Research Square

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Admission and In-Hospital Laboratory Parameters Predict Mortality in Acute Paraquat Poisoning

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Abstract

Background

Paraquat is a highly toxic herbicide with no effective antidote, associated with mortality rates ranging from 50% to 90%. Urinary paraquat concentration is the most important prognostic factor; however, measurement kits are unavailable in many regions. This study aimed to investigate the relationship between routine laboratory findings and the outcome of patients with paraquat poisoning.

Methods

This descriptive-analytical study was conducted on 119 patients with paraquat poisoning admitted to Shahid Rahimi Hospital, Khorramabad, Iran, from 2013 to 2023. Demographic data, laboratory parameters (creatinine, potassium, sodium, calcium, and oxygen saturation) upon admission and during hospitalization, and outcomes (complete recovery, partial recovery, or death) were collected using a researcher-developed checklist. Data were analyzed using SPSS software with one-way ANOVA, Kruskal-Wallis, and Chi-square tests. A p-value < 0.05 was considered statistically significant.

Results

The overall mortality rate was 56.3% (67 patients). No significant differences were observed in age (P = 0.153) or gender (P = 0.853) among outcome groups. Deceased patients had significantly higher admission creatinine (1.20 ± 0.36 mg/dL, P = 0.005) and sodium levels (142.06 ± 4.46 mEq/L, P = 0.001), and lower oxygen saturation (88.97 ± 3.11%, P < 0.001) compared to recovered patients. During hospitalization, deceased patients demonstrated the highest creatinine levels (3.09 ± 0.82 mg/dL, P < 0.001), lowest potassium levels (3.25 ± 0.28 mEq/L, P < 0.001), and most pronounced decrease in oxygen saturation (-6.64 ± 4.21%, P < 0.001). Calcium levels showed no consistent association with outcome.

Conclusion

Increased creatinine, decreased potassium, and decreased oxygen saturation were independent risk factors for poor prognosis in acute paraquat poisoning. These readily available laboratory parameters can serve as valuable prognostic indicators, particularly in settings where urinary paraquat measurement is unavailable.

Introduction

Paraquat (1,1'-dimethyl-4,4'-bipyridinium dichloride) is a non-selective herbicide widely used in agriculture and horticulture worldwide (1) and is currently the second best-selling herbicide globally,

available in over 100 countries (2). Although ingestion represents the most common route of poisoning (3), cases of toxicity through dermal or mucous membrane contact (4), inhalation (5), and injection have also been documented (6).

In adults, the estimated lethal dose is approximately 30 mg/kg (7) or 3–6 grams of paraquat ion (8), equivalent to 10–20 mL of a 20% solution (9). Remarkably, as little as one teaspoon of concentrated paraquat can be fatal (10).

Following ingestion, paraquat is rapidly but incompletely absorbed and is largely excreted unchanged in urine within 12–24 hours (11). The compound is actively taken up against a concentration gradient into lung tissue, where it induces pneumonitis and pulmonary fibrosis (12). Additionally, paraquat causes damage to the heart, kidneys, liver, adrenal glands, central nervous system, muscles, and spleen, culminating in multi-organ failure (13). Clinical manifestations associated with paraquat poisoning include acute lung injury, increased pulmonary artery pressure, leukocytosis, metabolic acidosis, cardiomegaly, acute kidney injury, generalized edema, and elevated levels of amylase, glucose, and creatinine (14, 15).

To date, no effective antidote has been identified for paraquat poisoning (16). Despite considerable variation in treatment approaches, mortality rates remain exceedingly high across all centers, ranging from 50% to 90% (17, 18). In cases of deliberate self-poisoning with concentrated formulations, mortality approaches 100% (19).

These factors underscore the severity and high complication rate of paraquat toxicity (20). Consequently, due to its extreme toxicity, the European Union, followed by most countries worldwide, banned paraquat from their markets in July 2007 (21, 22).

Although intensive treatment protocols are employed to improve prognosis, controversy persists regarding the efficacy of secondary decontamination methods (23). Given that laboratory data are readily accessible in emergency settings, laboratory parameters may assist clinicians in predicting the clinical course of paraquat poisoning. Furthermore, given the close relationship between organ damage and poisoning severity, assessing disease progression through laboratory markers represents a practical approach (24).

However, kits for measuring urinary paraquat concentration are unavailable in Khorramabad, despite numerous cases of paraquat poisoning in this region. Therefore, the present study aims to determine initial laboratory parameters upon admission, before intensive medical intervention, and evaluate which laboratory findings serve as prognostic indicators for paraquat poisoning. The findings will enable physicians to incorporate prognostic factors other than urinary paraquat concentration into their clinical management of affected patients.

Materials and Methods

Study Design and Setting

This descriptive-analytical study was conducted to investigate the relationship between laboratory findings and the prognosis of patients with paraquat poisoning at Shahid Rahimi Hospital in Khorramabad, Iran, from 2013 to 2023.

Study Population

The study population comprised all patients with paraquat poisoning who were admitted to Shahid Rahimi Hospital during the ten-year study period. A census sampling method was employed, including all eligible patients. A total of 119 patients were enrolled in the study.

Inclusion and Exclusion Criteria

The inclusion criterion was all patients poisoned with paraquat who presented to Shahid Rahimi Hospital between 2013 and 2023. Patients were excluded if they: (1) had no vital signs upon arrival; (2) were simultaneously poisoned with other substances; (3) had diabetes, hypertension, or a history of cardiac, pulmonary, or renal diseases; (4) had immunodeficiency or were taking immunosuppressive doses of corticosteroids; or (5) had incomplete medical records.

Data Collection

Following ethical approval from the Vice Chancellor for Research, data were collected using a researcher-developed checklist. The researcher reviewed medical records from the hospital's archives and extracted the following information: age, sex, final outcome (death, complete recovery, or partial recovery), creatinine levels upon admission and during hospitalization, potassium and calcium levels upon admission and during hospitalization, sodium levels upon admission and during hospitalization, and oxygen saturation (SpO_2) upon admission.

Statistical Analysis

Data were analyzed using SPSS software (version X). Descriptive statistics including mean, standard deviation, minimum, and maximum values were calculated for continuous variables. The normality of data distribution was assessed using appropriate tests. For comparisons among outcome groups, one-way ANOVA was used for normally distributed data, and the Kruskal-Wallis test was used for non-normally distributed data. The Chi-square test was employed to examine associations between categorical variables. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 119 patients with paraquat poisoning were included in this study. The overall mortality rate was 56.3% (67 patients), while 21.8% (26 patients) achieved complete recovery and 21.8% (26 patients) achieved partial recovery (Table 1).

Table 1
Baseline Demographic Characteristics of Patient Groups by Final Outcome.

Variable		Recovery (n = 26)	Partial Recovery (n = 26)	Death (n = 67)	Total (N = 119)	P-value
Age (years), Mean ± SD		23.88 ± 7.59	22.92 ± 8.68	27.72 ± 14.36	25.71 ± 12.15	0.153[1]
Gender, N (%)	Male	15 (57.7%)	16 (61.5%)	40 (59.7%)	71 (59.7%)	0.853[2]
	Female	11 (42.3%)	10 (38.5%)	27 (40.3%)	48 (40.3%)	
[1]One-way ANOVA						
[2]Chi-square test						

Demographic Characteristics

The mean age of patients was 25.71 ± 12.15 years (range: 10–82 years). No significant differences were observed in age or gender distribution among the three outcome groups. The mean age was 23.88 ± 7.58 years in recovered patients, 22.92 ± 8.68 years in partially recovered patients, and 27.72 ± 14.36 years in deceased patients (P = 0.153). Males constituted 59.7% of the study population, with no significant gender differences across outcome groups (P = 0.853) (Table 2).

Table 2
Comparison of Creatinine Levels According to the Final Outcome of Patients

Time Point / Final Outcome	Mean	Std. Deviation	Minimum	Maximum	P Value
Upon Admission					
Recovery	1.038	0.1023	0.9	1.3	0.005
Partial Recovery	1.012	0.1275	0.8	1.5	
Death	1.200	0.3635	0.8	2.1	
During Hospitalization					
Recovery	1.6500	0.47265	0.80	3.00	0.000
Partial Recovery	2.1000	1.09581	0.70	3.90	
Death	3.0867	0.81869	1.20	6.50	
Change During Hospitalization					
Recovery	0.6115	0.46418	-0.20	1.90	0.000
Partial Recovery	1.0885	1.07938	-0.30	2.90	
Death	1.8867	0.84299	0.30	5.60	

Laboratory Findings

Significant differences in creatinine levels were observed among outcome groups at all time points. Admission creatinine was significantly higher in deceased patients (1.20 ± 0.36 mg/dL) compared to recovered (1.04 ± 0.10 mg/dL) and partially recovered patients (1.01 ± 0.13 mg/dL) ($P = 0.005$). During hospitalization, creatinine levels increased markedly in all groups, with the highest levels in deceased patients (3.09 ± 0.82 mg/dL) followed by partially recovered (2.10 ± 1.10 mg/dL) and recovered patients (1.65 ± 0.47 mg/dL) ($P < 0.001$). The mean change in creatinine was also significantly different among groups ($P < 0.001$), with the greatest increase observed in deceased patients (1.89 ± 0.84 mg/dL) (Table 3).

Table 3
Comparison of Laboratory Parameters According to Final Outcome of Patients

Parameter	Recovery (n = 26) Mean ± SD	Partial Recovery (n = 26) Mean ± SD	Death (n = 67) Mean ± SD	P-value*
Creatinine (mg/dL)				
Admission	1.04 ± 0.10	1.01 ± 0.13	1.20 ± 0.36	0.005
Hospitalization	1.65 ± 0.47	2.10 ± 1.10	3.09 ± 0.82	< 0.001
Change	0.61 ± 0.46	1.09 ± 1.08	1.89 ± 0.84	< 0.001
Potassium (mEq/L)				
Admission	3.98 ± 0.34	4.03 ± 0.35	3.91 ± 0.34	0.272
Hospitalization	3.62 ± 0.38	3.91 ± 0.56	3.25 ± 0.28	< 0.001
Change	-0.36 ± 0.50	-0.12 ± 0.68	-0.66 ± 0.38	< 0.001
Sodium (mEq/L)				
Admission	138.54 ± 2.93	140.31 ± 4.05	142.06 ± 4.46	0.001
Hospitalization	140.00 ± 2.79	139.88 ± 1.61	140.94 ± 2.44	0.077
Change	1.46 ± 3.60	-0.42 ± 2.97	-1.12 ± 3.57	< 0.001
Calcium (mg/dL)				
Admission	8.82 ± 0.13	8.75 ± 0.24	8.94 ± 0.10	0.005
Hospitalization	8.71 ± 0.20	8.70 ± 0.21	8.74 ± 0.10	0.689
Change	0.11 ± 0.23	0.05 ± 0.21	0.19 ± 0.13	0.275
Oxygen Saturation (%)				
Admission	93.35 ± 2.23	91.19 ± 3.82	88.97 ± 3.11	0.000
Hospitalization	94.27 ± 0.83	94.19 ± 1.02	82.33 ± 2.54	0.000
Change	0.92 ± 2.26	3.00 ± 3.92	-6.64 ± 4.21	0.000
*One-way ANOVA test				
Change = Hospitalization value - Admission value				

Admission potassium levels were similar across all outcome groups (P = 0.272). However, during hospitalization, significant differences emerged (P < 0.001), with deceased patients showing the lowest potassium levels (3.25 ± 0.28 mEq/L) compared to partially recovered (3.91 ± 0.56 mEq/L) and recovered patients (3.62 ± 0.38 mEq/L). The change in potassium also differed significantly among groups (P < 0.001), with deceased patients demonstrating the greatest decrease (-0.66 ± 0.38 mEq/L) (Table 3).

Admission sodium levels were significantly higher in deceased patients (142.06 ± 4.46 mEq/L) compared to partially recovered (140.31 ± 4.05 mEq/L) and recovered patients (138.54 ± 2.93 mEq/L) (P = 0.001). During hospitalization, sodium levels were not significantly different among groups (P = 0.077). However, the change in sodium showed significant differences (P < 0.001), with recovered patients demonstrating an increase (1.46 ± 3.60 mEq/L) while partially recovered (-0.42 ± 2.97 mEq/L) and deceased patients (-1.12 ± 3.57 mEq/L) showed decreases (Table 3).

Admission calcium levels differed significantly among outcome groups (P = 0.005), with partially recovered patients showing the lowest levels (8.75 ± 0.24 mg/dL) and deceased patients the highest (8.94 ± 0.10 mg/dL). During hospitalization, calcium levels were similar across all groups (P = 0.689), and no significant differences were observed in the change of calcium levels (P = 0.275) (Table 3).

Significant differences in oxygen saturation were observed at all time points (P < 0.001). Admission SpO_2 was lowest in deceased patients (88.97 ± 3.11%) compared to partially recovered (91.19 ± 3.82%) and recovered patients (93.35 ± 2.23%). During hospitalization, this disparity became more pronounced, with deceased patients showing markedly lower SpO_2 (82.33 ± 2.54%) compared to partially recovered (94.19 ± 1.02%) and recovered patients (94.27 ± 0.83%). The change in SpO_2 also differed significantly, with deceased patients showing a substantial decrease (-6.64 ± 4.21%) while recovered and partially recovered patients showed increases (0.92 ± 2.26% and 3.00 ± 3.92%, respectively) (Table 3).

Discussion

Given the very high mortality rate associated with paraquat poisoning and the lack of adequate facilities at Shahid Rahimi Hospital's teaching medical center for monitoring the health status of patients poisoned with paraquat, including urinary kits indicating paraquat levels, the presence of other criteria to assist physicians in following up these patients seems essential. Therefore, the present study was conducted to investigate the relationship between laboratory findings and the final outcome of patients with paraquat poisoning at Shahid Rahimi Hospital in Khorramabad during the years 2013 to 2023.

This study found that the mean serum creatinine levels upon admission and during hospitalization were significantly higher in patients who died compared to those who recovered. Admission potassium levels did not differ among patients with different prognoses; however, potassium levels during hospitalization were significantly lower in deceased patients compared to those who recovered. Admission sodium levels were significantly higher in deceased patients than in other patients, but no relationship was observed between patients' final outcome and their sodium levels during hospitalization. Although admission calcium levels differed statistically among the three groups (death, partial recovery, and complete recovery), this difference was not interpretable. Furthermore, no statistically significant difference in serum calcium levels was observed between deceased and recovered patients. Admission oxygen saturation and oxygen saturation during hospitalization were significantly lower in deceased patients compared to those who recovered.

The increase in creatinine levels among deceased patients was markedly higher than in recovered patients, reaching a value of 1.8, which clearly indicates that acute renal failure is significantly associated with patient mortality. The decrease in potassium levels was also significantly greater in deceased patients compared to others, demonstrating that hypokalemia is significantly associated with patient death. The decline in oxygen saturation was significantly greater in deceased patients than in other patients, reflecting pulmonary injury caused by paraquat. Additionally, no significant relationship was observed between patients' final outcome and their age or gender.

Previous studies have identified urinary paraquat concentration as the most important prognostic factor. Kim et al. (25), investigating renal manifestations of paraquat poisoning in 2009, and Yamaguchi et al. (26), examining prognosis in acute paraquat poisoning in 2000, both emphasized urinary paraquat levels as the primary predictor of outcome.

The findings of the present study regarding the prognostic value of patients' creatinine levels for their final outcome were consistent with the meta-analysis study conducted by Huang et al. (27). Furthermore, the findings of Zhao et al. were also consistent with the results of this study regarding the prognostic role of patients' oxygen saturation (28).

Furthermore, the findings of the study by Lin Lin et al. showed that hypokalemia and increased blood creatinine levels were independent factors for predicting patient mortality, which was consistent with the results of the present study (29).

In this study, calcium played no role in patient prognosis, whether upon admission, during hospitalization, or in terms of its changes; in this respect, the findings of this study were consistent with the findings of the study by Lin Lin et al (29).

This study showed that patients who died experienced a decrease in sodium concentration during their hospital course, whereas patients who recovered had stable or increased serum sodium levels. Unfortunately, studies investigating patient sodium levels are limited, and no comparison was possible.

Conclusion

Decreased potassium levels, increased creatinine levels, and decreased blood oxygen saturation were identified as independent risk factors for poor prognosis in patients with acute paraquat poisoning.

It is recommended that clinical trial studies be conducted on animals to find an effective drug for paraquat poisoning. Additionally, necessary facilities should be provided for rapid dialysis of patients poisoned with paraquat. Furthermore, it is suggested that paraquat be removed from the market and replaced with less toxic pesticides that have minimal impact on human health. Finally, similar studies are recommended to further investigate the role of sodium in predicting patient mortality.

Declariation

Declarations

Clinical trial number

Not applicable.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

AUTHORS' CONTRIBUTION

The authors confirm their contributions to the paper as follows: PA: conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript. MA and KKh: designed the data collection instruments, collected data, carried out the initial analyses, and reviewed and revised the manuscript. HA and MM: coordinated and supervised data collection and critically reviewed the manuscript for important intellectual content. All authors reviewed the results and approved the final version of the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Permission was taken from the Ethics Committee and Research Committee of Lorestan University of Medical Sciences (**IR.LUMS.REC.1402.334**).

HUMAN AND ANIMAL RIGHTS

All procedures performed in this study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

CONSENT FOR PUBLICATION

Informed consent was obtained (the under 16 years old was given by a parent or legal guardian).

AVAILABILITY OF DATA AND MATERIALS

The data and supportive information are available within the article.

STANDARDS OF REPORTING

Strobe guidelines were followed.

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