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Case Series

The effect of hemoperfusion on the outcome and prognosis of paraquat poisoning

Zohreh Oghabian[1], Maral Ramezani[2,3], Shahin Shadnia[4], Farah Pouramiri[5], Babak Mostafazadeh[4], Masoomeh Varzandeh[5], Peyman Erfan Talab Evini[4], Shahrad Tajaddini[5], Mitra Rahimi[4*]

[1]Department of Pharmacology and Toxicology, Medicine and Religion Research Center , School of Pharmacy, Kerman University of Medical Sciences, Kerman,Iran
[2]Department of Pharmacology, School of Medicine, Arak University of Medical Sciences, Arak, Iran
[3]Department of Pharmacology, Traditional and Complementary Medicine Research Center, Arak University of Medical Sciences, Arak, Iran
[4]Department of Clinical Toxicology,Toxicological Research Center, Excellence Center of Clinical Toxicology, Loghman Hakim Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[5]Department of Clinical Toxicology and Poisoning, Afzalipour Hospital, Faculty of Medicine , Kerman University of Medical Sciences, Kerman, Iran
[6]Department of Clinical Toxicology and Poisoning, Afzalipour Hospital, Faculty of Medicine , Kerman University of Medical Sciences, Kerman, Iran
[7]Department of Clinical Toxicology and Poisoning, Afzalipour Hospital,Faculty of Medicine , Kerman University of Medical Sciences, Kerman, Iran

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***Corresponding author:**
Mitra Rahimi,
Email: mrahimi744@gmail.com

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Abstract

Objective: Paraquat poisoning is a critical condition with a high mortality rate, and there are currently no established treatment guidelines for managing this toxin. Hemoperfusion constitutes an alternative treatment for paraquat poisoning. This study aimed to evaluate the efficacy of hemoperfusion therapy using the Jafron HA330 hemoperfusion cartridge in patients with paraquat poisoning.

Case Presentations: This case series study was conducted on paraquat poisoning patients in Tehran's Loghman Hakim and Kerman's Afzalipour hospitals. In addition to the standard treatment of poisoning patients, the patients underwent hemoperfusion using the HA330 cartridge three times at 24-hour intervals, each time lasting 180–240 minutes. Before and following the completion of the treatment program, patients' information and laboratory results were meticulously documented. Statistical analysis was performed using SPSS software version 21. The study noted that eight of the nine patients passed away. A notable finding was the significant reduction in potassium levels in the blood. Seven patients required intubation. A notable reduction in hemoglobin levels was detected following treatment. Furthermore, a decline in bicarbonate and pH levels was observed in patients, in post-treatment, though this decrease did not attain statistical significance. Conversely, the total bilirubin levels exhibited an increase in patients following treatment; however, this change was not statistically significant.

Conclusion: The findings of this study suggest that hemoperfusion with HA330 cartridges does not yield a substantial improvement in the survival of patients poisoned by paraquat.

Keywords: Extracorporeal, Circulation, Hemoperfusion, Paraquat, Poisoning

Introduction

Paraquat (1,1-dimethyl-4,4'-bipyridinium chloride), a prominent herbicide from the bipyridyl group, is extensively utilized in the agricultural sector as a non-selective herbicide. This pesticide can be administered from the ground or air. It is a well-documented toxicant that primarily affects the pulmonary system (1). Paraquat exerts its herbicidal effect by interfering with the intracellular electron transport system and inhibiting the conversion of NADP to NADPH during photosynthesis, causing the formation of superoxide and its radicals, which are clearly deleterious to cells. Any cell that is exposed to this substance becomes poisoned. This chemical changes the cell cycle, ultimately leading to cell damage and death. It is important to note that this chemical exerts its toxic effects on other organisms, including humans and animals, in a manner analogous to its impact on insects (2).

The clinical manifestations of paraquat poisoning in humans have been documented in various physiological systems. In instances where the substance affects the integumentary system and mucous membranes, clinical manifestations include cutaneous and nail destruction,

as well as damage to the cornea, conjunctiva, and nasal mucosa. In the event of the digestive system being affected by the ingestion of this substance, the clinical manifestations include the presence of oral and pharyngeal ulcers, nausea, bloody vomiting, dysphagia, esophageal perforation, pancreatitis, central lobular necrosis, and cholestasis (3,4). A sensitive urine test can qualitatively diagnose paraquat poisoning at concentrations of one microgram per milliliter or more. Radioimmunoassay has enhanced the ability to identify paraquat and better predict a person's survival (5).

A plethora of treatments have been evaluated in clinical and experimental settings for their efficacy in addressing paraquat poisoning. These treatments encompass a wide range of pharmacological modalities, including corticosteroids, immunosuppressive agents, fibrinolytic agents, colchicine, radiotherapy, iron removal through the use of chelating agents such as deferoxamine, and selenium, which functions as a cofactor for glutathione enzyme peroxidase (6,7). Despite the absence of compelling evidence, some medical practitioners have adopted the practice of prescribing vitamin C and vitamin E for cases of paraquat poisoning. This approach is primarily driven by the perceived safety and minimal adverse effects of these substances (8-11). Lung transplantation has been performed in some cases of paraquat poisoning. In patients who survive for three weeks and demonstrate a favorable general condition, a bilateral lung transplant can be considered in the event of imminent respiratory failure (12,13).

In the treatment of paraquat poisoning, hemoperfusion (HP) stands as an alternative therapeutic modality. Poisons with a low volume of distribution and rapid intercompartmental transfer are likely to be effectively removed by hemoperfusion (14). It is the prevailing opinion among researchers that HP is an effective method for the elimination of paraquat from plasma (15-19). The present study was conducted to investigate the effect of hemoperfusion with the HA330 cartridge (Jafron Company) on patients poisoned with paraquat and their laboratory factors.

Table 1 presents the patients' demographic and basic information. Only nine patients met the inclusion criteria for the study. Individuals who died before hemoperfusion, exhibited active bleeding, experienced thrombocytopenia with platelet counts below 20 000, or declined to provide consent were excluded from the study. The study included nine patients: five males (55.6%) and four females (44.4%). The mean age of the participants was 40.78 years (±21.3 years) with an age range of 17–82 years.

Two subjects resided in urban areas, and seven resided in rural communities. It is noteworthy that none of the patients had a history of suicide attempts. In eight cases (88.9%), the utilization of paraquat was deliberate, and in one case, it was unintentional. The patients' occupations are listed as follows: two freelancers, one student, four homemakers, one farmer, and one retiree.

Table 1. Demographic data and important information about the examined patients

	Frequency (%) or mean ± SD
Gender (male)	5 (55.6%)
Age (year)	40.78 ± 21.3
Ingestion dose (CC)	130 ± 96.13
History of suicide (no)	9 (100%)
Home location (city)	2 (22.2%)
History of substance abuse (no)	8 (88.9%)
Cause of poisoning (intentional)	8 (88.9%)
Mechanical ventilation (yes)	7 (77.8%)
Hospitalization period (day)	5.06 ± 3.5
Length of stay in the ICU (day)	4.4 ± 3.3
Number of dialyses	3.9 ± 3.2
Number of hemoperfusions	3.11 ± 2
Duration of hemoperfusions (hour)	2.7 ± 1.3
Outcome (died)	8 (88.9%)

Only one individual had a documented history of substance abuse, and the substance was opium. Three patients had a medical history marked by neurological and psychiatric illnesses, and one individual had a medical history marked by renal disease and nephrectomy.

Methods

This case series study examined patients who referred with paraquat poisoning to Tehran's Loghman Hakim and Kerman's Afzalipour hospitals. The patients from Kerman were from 2017, and the patients from Tehran were from 2023. The study encompassed a total of nine patients. The study included patients aged 14–75 years who had been poisoned by the herbicide paraquat, were not pregnant, and had consented to participate.

In addition to the standard treatment of poisoned patients, hemoperfusion was performed using the HA330 cartridge three times at 24-hour intervals, each time lasting 180–240 minutes. Before and following the initiation of the treatment program, patient information was collected, including age, sex, occupation, place of residence, history of underlying disease, previous suicide attempts, route of poisoning, amount of substance ingested per kilogram of body weight, duration of hemoperfusion treatment, need for mechanical ventilation, length of hospitalization, and length of stay in the ICU. In addition, the final status of the patient was documented, along with the results of laboratory tests, including white blood cell count, red blood cell count, hemoglobin, neutrophil, lymphocyte, platelet, urea, creatinine, sodium, blood sugar, potassium, calcium, Glasgow Coma Scale, blood pressure, heart rate, respiratory rate, arterial blood gas, aspartate aminotransferase (AST), alanine aminotransferase (ALT),

alkaline phosphatase (ALP), and total bilirubin.

A statistical analysis was conducted using descriptive statistical methods, including frequency, mean, and standard deviation. The normality of the data was checked using the Kolmogorov-Smirnov test. Paired *t* tests, or their non-parametric equivalents such as the Mann-Whitney and Wilcoxon tests, as well as chi-square tests were performed using SPSS software version 21.

The maximum recorded intake was 250 mL, while the minimum was 15 mL. Table 1 presents the demographic and basic information of the patients. Upon admission, all patients exhibited a Glasgow Coma Scale (GCS) score of 15, indicating a state of high consciousness. The following are the average blood indices at admission: white blood cell (WBC) count 14,011.11 cells/μL, red blood cell (RBC) count 5.19×10^6 cells/mL, lymphocyte percentage 6.98%, neutrophil percentage 86.80%, hemoglobin (Hb) 13.36 g/dL, and platelet (PLT) count 158 555.56 cells/mL (see Table 2).

Upon admission, the biochemical parameters were recorded as follows: urea 44.86 mg/dL, creatinine (Cr) 2.40 mg/dL, sodium (Na) 140.33 mEq/L, blood sugar (BS) 141.78 mg/dL, potassium (K) 3.66 mEq/L, ALT 118.71 U/L, AST 139.86 U/L, ALP 226.86 U/L, and total bilirubin 3.06 mg/dL (Table 3). The patient's vital signs upon admission were as follows: heart rate 95.11 beats per minute, respiratory rate 35 breaths per minute, systolic blood pressure (SBP) 120.78 mm Hg, and diastolic blood pressure (DBP) 77.22 mm Hg (Table 4).

Upon admission, the mean of blood gas analysis results was as follows: pH 7.39, bicarbonate 20.24 mEq/L, and PCO2 33.66 mmHg (see Table 4). No definitive laboratory test was accessible, and the poisoning diagnosis relied on the patient's history and the container with paraquat found near them. It should be noted that no CT scans or X-rays were available for the patients in Kerman. Conversely, for the patients in Tehran, CT scans and X-rays were conducted, but no indications of paraquat poisoning were identified. This finding is consistent with the known clinical presentation of paraquat poisoning, in which lung lesions typically manifest after the second week of exposure.

In addition to the administration of standard treatments for poisoning, including the administration of vitamins E and C, corticosteroids, and N-acetylcysteine, hemoperfusion was also performed. Seven patients required mechanical ventilation. The mean number of dialysis sessions was 3.9 ± 3.2. Two patients did not undergo hemodialysis, while one underwent the procedure ten times. The mean number of performed hemoperfusion was 3.11 ± 2, and one patient underwent the procedure six times. The hemoperfusion procedure lasted between two and six hours, with an average duration of 2.7 hours. The average hospital stay was 5.06 ± 3.6 days, ranging from 2 to 12 days, and the average ICU stay was 4.4 ± 3.3 days, ranging from 2 to 11 days.

Seven patients were intubated, and the remaining two had a final GCS of 14 and 15, respectively. The mean blood indices after treatment were as follows: WBC: 15 022.22 cell/μL, RBC: 5.04×10^6 cell/mL, lymphocytes: 7.77%, neutrophils: 84.06%, Hb: 11.29 g/dL, and PLT: 126 888.89 cell/mL (see Table 2).

The post-treatment average of biochemical parameters was as follows: urea: 118.43 mg/dL, Cr: 3.4 mg/dL, Na: 139 mEq/L, BS: 124.33 mg/dL, K: 3.65 mEq/L, ALT: 186.43 U/L, AST: 158.57 U/L, ALP: 268.71 U/L, and total bilirubin: 7.49 mg/dL (Table 3). The mean of vital signs post-treatment was as follows: heart rate: 87.22 beats per minute, respiratory rate: 18.5 breaths per minute, SBP:

Table 2. CBC results before and after treatment of patients

	Before treatment	After treatment	*P* value
WBC (cell/μL)	14011.11 ± 3720.7	15022.22 ± 10679.4	0.75
RBC (10^6 cell/mL)	5.19 ± 0.89	5.04 ± 2.5	0.869
Hb (g/dL)	13.36 ± 2.5	11.29 ± 3.03	0.033*
Platelet (cell/mL)	158555.56 ± 34583.6	126888.9 ± 48755.6	0.193
Lymphocyte (%)	6.97 ± 5.8	7.78 ± 4.2	0.742
Neutrophil (%)	86.8 ± 9.04	84.06 ± 8.8	0.339

WBC: white blood count, RBC: red blood count, Hb: hemoglobin.
*$P < 0.05$. The analysis was done by paired *t*-test.

Table 3. Other results of laboratory tests before and after treatment

	Before treatment	After treatment	*P* value
Urea (mg/dL)	44.86 ± 39.9	118.43 ± 103.6	0.169
Cr (mg/dL)	2.4 ± 2.1	3.4 ± 1.8	0.238
BS (mg/dL)	141.78 ± 88.9	124.33 ± 68.5	0.608
Na (mEq/L)	140.33 ± 4	139 ± 6.4	0.517
K (mEq/L)	4.31 ± 0.71	3.65 ± 0.39	0.037*
ALT (U/L)	118.7 ± 219.05	186.43 ± 151.6	0.426
AST (U/L)	139.86 ± 185.2	158.57 ± 216.3	0.865
ALP (U/L)	226.9 ± 89.9	268.71 ± 198.3	0.611
Total bilirubin (mg/dL)	3.06 ± 4.3	7.49 ± 7.4	0.069

Cr: creatinine, Na: sodium, BS: blood sugar, K: potassium, ALT: alanine aminotransferase, AST: aspartate aminotransferase, ALP: alkaline phosphatase.
*$P < 0.05$. The analysis was done by paired *t*-test.

Table 4. Results of blood gases and vital signs of patients before and after treatment

	Before treatment	After treatment	*P* value
Heart rate (beats/min)	95.11 ± 15.4	87.22 ± 33.8	0.579
Respiratory rate (breaths/min)	35 ± 30.3	18.5 ± 4.1	0.394
Systolic blood pressure (mm Hg)	120.78 ± 11.7	105.78 ± 37.9	0.206
Diastolic blood pressure (mm Hg)	77.22 ± 12.3	65.89 ± 22.2	0.151
pH	7.39 ± 0.1	7.14 ± 0.2	0.053
Bicarbonate (mEq/L)	20.24 ± 6.6	14.81 ± 5.04	0.062
PCO_2 (mm Hg)	33.66 ± 9.8	40.87 ± 11.4	0.272

The analysis was done by paired *t*-test.

105.78 mm Hg, and DBP: 65.89 mm Hg (see Table 4).

Following treatment, the mean of blood gas analysis results was as follows: pH: 7.14, bicarbonate: 14.81 mEq/L, and PCO2: 40.87 mmHg (see Table 4). An analysis of the CBC (complete blood count) test shows that results of the patients revealed no substantial differences in the levels of red blood cells, white blood cells, platelets, lymphocyte percentage, and neutrophil percentage after undergoing hemoperfusion treatment (Table 2). However, a significant decrease in hemoglobin levels was observed after treatment ($P=0.033$).

Table 3 presents the findings of additional laboratory tests. A notable change in blood potassium levels was observed between the pre and post-treatment measurements ($p=0.037$). This alteration was characterized by a decline in potassium levels following treatment. The results presented in Table 4 did not reveal any statistically significant differences in blood pressure, heart rate, respiratory rate, PH, bicarbonate level, and partial pressure of carbon dioxide (PCO2). The mortality rate of the patients was 88.9%.

Discussion

The first artificial kidney was created in the United States in 1913. Its primary function was to eliminate toxins from the bloodstream; salicylates, for example, were successfully removed from blood in dogs (20). Multiple *ex vivo* studies and experimental animal studies demonstrate that a wide range of endogenous and exogenous toxins, including endotoxin, poisons, and drugs, can be removed through blood purification techniques (21-24). This study examined the impact of hemoperfusion using the Jafron H330 cartridge on paraquat-poisoned patients. The study's findings revealed that eight out of the nine patients who underwent examination did not survive. Apart from the noteworthy disparities in hemoglobin and blood potassium levels that ensued after hemoperfusion, no other substantial variations were identified in the remaining parameters.

The present study demonstrated a substantial decrease in hemoglobin levels following hemoperfusion. Similarly, Gil and colleagues' study demonstrated a comparable decrease in hemoglobin levels among poisoned patients who underwent hemoperfusion. In their study, out of 803 people, 492 people were poisoned with paraquat (25). Park et al reported that hemoglobin levels underwent a substantial decline within the initial 30 minutes of hemoperfusion, persisting at a reduced level until the conclusion of the procedure in 250 patients diagnosed with acute pesticide poisoning (26).

In the present study, it was observed that blood potassium levels decreased after hemoperfusion. On the other hand, no substantial variations were observed in the levels of sodium, pH, bicarbonate, and PCO2. Concurrently, Li et al reported that the partial pressure of CO2, pH, blood sodium, and bicarbonate ion levels did not demonstrate significant differences at the onset and 30 minutes and 120 minutes into the hemoperfusion. In their study, potassium levels exhibited a decline over time, though this decline did not reach statistical significance (27).

Guo et al conducted a study to examine the impact of early repeated hemoperfusion in combination with hemodialysis in cases of paraquat poisoning. The treatment approach employed by the researchers encompassed several key components, including immediate gastric lavage using a 2% sodium bicarbonate solution, bowel cleansing using a mixture of 20% polyethylene glycol or mannitol with 50 g of powdered medicinal carbon in 2 L of water, intravenous administration of methylprednisolone, thalidomide, and antioxidants (intravenous vitamin C, N-acetylcysteine, and oral vitamin E), and hemoperfusion using the HA330 cartridge. The efficacy of this multifaceted approach was evident in the observed outcomes. Early and repeated hemoperfusion in conjunction with hemodialysis significantly improved blood-gas indices, as well as liver and kidney function, in patients with paraquat poisoning. Concurrently, this treatment strategy led to an enhancement in short-term survival rates (28). The findings of the present study revealed contrasting results; however, the sample size was quite limited, and the extent of prior drug treatments varied to some extent.

In a study of 213 cases of paraquat poisoning, Yeh et al found that hemoperfusion did not improve 60-day survival rates. Additionally, the study revealed that neither the initial hemoperfusion nor multiple sessions of hemoperfusion demonstrated a correlation with enhanced survival outcomes (29). The findings of the study demonstrated that hemoperfusion did not affect the survival rate. While hemoperfusion is regarded as a viable alternative treatment modality, its efficacy remains a subject of debate. This is primarily due to the multifaceted nature of the condition, which can result in variable outcomes, and the inconsistent findings reported across studies.

The most significant limitation of this study is the relatively small number of patients. Additionally, the study did not investigate the blood concentration of paraquat before and after treatment. Additionally, it would have been better if the variable levels were checked after each hemoperfusion session.

Conclusion

Despite the implementation of hemoperfusion, patient mortality remained high. It underscores the need for alternative or supplementary therapeutic interventions. The employed method resulted in a decline in potassium and hemoglobin levels, which are recognized as complications associated with hemoperfusion. Further research with larger sample sizes is necessary to draw more generalizable conclusions from the available data.

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Authors' Contribution
Conceptualization: Zohreh Oghabian, Mitra Rahimi.
Data curation: Farah Pouramiri, Masoomeh Varzandeh, Shahrad Tajaddini, Zohreh Oghabian, Mitra Rahimi.
Formal analysis: Maral Ramezani.
Investigation: Shahin Shadnia, Babak Mostafazadeh, Peyman Erfan Talab Evini.
Methodology: Maral Ramezani, Zohreh Oghabian, Mitra Rahimi.
Project administration: Zohreh Oghabian, Mitra Rahimi.
Resources: Maral Ramezani, Zohreh Oghabian, Mitra Rahimi.
Software: Maral Ramezani.
Supervision: Zohreh Oghabian, Mitra Rahimi.
Validation: Shahin Shadnia, Babak Mostafazadeh, Peyman Erfan Talab Evini, Farah Pouramiri, Masoomeh Varzandeh, Shahrad Tajaddini, Zohreh Oghabian.
Visualization: Shahin Shadnia, Babak Mostafazadeh, Peyman Erfan Talab Evini, Farah Pouramiri, Masoomeh Varzandeh, Shahrad Tajaddini, Zohreh Oghabian, Maral Ramezani, Mitra Rahimi.
Writing–original draft: Maral Ramezani, Zohreh Oghabian, Mitra Rahimi.

Competing Interests
None.

Ethical Approval
This study was approved by the Institutional Ethics Board of Shahid Beheshti University of Medical Sciences (No. IR.SBMU.RETECH.REC.1401.261). Patients or their legal guardians provided informed consent to participate in the study.

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