was reported that tachycardia was observed more frequently in workers with lead exposure than in those without [20]. An animal study found that early-life lead exposure was associated with decreased heart rate [21]. Other animal studies have reported lead exposure to be negatively inotropic, while another study has reported it to be positively inotropic [22,23]. Studies have shown that lead exposure may have different effects on heart rate.

ECG reveals the electrical activities occurring in the heart muscle. The first electrical signal generated in the heart originates from the atrium and forms the P wave. The PR interval occurs when electrical activity is in the atrioventricular node. Depolarization occurs when it is transmitted to the ventriculeand the QRS complex is formed. The normal range of the PR interval is 20-200 ms, and the normal duration of the QRS complex is 120 ms at most. QT interval refers to the time from the beginning of the Q wave to the end of the T wave, and its normal range is up to 440 ms [24]. In a study conducted on workers exposed to lead, the PR interval was reported to be 159.4±28.0, 158.86±15.99, and 159.62±18.06 ms in intoxicated patients [13,16,17]. Our study result is compatible with the literature. While one study reported that the PR interval was shorter in exposed workers compared to unexposed workers, another study reported that it was similar [13,16]. Animal studies found that early-life lead exposure was associated with prolonged PR interval [21]. In the literature, it has been reported that the QRS duration of workers exposed to lead was reported as 91.34±19.63, 92.77±6.16 ms [13,17]. In our study, the QRS duration was higher than in other studies, but it was noted to be within normal ranges. It has been reported that workers with lead exposure are similar to those without it [13,25]. An animal study associated Early-life lead exposure with short QRS [21]. QTc times of workers exposed to lead were reported as 411.71±25.60, QTc 349.6±27.1, 377±27, 412.6±7.98 ms [9,13,14,17]. The QTc interval in exposed workers was reported as longer in one study and similar in other studies, compared to unexposed workers [9,13,14,25]. In one study, heart rate and QT interval were reported as 347±29 ms in workers exposed to lead [9]. Our results were consistent with the literature.

Studies show that lead exposure can affect cardiac functions in many ways. These may affect arteries and nerve innervation, affecting functions through humoral and neuronal dysregulation. it can also enter cardiomyocytes and affect calcium signalling mechanisms and homeostasis. Additionally, it is thought to be effective through potassium channels [26]. The effectiveness of these pathways is not clearly understood. In the general population, people with high blood lead levels had shorter survival times and higher mortality due to cardiovascular disease than people with low lead levels [27]. Lead exposure has effects on the cardiac conduction system. This condition may be related to heart rhythm disturbance [28]. In the study, which included workers working in the same industry with and without lead exposure, the lead level in those exposed was reported to be 242.11±145.73 µg/L, and the ECG was normal in 55% of them. Abnormalities include rhythm disorders and conduction disorders and are more common than the normal group [25]. In the study by Qu et al., abnormal ECG was reported in 29.9% of the lead-exposed group. These include sinus arrhythmia, prematurity, and wave abnormalities. Additionally, it has been determined that the frequency of abnormalities increases as the lead level in the blood increases [29]. In our study, patients were found to have sinus arrhythmia and atrial rhythm with abnormal ECG findings. Consistent with the literature, our results reveal that workers exposed to lead are at risk for cardiac rhythm problems.

Karakulak et al. reported that workers' median blood lead level was 33.9 (min=4.9–max=90) and that there was no correlation between blood lead level and QTc [14]. he study by Chen et al. determined that there was no relationship between blood lead level (26.05±13.98 µg/dL) and PR, and QTc was prolonge [13]. Kieltuckive et al. reported that a positive correlation between lead level and QT interval was determined. However, it was determined that there was no correlation between heart rate and QTc interval [9]. Consistent with the literature, our results reveal that PR, QT and QTc intervals did not correlate. In their multivariable regression analysis, Xie et al., concluded an increased blood lead level and a decreased heart rate [16]. In our study, it was found that there was no relationship between blood lead level and parameters.

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Conclusion

In conclusion, our findings suggest that foundry workers are at risk of lead intoxication. In our study, we found that ECG changes may occur in workers with lead intoxication. However, there was no statistical relationship between heart rate, PR interval, QRS complex, QT and QTc. Our findings may help elucidate the pathogenesis of lead-induced cardiovascular system diseases and may point to the utility of ECG monitoring in workers occupationally exposed to lead.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
The study has been approved by the Board of Ethichs of Gazi University Approval number: 2023-22).

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