International Journal of Medicine
pISSN 1468-3814 | eISSN 2667-7008
https://theinternationalmedicine.com/

Original Researcher Article *DOI: 10.61336/im/26-2-12*

Effect of Early Hemodialysis on Survival in Paraquat Poisoning: A Longitudinal Observational Study from a Tertiary Care Center in India.

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Received: 03-03-2026
Revised: 28-03-2026
Accepted: 04-04-2026
Published: 25-04-2026

Abstract

Background: Paraquat is a widely used but highly toxic herbicide, with poisoning cases often resulting in multi-organ failure and high mortality rates. In developing countries like India, unregulated availability and low awareness worsen the risk of accidental or intentional ingestion. This study was conducted to assess the demographic and clinical profile of PQ poisoning and to evaluate the impact of the timing of hemodialysis initiation on clinical outcomes. ***Methods:*** This was an observational longitudinal study conducted at a tertiary care teaching hospital from August 2019 to January 2021. Patients with confirmed paraquat poisoning were included in the study. Patients were grouped based on the timing of hemodialysis initiation: within 48 hours (Group 1) and after 48 hours (Group 2). Clinical, demographic, and laboratory data were collected, and outcomes were compared using appropriate statistical tests. ***Results:*** A total of 72 patients were included in the study, of whom 61 (84.7%) died. Early initiation of hemodialysis (Group 1) significantly improved survival (p=0.0033), with a fatality rate of 70% compared to 95.2% in Group 2. Survivors had significantly better renal (urea) and hepatic (AST, ALT, bilirubin) function profiles. ***Conclusion:*** Early hemodialysis initiation (within 48 hours of ingestion) was associated with significantly improved survival in paraquat poisoning cases. Urea, liver enzymes, and bilirubin levels may serve as valuable predictors of prognosis.

Keywords: Extracorporeal elimination, Hemodialysis, Hemoperfusion, Paraquat poisoning.

INTRODUCTION

Paraquat dichloride (1,1'-dimethyl-4,4'-bipyridinium dichloride) is a fast-acting, non-selective herbicide introduced in the 1960s. Despite its agricultural utility, it is highly toxic to humans and is classified as a restricted-use chemical in many countries.[1] However, paraquat poisoning remains a serious public health problem in developing nations such as India, especially in rural areas where accidental or intentional ingestion is common due to its low cost, easy accessibility, and limited awareness of its toxicity.[1, 2]

Clinical outcomes after paraquat ingestion are dose-dependent. Even small quantities can cause acute respiratory distress syndrome (ARDS), renal and hepatic failure, and progressive pulmonary fibrosis.[3] Larger doses (>20 mg/kg) lead to rapid multi-organ failure and death, while smaller doses result in delayed but progressive pulmonary injury.[1, 4] Reported case fatality rates are as high as 70%.[1, 4] Paraquat toxicity results mainly from redox cycling and the generation of reactive oxygen species (ROS), which cause oxidative stress, mitochondrial injury, and cell death.[3, 5] The compound preferentially accumulates in alveolar type II cells, kidneys, and liver, producing pulmonary fibrosis, nephrotoxicity, and hepatocellular damage.[1, 4, 6] There is no specific antidote for paraquat poisoning. Its current management includes gastric decontamination (activated charcoal or Fuller's Earth), antioxidants (N-acetylcysteine, vitamins C and E), immunosuppressants (methylprednisolone, cyclophosphamide), and extracorporeal elimination therapies such as hemodialysis or hemoperfusion.[1, 2, 5] However, survival benefits from these interventions remain inconsistent.

Early initiation of hemodialysis or hemoperfusion, ideally within 48 hours of ingestion, may reduce systemic paraquat levels and improve outcomes by preventing further pulmonary accumulation and preserving renal function; however, the existing evidence is limited and inconclusive.[7] The present study evaluated the demographic and clinical profile of paraquat poisoning cases in our tertiary care center and examined the impact of hemodialysis timing on survival outcomes.

MATERIALS AND METHODS

Study design and ethical considerations

This was a longitudinal observational study conducted at a tertiary care teaching hospital between August 2019 and January 2021. The Institutional Ethics Committee approved the study (dated March 10, 2025). It adhered to International Council on Harmonization (ICH) Good Clinical Practice guidelines and the Declaration of Helsinki. Informed consent was obtained from the patient or their accompanying person after the study procedure in a language they understood.

Study Population

All consecutive patients (aged 12–80 years) with confirmed paraquat poisoning admitted during the study period were included. Diagnosis was based on a documented history of ingestion and compatible clinical or laboratory evidence. Patients with mixed or unknown poison ingestion, pre-existing kidney disease, severe allergic reactions to hemodialysis materials, or incomplete medical records were excluded.

Intervention

All patients received standard care for paraquat poisoning, including stabilization, gastric decontamination, supportive management, and organ function monitoring. Hemodialysis was performed as indicated based on clinical judgment and renal function. Patients were categorized according to the timing of the first dialysis session as Group 1, within 48 hours of ingestion, and Group 2, after 48 hours.

Data Collection

Demographic and clinical variables were extracted from hospital records, including age, sex, body mass index (BMI), hypertension, smoking history, time to hospital presentation, and time to first hemodialysis. Laboratory investigations included serum creatinine, blood urea, liver enzymes (AST, ALT), and total bilirubin. Clinical outcomes (survival or death) were recorded at discharge.

Sample size calculation

As no regional prevalence data were available, formal sample size calculation was not feasible. All eligible confirmed cases presenting during the study period were included to ensure maximum representation.

Statistical analysis

Descriptive statistics summarized demographic and clinical data. Categorical variables were presented as frequencies and percentages, and continuous variables as mean ± standard deviation or median, as appropriate. Associations were tested using Chi-square or independent t-tests. Odds ratios (OR) with 95% confidence intervals (CI) were calculated to assess the effect of hemodialysis timing on survival. A p-value <0.05 was considered statistically significant. Analyses were performed using standard statistical software.

RESULTS

Patient demographic and baseline characteristics

A total of 72 patients with confirmed paraquat poisoning were included in the study (Table 1). The mean age of the patients was 43.0 ± 17.9 years, with most of them (40.3%) in the 21-30-year group. Females constituted 54.2% of the cohort. Most patients had normal or overweight BMI, and 12.5% were obese. Hypertension and smoking were reported in 70.8% and 44.4% of patients, respectively.

The mean time to hospital arrival following paraquat ingestion was 12.4 ± 5.9 hours. Based on hemodialysis timing, 30 patients (Group 1) received dialysis within 48 hours, and 42 (Group 2) after 48 hours (Table 1). The mean time to first dialysis was significantly shorter in Group 1 (34.8 ± 5.2 h) than in Group 2 (70.6 ± 11.0 h).

Time to first hemodialysis and laboratory parameters

Patients receiving early hemodialysis (<48 h) showed better renal and hepatic profiles at all intervals (Table 2). Pre- and post-dialysis urea and creatinine values were significantly lower in Group 1 ($p < 0.05$). Similarly, AST, ALT, and total bilirubin were all lower in the early dialysis group ($p < 0.01$).

Survival outcomes and association with patient characteristics

Overall mortality was 84.7% (n = 61), with 11 survivors (15.3%). Age, sex, BMI, hypertension, and smoking history were not significantly associated with mortality (all $p > 0.05$). Early hemodialysis within 48 hours significantly improved survival ($p = 0.0033$), with markedly higher odds of survival compared to delayed dialysis (Table 3).

Association of survival outcomes with laboratory parameters and dialysis response.

Renal and hepatic function markers differed significantly between survivors and non-survivors (Table 4). Survivors had lower pre-dialysis urea ($p = 0.0007$), post-first ($p < 0.0001$), and post-third dialysis urea levels (14.6 ± 2.9 vs 66.9 ± 35.3

mg/dL, p < 0.0001). Post-third dialysis creatinine was also significantly lower among survivors (p = 0.0008). Liver enzymes (AST, ALT) and total bilirubin were markedly higher in non-survivors (all p < 0.0001), indicating greater hepatic dysfunction.

Table 1: Demographic and clinical characteristics

Characteristic	Frequency (%)
Age Group (years)	
21–30	29 (40.3%)
31–40	15 (20.8%)
41–50	2 (2.8%)
51–60	8 (11.1%)
61–70	10 (13.9%)
71–80	8 (11.1%)
Sex	
Male	33 (45.8%)
Female	39 (54.2%)
BMI Category	
Normal	30 (41.7%)
Overweight	33 (45.8%)
Obese	9 (12.5%)
Hypertension	
Yes	51 (70.8%)
No	21 (29.2%)
Smoking History	
Yes	32 (44.4%)
No	40 (55.6%)
Time to first hemodialysis	
<48 hrs.	30 (41.7%)
>48 hrs.	42 (58.3%)

Table 2: Comparison of laboratory parameters by time to first hemodialysis

Parameter	Group 1 (<48 hrs.) n=30	Group 2 (>48 hrs.) n=42	p-value
Pre-dialysis Urea (mg/dL)	49.67 ± 24.31	98.69 ± 56.41	<0.0001
Post-1 Dialysis Urea (mg/dL)	56.33 ± 27.94	90.81 ± 55.53	0.0026
Post-3 Dialysis Urea (mg/dL)	43.27 ± 23.18	70.10 ± 41.95	0.0023
Pre-dialysis Creatinine (mg/dL)	2.56 ± 1.38	2.79 ± 1.64	0.5395
Post-1 Dialysis Creatinine (mg/dL)	2.84 ± 1.77	2.86 ± 1.59	0.9743
Post-3 Dialysis Creatinine (mg/dL)	1.79 ± 1.09	2.47 ± 1.28	0.0196
AST (U/L)	56.30 ± 15.19	66.62 ± 15.76	0.0070
ALT (U/L)	55.10 ± 16.62	67.62 ± 17.31	0.0030
Total Bilirubin (mg/dL)	1.42 ± 0.58	1.83 ± 0.50	0.0018

Data presented as Mean ± SD. AST: Aspartate Transaminase; ALT: Alanine Transaminase.

Table 3: Survival outcomes by time to first hemodialysis

Hemodialysis Group	Total	Alive (%)	Death (%)	Chi-square p-value	Odds Ratio (95% CI)
Group 1 (<48 hrs.)	30 (41.7%)	9 (30.0%)	21 (70.0%)	0.0033	8.57 (1.70–43.34)
Group 2 (>48 hrs.)	42 (58.3%)	2 (4.8%)	40 (95.2%)		
Total	72 (100%)	11 (15.3%)	61 (84.7%)		

Table 4: Comparison of laboratory parameters by survival outcomes

Parameter	Survivors (n=11)	Non-survivors (n=61)	p-value
Pre-dialysis Urea (mg/dL)	31.18 ± 2.68	86.75 ± 51.77	0.0007
Post-1 Dialysis Urea (mg/dL)	24.64 ± 3.04	85.79 ± 47.42	<0.0001
Post-3 Dialysis Urea (mg/dL)	14.55 ± 2.91	66.92 ± 35.28	<0.0001
Pre-dialysis Creatinine (mg/dL)	2.31 ± 0.89	2.77 ± 1.62	0.3674
Post-1 Dialysis Creatinine (mg/dL)	2.41 ± 1.10	2.93 ± 1.73	0.3359
Post-3 Dialysis Creatinine (mg/dL)	1.06 ± 0.14	2.39 ± 1.25	0.0008
AST (U/L)	43.91 ± 5.41	65.64 ± 15.30	<0.0001
ALT (U/L)	41.91 ± 3.99	66.10 ± 17.04	<0.0001
Total Bilirubin (mg/dL)	1.00 ± 0.15	1.78 ± 0.53	<0.0001

Data presented as Mean ± SD. AST: Aspartate Transaminase; ALT: Alanine Transaminase.

DISCUSSION

Paraquat poisoning continues to be a significant public health concern, particularly in developing countries such as India, where its agricultural utility is outweighed by its high human toxicity and easy availability.[1, 2] The widespread use of paraquat, low cost, and lack of regulatory control contribute to both accidental and intentional poisonings, often with fatal outcomes. In the absence of a specific antidote, management depends on supportive measures, gastrointestinal decontamination, antioxidants, immunosuppressants, and extracorporeal elimination therapies such as hemodialysis or hemoperfusion. However, most of these interventions lack standardized protocols or strong evidence from large clinical trials, and current practices are largely based on small observational studies or animal data.[8] Our study evaluated the impact of early versus delayed hemodialysis in paraquat poisoning and found that initiating hemodialysis within 48 hours significantly improved survival outcomes. Early treatment was also associated with better renal and hepatic function profiles, highlighting its role in mitigating systemic toxicity. The mean age of patients who experienced paraquat poisoning has been widely reported in several studies. Rao et al. reported a mean age of approximately 26 years, indicating that paraquat poisoning predominantly affects younger individuals.[7] Similarly, a study by Tanuj Kanchan et al. found the mean age to be around 30 years, further supporting the trend of paraquat poisoning occurring more frequently in younger populations.[5] In contrast, our cohort had a higher mean age of 43.0 ± 17.9 years, though the largest proportion still fell in the 21-30-year group. This variation may reflect regional differences, changing agricultural practices, or greater awareness leading to delayed hospital presentation among older individuals.

The fatality rate of paraquat poisoning has been consistently high across various studies. Rao et al. reported a fatality rate of approximately 61%,[7] while a retrospective study conducted at a tertiary care center in Southern India also found the in-hospital mortality rate to be 72.7%.[9] The reported fatality rate across the literature varies between 35% and 62%, with a mortality rate reported as high as 90% in some studies.[4, 7, 10] The overall mortality of 84.7% in our study aligns with the more severe end of this spectrum. Importantly, patients receiving hemodialysis within 48 hours had a markedly lower fatality rate (70%) compared to those treated later (95.2%), emphasizing the critical importance of early initiation.The effectiveness of hemodialysis in paraquat poisoning has been debated, but accumulating evidence supports its early use. Paraquat is rapidly distributed to the lungs, kidneys, and liver, where it generates reactive oxygen species and causes irreversible damage. Approximately 90% of absorbed toxin is excreted unchanged within 24 hours, underscoring the narrow therapeutic window for extracorporeal removal.[1, 3-5] Early hemodialysis can reduce circulating toxin levels before extensive organ accumulation occurs. Karmakar et al. reported that survivors began dialysis within 1.1 days compared to 2 days in non-survivors,[11] while multicenter data confirmed that hemodialysis within hours of ingestion improves outcomes.[12] Case reports of early continuous hemodiafiltration also demonstrated complete recovery without sequelae.[13] Moreover, combining hemodialysis with hemoperfusion may enhance paraquat clearance and organ protection, as shown by Guo et al., who observed improved renal and hepatic function and better short-term survival.[14] Our findings support these reports, showing that early hemodialysis was associated with lower urea, creatinine, and liver enzyme levels, indicating preserved organ function.

Several clinical and biochemical variables have been identified as predictors of survival in paraquat poisoning. The ingested dose, time to hospital presentation, and biochemical markers of renal and hepatic injury are crucial determinants of outcome.[2, 15, 16] Elevated urea and creatinine reflect renal impairment, while raised AST, ALT, and bilirubin indicate hepatic injury, all associated with increased mortality.[4, 15] In our study, survivors had significantly lower levels of urea, AST, ALT, and bilirubin, suggesting that these parameters can serve as valuable prognostic indicators. Interestingly, serum creatinine showed less predictive value, implying that urea and hepatic enzymes may better reflect ongoing systemic injury in paraquat toxicity. Collectively, our results reinforce the importance of early extracorporeal elimination in reducing mortality and improving organ function. Prompt initiation of hemodialysis can prevent further paraquat accumulation in

pulmonary tissue, limit oxidative injury, and enhance survival. Regular monitoring of urea and liver enzymes may help identify patients at higher risk and guide treatment intensity.This study has certain limitations. Being an observational single-center study, the results may not be generalizable to other populations. The modest sample size and lack of serum paraquat concentration data limited our ability to correlate biochemical severity with toxin levels. In addition, the timing of hemodialysis initiation was based on clinical judgment rather than a standardized protocol, introducing potential selection bias. Future multicenter prospective studies with larger cohorts and standardized treatment protocols are needed to validate and extend these findings.

CONCLUSION

This study demonstrated that early initiation of hemodialysis within 48 hours significantly enhances survival and is associated with more favorable renal and hepatic profiles. Urea and liver enzyme levels emerged as potential predictors of survival. Early therapeutic intervention, alongside vigilant monitoring of biochemical parameters, can improve outcomes and should be prioritized in treatment strategies for paraquat toxicity.

Acknowledgments
None
Funding
None.

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