DOI: 10.24996/ijs.2026.67.3.10

ISSN: 0067-2904

Investigation of Cadmium, Lead, and Mercury Levels in the Urine of Renal Stone Patients in Najaf Governorate of Iraq

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Received: 12/9/2024 Accepted: 5/3/2025 Published: 30/3/2026

Abstract

This study aims to determine the levels of cadmium (Cd), lead (Pb), and mercury (Hg) in the urine of renal stone patients and a healthy control group in the Najaf Governorate of Iraq using Atomic absorption spectrometry (AAS). The study included 20 renal stone patients and 20 healthy individuals as a control group. Both groups consisted of 10 women and 10 men. The results demonstrated that there was a significant difference ($p < 0.001$) in the levels of (Cd, Pb, and Hg) in the urine of renal stone patients compared with the control group. Also, there was a statistically significant difference in Pb and Hg levels in the urine of females, which were seen to be more than that of males ($p < 0.005$). The difference was statistically significant $p < 0.001$, in the Receiver Operator Characteristic (ROC) curve analysis for levels of Cd, Pb, and Hg in urine, which showed a high area under the ROC curve (AUC) values of 0.978,1.000, 1.000, respectively. The high levels of cadmium, lead, and mercury in urine may affect kidney function and impose certain toxic issues for the kidney and can be considered as a potential factor for the occurrence of renal stones.

Keywords: renal stone patients, Cadmium, Lead, Mercury.

التحقيق في مستويات الكادميوم والرصاص والزئبق في ادرار مرضى حصوات الكلى في محافظة النجف العراقية.

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الخلاصة

تهدف هذه الدراسة إلى تحديد مستويات الكادميوم (Cd) والرصاص (Pb) والزئبق (Hg) في ادرار مرضى حصى الكلى ومجموعة التحكم السليمة في محافظة النجف في العراق باستخدام مطيافية الامتصاص الذري (AAS). شملت الدراسة 20 مريضاً بحصى الكلى مقارنة بـ 20 شخص من مجموعة التحكم السليمة. تتكون كلتا المجموعتين من 10 نساء و10 رجال. أظهرت النتائج وجود فروق معنوية ($p < 0.001$) في مستويات (Cd, Pb, Hg) في ادرار مرضى حصى الكلى مقارنة بمجموعة التحكم. كذلك كان هناك فروق معنوية احصائيا في مستويات الرصاص والزئبق شوهدت في ادرار الإناث أكثر من الذكور ($p < 0.005$). كان الفرق معنوي احصائيا ($p < 0.001$) في تحليل ROC لمستويات الكادميوم والرصاص والزئبق في

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الادرار كما أظهرت قيم AUC المرتفعة والتي بلغت 0.978 و1.000 و1.000 على التوالي. المستويات العالية للكادميوم والرصاص والزئبق في الادرار قد يؤثر على وظائف الكلى ويتسبب ببعض المشاكل السامة في الكلى والتي يمكن ان تعتبر كعامل محتمل في حدوث حصوات الكلى.

1. Introduction

Renal stone (also called renal calculi, nephrolithiasis, or urolithiasis) are hard deposits of minerals and salts that form inside the kidneys[1]. Diet, being overweight, certain medical conditions, and some supplements and medications can cause renal stone [2]. Food type, lifestyle, and exposure to chemicals are potential risk factors for the formation and development of renal stone. Cadmium, lead, and mercury are among the causes of kidney disease. Exposure to these metals may cause renal stone [3]. Extracorporeal shock wave lithotripsy uses sound waves to create strong vibrations (shock waves) that break the stones into small pieces that can be passed in the urine[4]. The procedure takes about 45 to 60 minutes and can be moderately painful, so the patients may be given sedation or light anesthesia so the patients don't feel the pain[5]. The four most prevalent kinds of renal stone are struvite, calcium phosphate, calcium oxalate, and uric acid. Renal stone can also be categorized based on the minerals they contain, calcium together with alkaline and alkali elements[6]. Renal stone vary in shape depending on their occurrence and are affected by several variables such as environment, climate, race, social characteristics, and urinary tract infections[7]. Crystal creation, aggregation, and retention in the kidney cause nephrolithiasis[8]. There is a serious risk to human health when exposed to many metals and minerals, including lead, cadmium, mercury, manganese, aluminum, iron, copper, thallium, arsenic, and chromium. In the past three decades, lead poisoning has been understood, and exposure to low doses does not cause symptoms. Clinical symptoms appear as a result of the effects of high doses; modern. Good sensitive techniques have helped to measure the low concentrations of these doses[9]. The element cadmium is another environmental pollutant whose toxicity varies in human and animal tissues. Chronic exposure to cadmium can be a cause of lung fibrosis, renal tubular failure, high blood pressure, osteoporosis, and cancer. These metals are exposed through food, polluted air, or dust[10]. Lead is carried by red blood cells and accumulates in the bones. According to the International Agency for Research on Cancer in 2006, lead compounds and inorganic lead are classified as potentially carcinogenic to humans[11-13]. It is a toxic metal that causes oxidative stress and affects the skeletal system, kidneys, blood, nervous system, and endocrine glands[14]. This study aims to examine the levels of Cd, Pb, and Hg in the urine of renal stone patients treated with lithotripsy and to compare the results with those of healthy control using atomic absorption spectrometry.

2. Materials and Methods

The urine samples were collected from Al-Sadr Teaching Hospital in Al-Najaf, Iraq. Healthy urine samples were taken from different regions of the governorate. The urine was taken from renal stone patients treated with lithotripsy. The study included two groups, 20 patients and 20 healthy individuals as a control. Both groups consisted of 10 women and 10 men. The age range was 21-69 years. Using atomic absorption spectroscopy (AAS), the levels of cadmium, lead, and mercury in the urine samples were measured at reference wavelengths of 228.8, 283.3, and 253.7 nm for cadmium, lead, and mercury, respectively[15]. The urine was subjected to digestion to estimate the heavy metal levels in the urine sample. This involved transferring 1 ml of urine into a test tube and adding 1 ml of concentrated nitric acid (HNO_3). The mixture was then allowed to incubate for 24 hours. The solution is prepared by combining hydrogen peroxide (H_2O_2) and nitric acid in a ratio of 1:2 and maintaining a temperature of 70 °C. The resulting mixture is allowed to stand for a duration of one to two hours until it achieves a state of clarity [16,17] The device was calibrated by establishing dilute concentrations for each element independently, as shown in Figure 1.

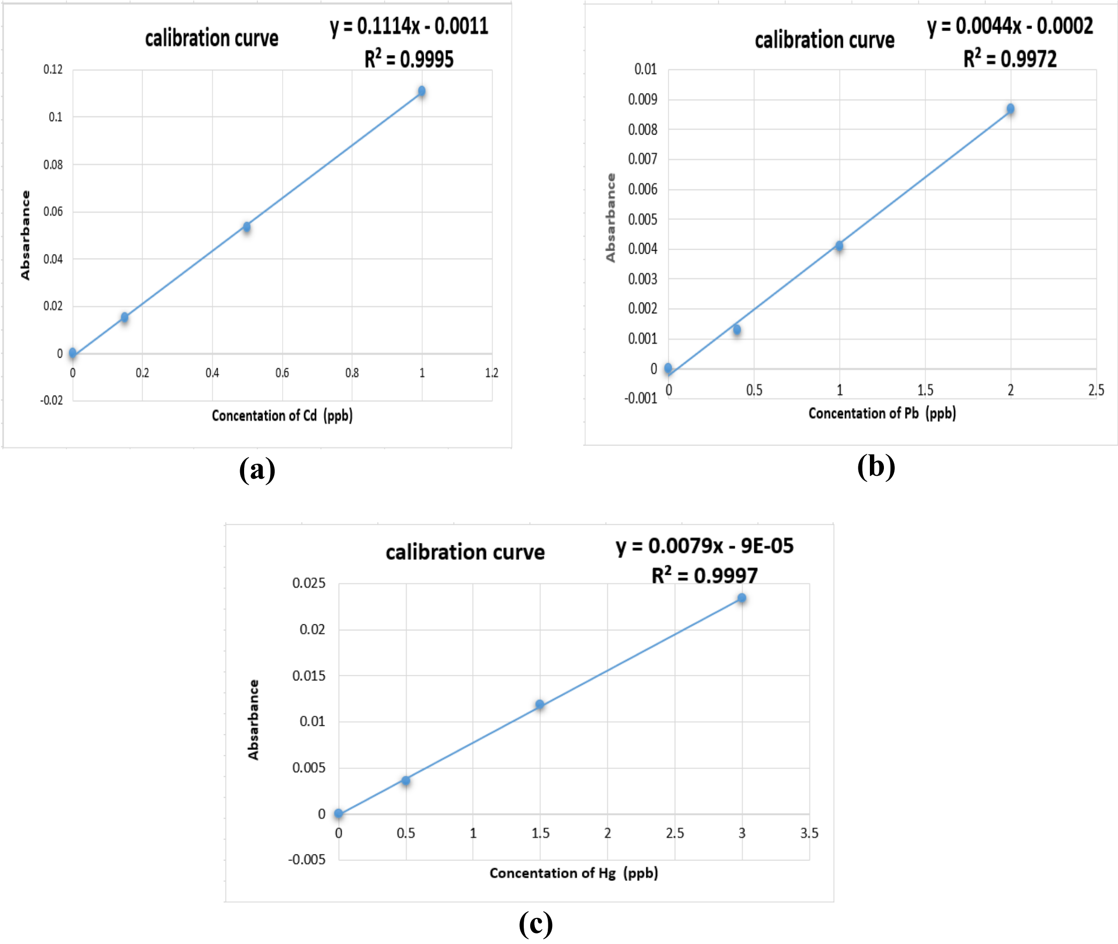


Figure 1: (a) Calibration curve of Cd, (b) Calibration curve of Pb, (c) Calibration curve of Hg

3. Statistical Analysis

Data were analyzed using SPSS. In this analysis, frequency, percentage, mean, standard deviation (SD), and range were considered, and qualitative data were analyzed using Pearson's chi-square test. Receiver Operation Curve (ROC) was used to determine the area under the curve with confidence interval (95% CI) for the urine levels of (Cd, Pb, and Hg) to discriminate between the renal stone patients against the healthy controls through obtaining the cut-off point. P values less than 0.005 and 0.001 indicated that the differences were statistically significant.

4. Results

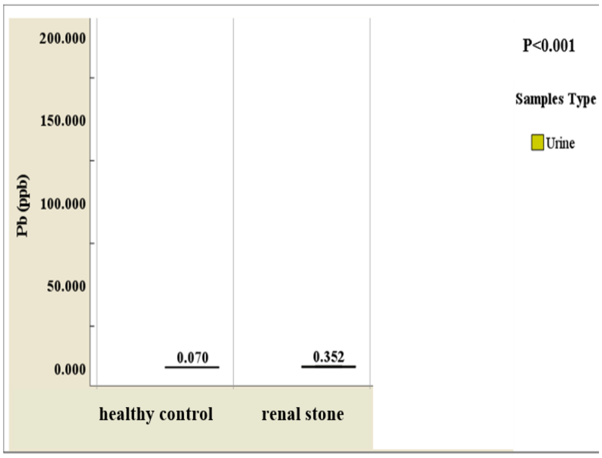
4.1 Comparison of the levels of (Cd, Pb, and Hg) in the urine of healthy control and renal stone patients

Table 1 shows a comparison between the renal stone patients with healthy controls. It is clear that there was a significant difference ($P<0.001$) between the mean (±SD) concentration of Cd 0.007 (±0.007) (ppb) in healthy control as compared to the mean (±SD) 0.150 (±0.077) (ppb) of the renal stone patients' samples. Also, the results demonstrated a significant difference ($P<0.001$) between the mean (±SD) concentration of lead 0.061 (±0.035) in healthy control as compared to the mean (±SD) 0.464 (±0.305) (ppb) in renal stone samples. Comparing the results of the mean (±SD) of the concentration of mercury 0.000 (±0.000) in healthy control with the mean (±SD) 10.499 (±11.125) (ppb) in renal stone patients revealed the significant difference between the two groups (p<0.001), the Median (IQR) was (0.006, 0.144), (0.070, 0.352), (0.000, 7.679) (ppb) of Cd, Pb, and Hg in healthy control and renal stone patients, as shown in Figure 2.

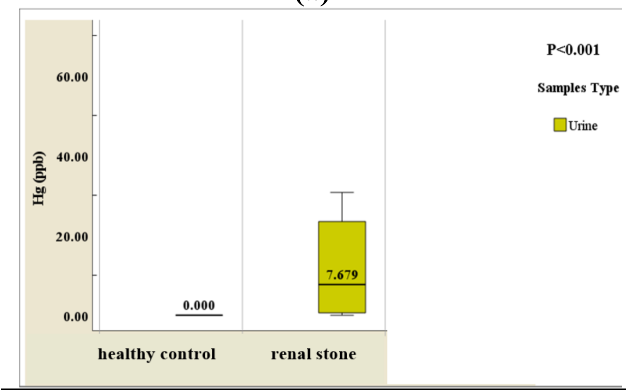
Table 1: Comparison levels of (Cd, Pb, Hg) in urine among the healthy control and renal stone patients

Groups		Cd (ppb)	Pb (ppb)	Hg (ppb)
		urine	urine	urine
healthy control	N	20	20	20
	Mean	0.007 *B	0.061 *B	0.000
	SEM	0.002	0.008	0.000
	±SD	0.007	0.035	0.000
	Min-Max	0.000-0.018	0.010-0.109	0.000-0.000
	Median (IQR)	0.006 (0.00-0.014)	0.070 (0.023-0.090)	0.000
renal stone	N	20.000	20	20
	Mean	0.150 *A	0.464 *A	10.499 *A
	SEM	0.017	0.068	2.488
	± SD	0.077	0.305	11.125
	Min-Max	0.009-0.282	0.115-1.078	0.000-30.718
	Median (IQR)	0.144(0.107-0.215)	0.352 (0.198-0.789)	7.679(0.295-23.973)
	p-value	T= -4.353 <0.001	T= -5.411 <0.001	T= -5.789 <0.001

(a)



(b)



(c)

Figure 2: (a) comparison of median levels of Cd, (b) comparison of median levels of Pb, (c) comparison of median levels of Hg of the Studied Groups

4.2 Comparison of the levels of (Cd, Pb, and Hg) in the urine of male and female healthy control and renal stone patients

The statistics analysis results in Table 2 showed that the mean (±SD) of Cd levels do not significantly differ in male and female urine for the healthy control group and renal stone patients group. Also, no significant difference was seen in the mean (±SD) of Pb levels in the urine for healthy control, but there was a significant difference ($p < 0.005$) in the mean (±SD) of Pb levels for renal stone patients in females (0.6±0.103) (ppb), which was more than that of males (0.328±0.07) (ppb). There was a significant difference ($p < 0.005$) in mean (±SD) of Hg levels for renal stone patients in females (15.503±3.63) (ppb) compared to males (5.495) (p values = 0.004)

Table 2: Comparison between levels of (Cd, Pb, and Hg) of males and females for healthy control and renal stone patients

Groups	Sex	Cd (ppb)		Pb (ppb)		Hg (ppb)	
		Urine	p-value	urine	p-value	urine	p-value
healthy control	Male	0.007±0.002	0.998 ns	0.067±0.011	0.882 ns	0±0	1.000
	Female	0.007±0.002		0.054±0.011		0±0	
renal stone	Male	0.14±0.019	0.465 ns	0.328±0.07	0.004*	5.495±2.718	0.004*
	Female	0.159±0.03		0.6±0.103		15.503±3.63	

4.3. ROC curves for (Cd, Pb, and Hg) levels in renal stone patients

ROC curve shows the sensitivity and specificity for the urine levels of (Cd, Pb, and Hg) for the renal stone patients, the cut-off point was (0.032,0.112, and 0.0001), AUC= (0.978,1.000, and 1.000), P value <0.001, CI (0.932-1.023, 1.000-1.000, and 1.000-1.000), the sensitivity (0.95, 1.00, and1.00) and the specificity was (1.00, 1.00, and1.00), as shown in Table 3 and Figure 3.

Table 3: ROC curve for levels of (Cd, Pb, and Hg) of the renal stone patients with healthy controls.

	Area under the ROC Curve renal stone with healthy control						
Samples Type	Predicts	Area (AUC)	p-value	95%CI	Cut-off Point	Se.	Sp.
urine	Cd (ppb)	0.978	<0.001	0.932-1.023	0.032	0.95	1.00
	Pb (ppb)	1.000	<0.001	1.000-1.000	0.112	1.00	1.00
	Hg (ppb)	1.000	<0.001	1.000-1.000	0.0001	1.00	1.00

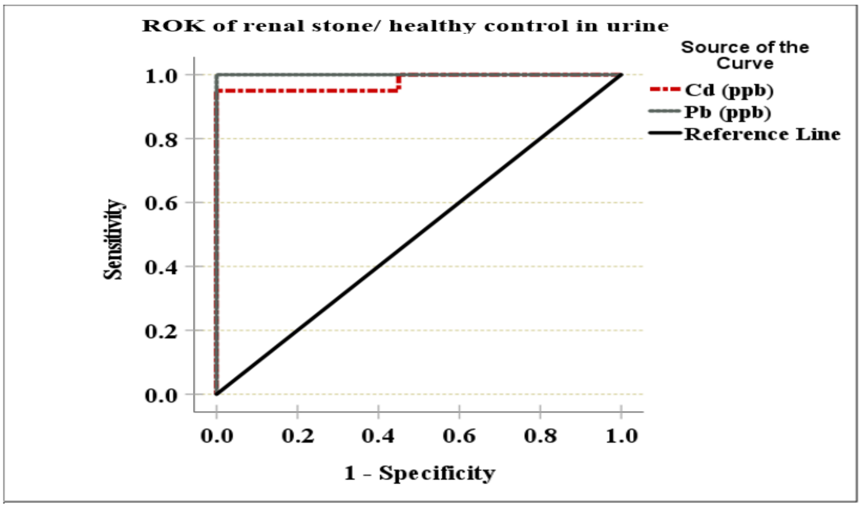


Figure 3: ROC curve of the renal stone patients with healthy controls.

5. Discussion

The results presented in Table 1 obtained from the employment of Mann Whitney test show a significant difference in Cd, Pb, and Hg levels in urine between the healthy control and renal stone patients [18]. As demonstrated in Table 2, the statistics analysis results indicated that there was no significant difference in levels of Cd, Pb, and Hg in the urine of males and females in healthy control groups, also no significant difference in Cd levels in healthy control, but there was a significant increase in the levels of Pb and Hg in females and males of renal stone patients samples[19-21]. Table 3 shows that the levels of Cd and Pb in urine have high AUC values (ranging from 0.978 to 1.000), which indicates that there are high predictions for the levels of these elements in urine it may be due to exposure to contaminated sources (such as contaminated foods or industrial environments)[22]. All AUC values were statistically significant ($p < 0.001$). Sensitivity shows good performance across all predictors. The AUC values are quite high in most cases, indicating good to excellent discriminatory ability of these tests [23,24] . The high AUC values and the large decrease in p-values show that the levels of these elements can be, to a good extent, reliably used as biomarkers to predict health status (e.g., the effect of kidney stones present), which is potential scientific evidence for the relevance of these elements to biological changes in the body. There is a strong possibility that chronic exposure to these elements is associated with certain conditions, such as kidney tissue damage or kidney disease, making them important biomarkers[25-27].

6. Conclusions

The results indicate that the accumulation of Cd, Pb, and Hg in the urine affects the presence of renal stone patients. These findings suggest that renal stone patients may be associated with higher lead levels in urine compared to the healthy control group. The result data demonstrated that renal stone patients have measurable urine Hg levels, which are undetectable (0.000 ppb) in the healthy control group. These results suggest that these tests have promising potential in distinguishing individuals with renal stone from healthy controls, with some tests showing near-perfect discrimination (AUC = 1.000) and high sensitivity and specificity.

Ethical clearance

This study performed based on ethical clearance by the Ethics Committee of the Kufa University, with approval number of (2013) and date of (21/02/2024).

Acknowledgements

We would like to express our warm thanks and praise to the University of Kufa, Iraq, for the support and facilities it provides to researchers.

Disclosure and conflict of interest

The authors declare that they have no conflicts of interest.

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