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Preliminary experience of combined dual plasma molecular adsorption system and plasma exchange in pediatric acute liver failure: a retrospective case series

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Abstract

Background Pediatric acute liver failure (PALF) is a life-threatening condition with no definitive treatment. This study evaluated the combined use of the dual plasma molecular adsorption system (DPMAS) and plasma exchange (PE) to improve liver function and survival outcomes in PALF patients.

Methods A retrospective study was conducted on 7 PALF patients treated with DPMAS and PE. Data on liver function scores (Liver Injury Unit [LIU], Model for End-Stage Liver Disease [MELD], Model for End-Stage Liver Disease with Sodium [MELD-Na], MELD 3.0), bilirubin levels, and coagulation indices were collected before and after treatment.

Results DPMAS and PE treatments significantly reduced total bilirubin (382.2 μmol/L to 52.0 μmol/L) and improved coagulation indices. Liver injury scores decreased notably (e.g., LIU from 184 to 52 in one case). Five patients recovered, while two with severe comorbidities showed limited improvement.

Conclusion The combination of DPMAS and PE therapy improves liver function and survival outcomes in PALF. These results support its use as a bridge to recovery or transplantation in PALF patients, though further studies with larger sample sizes are needed.

Keywords Pediatric acute liver failure, Plasma exchange, Dual plasma molecular adsorption system, Hyperbilirubinemia, Liver function

Introduction

Pediatric acute liver failure (PALF) is a rare but life-threatening condition characterized by rapid deterioration of liver function, leading to hepatic encephalopathy and coagulopathy [1]. With a high mortality rate, PALF presents a significant challenge to pediatric intensive care, and effective treatment options remain limited [2]. The etiology of PALF is diverse, including drug-induced hepatotoxicity, viral infections, autoimmune disorders, and metabolic diseases, while a considerable number of cases remain idiopathic. Early identification and intervention are critical, yet the unpredictable progression of PALF often limits the window for effective therapeutic action [3, 4].

Among existing therapeutic strategies, plasma exchange (PE) has been widely used as a bridging therapy for liver regeneration or transplantation [5–7]. PE functions by replacing the patient's plasma with donor

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plasma, facilitating the removal of bilirubin, ammonia, and inflammatory mediators [8]. However, its application is often hindered by limited plasma supply, transfusion-related risks [9], and insufficient impact on certain critical aspects such as improving coagulopathy. These limitations underscore the need for alternative or complementary therapies to enhance the efficacy of PALF management [10].

The dual plasma molecular adsorption system (DPMAS) represents an innovative approach to managing liver failure by utilizing a dual-resin adsorption technique [11]. This system effectively removes both hydrophilic and lipophilic toxins, including bilirubin and damage-associated molecular patterns (DAMPs), alleviating the systemic inflammatory response associated with liver failure [12]. Despite its advantages, DPMAS alone demonstrates limited efficacy in correcting coagulopathy, which is a crucial determinant of PALF prognosis. Therefore, the combination of DPMAS with PE offers a promising therapeutic strategy that leverages the strengths of both modalities—DPMAS for comprehensive toxin removal and PE for replenishing coagulation factors and addressing coagulopathy [13, 14].

While the combined use of DPMAS and PE has shown potential in clinical practice, standardized protocols for their application in pediatric populations remain lacking [15]. Key aspects such as timing of intervention, optimal treatment duration, and safety considerations require further investigation. Moreover, existing studies primarily focus on adult populations, with limited evidence available for pediatric patients, who present unique physiological and pathophysiological challenges in PALF management.

Therefore, this study aims to further explore the potential of combining DPMAS with PE in the management of PALF by retrospectively evaluating their efficacy and safety. Through the analysis of changes in liver function indicators, coagulopathy metrics, and clinical outcomes, this research seeks to provide valuable insights into the possible benefits of this combined therapy as a bridge to recovery or liver transplantation. The findings aim to contribute to refining treatment approaches and enhancing the management of this critical condition in pediatric patients, ultimately supporting the development of more effective and standardized treatment protocols.

Materials and methods

Study design and participants

This study is a retrospective observational case series conducted between January 2021 and December 2023, including seven pediatric patients diagnosed with acute liver failure (PALF) from the Pediatric Intensive Care Unit of our hospital. The inclusion criteria were: (1) diagnosis of PALF according to Pediatric Acute Liver Failure Study Group criteria; (2) absence of pre-existing chronic liver disease; and (3) informed consent from guardians for anonymous data usage. Exclusion criteria included: (1) incomplete medical records; and (2) patients receiving other experimental treatments. This report had been approved by the Ethics Committee of our hospital, and informed consent for the use of anonymous data had been obtained from the guardians of all patients upon admission.

To investigate the etiologies of PALF, detailed medical histories including toxin and/or drug exposures were collected, and serological virus screenings (hepatitis A virus, hepatitis B virus, hepatitis C virus, cytomegalovirus, Epstein-Barr virus) were performed. Possible metabolic disorders, autoimmune liver diseases, ultrasound imaging, and/or computed tomography imaging were also evaluated.

Comprehensive medical treatment

All patients received comprehensive treatment, including the use of antibiotics, liver-protective drugs, supplementation of energy and vitamins, as well as supplementation of blood products such as albumin, plasma, and prothrombin complex. Appropriate supportive treatments such as mechanical ventilation and vasopressors were given when necessary.

Dual plasma molecular adsorption system (DPMAS) and plasma exchange (PE)

Indications

DPMAS: Applied in cases of severe hyperbilirubinemia (> 340 μmol/L and rapidly increasing) or hepatic encephalopathy without significant coagulation disorders.

PE: Performed for patients with coagulopathy or systemic inflammatory response syndrome requiring plasma replacement.

Contraindications

There are no absolute contraindications for dual treatment with DPMAS and PE. However, caution is necessary for patients with severe cardiovascular dysfunction, as they may not tolerate hemodynamic fluctuations; significant coagulopathy (e.g., large bruises, nosebleeds, gastrointestinal bleeding), which increases bleeding risks; and severe malnutrition or cachexia, where the patient's frailty and poor prognosis may lead to worsened outcomes, increased suffering, or premature death.

Procedure

Blood Access: A double-lumen catheter was inserted into the femoral vein, with size adjusted according to patient age.

PE: Performed with a continuous renal replacement machine (MultiFiltrate, Fresenius Medical Care). Fresh

frozen plasma (50 mL/kg) was exchanged over 2 h without anticoagulant use. The frequency and interval of treatments were determined based on clinical improvements and plasma availability.

DPMAS: Conducted using a hemoperfusion machine (JF-800 A, Zhuhai Jianfan Bio-Technology Co., Ltd.) and adsorption resins (HA330-II and BS330). Each session lasted 2 h.

Since the duration of each PE or DPMAS was only 2 h and the intervals were not fixed, no special drug adjustments were made.

Assessments

① Clinical Improvement: Progression from coma to drowsiness to full alertness, along with improved mental state, appetite, and reduced symptoms (e.g., fatigue, abdominal distension), suggests effective treatment and adequate session completion. ② Bilirubin Levels: A daily reduction of >17.1 μmol/L in bilirubin signals effective treatment. Once bilirubin stabilizes or approaches normal levels (total < 17.1 μmol/L, direct < 6.8 μmol/L), treatment is deemed adequate. In severe cases, a 50% reduction with stabilization indicates sufficient therapy. ③ Coagulation Function: Shortened PT and decreased INR (from >1.5 to 1.2–1.5) reflect improved coagulation, indicating effective treatment. ④ Liver Function Indicators: ALT and AST levels decreasing to 2–3 times the upper normal limit and rising albumin levels above 30 g/L signify liver recovery and treatment adequacy. ⑤ Blood Purification Monitoring: Reduction in plasma concentrations of bilirubin, bile acids, ammonia, and endotoxins suggests successful purification. If levels stabilize, additional sessions may not be necessary.

Data collection and measurements

Clinical data, including demographic characteristics, laboratory evaluations (e.g., ALT, AST, total bilirubin, INR, ammonia levels), and scoring metrics (LIU, MELD, MELD-Na, and MELD 3.0), were collected before and after treatment.

LIU = (3.507 × peak total bilirubin in mg/dL) + (45.51 × peak INR) + (0.254 × peak ammonia in μmol/L) [16].

MELD = 9.57 × $\log_e$ (creatinine in mg/dL) + 3.78 × $\log_e$ (total bilirubin in mg/dL) + 11.20 × $\log_e$ (INR) + 6.43 [17].

MELD-Na = MELD + 1.32 × (137 - Na) - [0.033 × MELD × (137 - Na)] [18].

MELD3.0 = 1.33 (if female) + 4.56 × $\log_e$ (total bilirubin in mg/dL)] + 0.82 × (137 - Na) − 0.24 × (137 - Na) × $\log_e$ (bilirubin in mg/dL)] + 9.09 × $\log_e$ (INR) + 11.14 × $\log_e$ (creatinine in mg/dL) + 1.85 × (3.5 - albumin) − 1.83 × (3.5 - albumin) × $\log_e$ (creatinine in mg/dL) + 6 [19].

All calculations followed standard protocols, with data rounded to the nearest whole number.

Statistical analysis

All statistical analyses were performed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation, and paired t-tests were used to compare pre- and post-treatment scores. A p-value < 0.05 was considered statistically significant.

Results

Baseline characteristics

The study included 7 pediatric patients (5 females, 2 males) diagnosed with pediatric acute liver failure (PALF). The median age was 6 years (range: 2 months to 15 years). The etiologies of PALF were diverse: Viral infections (n = 3, 42.9%): including human herpesvirus type 5 and cytomegalovirus; Autoimmune liver disease (n = 2, 28.6%): characterized by positive autoimmune markers; Drug-induced liver injury (n = 1, 14.3%): associated with acetaminophen overdose; Idiopathic causes (n = 1, 14.3%): no identifiable trigger despite extensive diagnostic testing.

Common clinical features included hyperbilirubinemia (mean total bilirubin: 291.5 ± 68.2 μmol/L), coagulopathy (mean INR: 2.8 ± 0.7), and elevated liver enzymes (mean ALT: 1257 ± 432 U/L; AST: 1103 ± 385 U/L). Three patients (42.9%) presented with hepatic encephalopathy, and two (28.6%) had multi-organ dysfunction syndrome (MODS) at admission.

Treatment details

All patients underwent a combination of DPMAS and PE, with 3 to 8 sessions per patient. DPMAS, used to remove bilirubin and inflammatory mediators, was administered with HA330-II and BS330 resins in 2-hour sessions, averaging 4.5 sessions per patient. PE, aimed at improving coagulopathy and providing plasma replacement, involved a plasma volume of 50 mL/kg per session, lasting 2 h, with a mean of 3.2 sessions per patient. Treatment strategies were tailored to each patient's condition.

Clinical outcomes

The combination therapy led to significant improvements in clinical and laboratory parameters, with total bilirubin reduced by 72% on average (291.5 ± 68.2 μmol/L to 81.7 ± 42.1 μmol/L), INR improved from 2.8 ± 0.7 to 1.5 ± 0.3, LIU scores decreased by 65%, and MELD 3.0 scores improved from 26.4 ± 5.2 to 11.8 ± 4.3. Among the patients, five (71.4%) achieved full recovery and were discharged, one (14.3%) showed partial improvement but remained critically ill, and one (14.3%) experienced treatment failure, with therapy discontinued due to progressive sepsis and deterioration (Table 1).

Table 1 Clinical and laboratory findings across 7 cases

Case ID	Age	Sex	Etiology	Total Bilirubin (μmol/L)	INR	LIU Score	Sessions (DPMAS / PE)	Clinical Outcome
1	12	F	Viral infection	382.2 → 52.0	2.9 → 1.3	184 → 52	8 / 4	Full recovery
2	0.2	F	Viral infection	253.5 → 121.0	2.7 → 2.0	212 → 121	1 / 3	Treatment abandoned
3	6	F	Idiopathic	302.3 → 78.0	2.5 → 1.6	184 → 78	3 / 2	Full recovery
4	14	F	Autoimmune + AML	299.3 → 156.0	3.2 → 2.4	113 → 156	1 / 3	Treatment abandoned
5	4	M	Drug-induced	375.2 → 67.0	3.0 → 1.4	106 → 60	6 / 6	Full recovery
6	15	M	Idiopathic	204.0 → 94.4	2.8 → 1.5	141.9 → 94.4	3 / 8	Full recovery
7	2	F	Autoimmune	223.0 → 67.0	2.7 → 1.6	111 → 67	4 / 6	Partial improvement

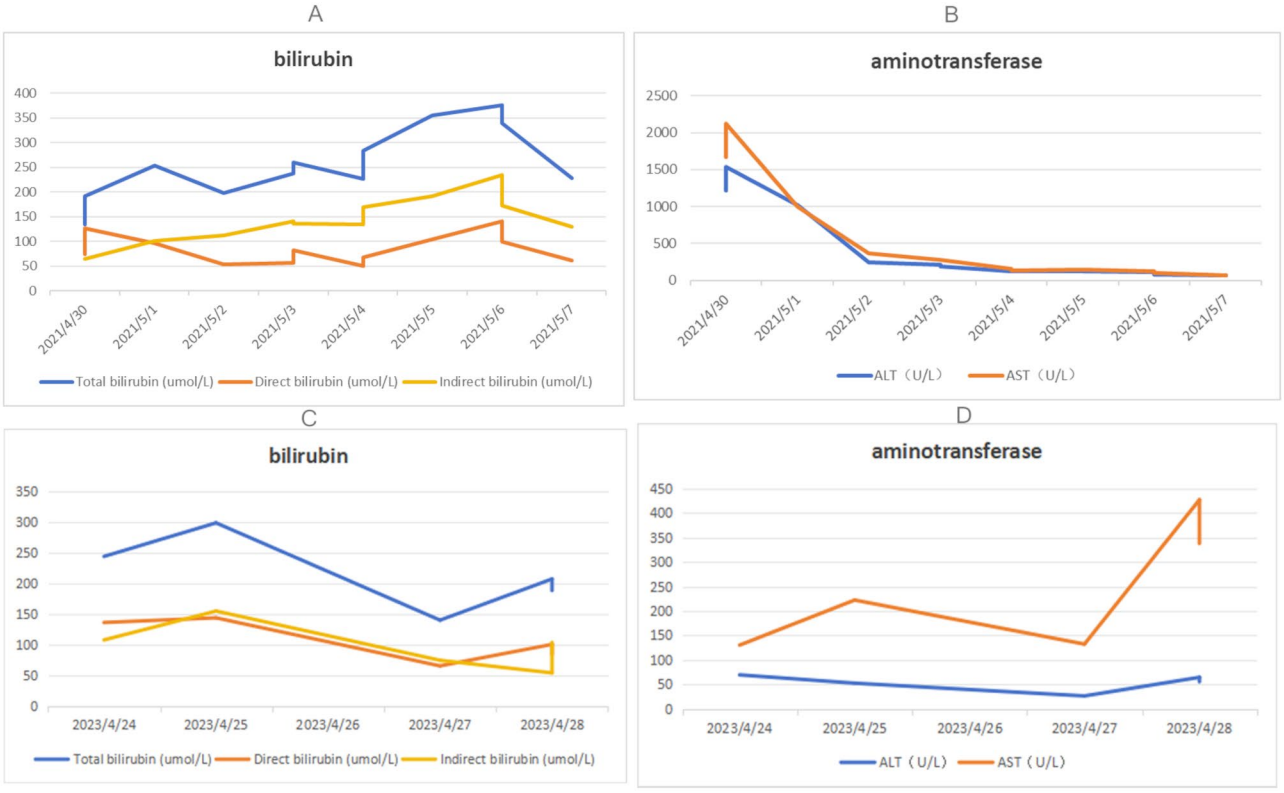

Fig. 1 Bilirubin and aminotransferase levels in representative cases before and after treatment. **A-B (Case 1)**: These panels illustrate the significant clinical improvements observed in Case 1 following 8 DPMAS sessions and 4 PE treatments. Panel A demonstrates a marked reduction in total bilirubin levels, accompanied by a steady decrease in direct and indirect bilirubin. Panel B shows a parallel decline in ALT and AST levels, reflecting substantial liver function recovery and ultimately leading to full recovery of the patient. **C-D (Case 4)**: These panels depict the outcomes for Case 4, which highlight the challenges faced despite receiving 3 PE sessions. Panel C shows persistently elevated bilirubin levels, with only minor fluctuations in total, direct, and indirect bilirubin, indicating limited improvement in liver detoxification. Panel D demonstrates inconsistent trends in ALT and a sharp increase in AST, correlating with poor clinical outcomes and treatment failure

Comparative analysis

All patients showed significant reductions in bilirubin levels and liver injury scores (Figures 1 and 2, Supplemental Fig. 1) with consistent improvements in coagulation profiles such as INR and prothrombin time. No severe adverse reactions, including hypotension or allergic responses, were observed. Viral and autoimmune cases responded more rapidly, achieving faster liver function stabilization, while idiopathic and drug-induced cases had slower recovery, with one idiopathic case discontinued due to progressive MODS (Table 1).

Adverse events

Adverse events were minimal, with no major complications. Delayed PE initiation occurred in two cases due to plasma shortages, and one patient experienced transient electrolyte imbalances, resolved with supportive care.

Discussion

This study explored the combined use of the Dual Plasma Molecular Adsorption System (DPMAS) and Plasma Exchange (PE) in pediatric acute liver failure (PALF). The results suggest that this combination therapy may be associated with reductions in bilirubin levels, as well

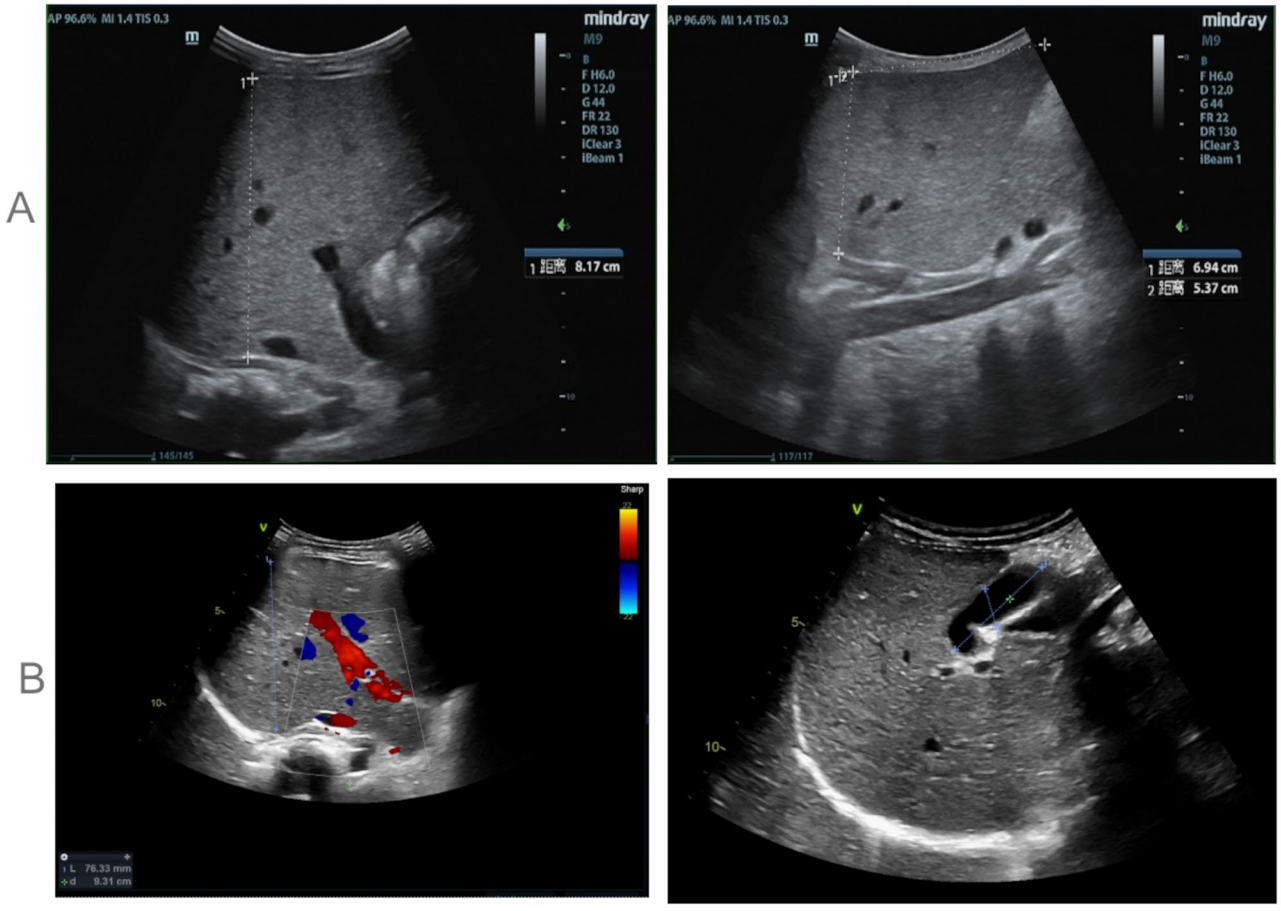

Fig. 2 Representative Imaging of Liver Condition Before and After Treatment. Case 3 (6-year-old female): Ultrasound imaging showing hepatomegaly and diffuse hyperechoic changes before treatment (**A**), with resolution of liver enlargement and echotexture normalization post-treatment (**B**)

as improvements in coagulation profiles and liver injury scores in the majority of patients, supporting its potential role as a bridge to recovery or transplantation. Among the seven cases, five patients experienced complete recovery, which may suggest the potential effectiveness of DPMAS and PE in managing PALF. However, the variability in outcomes, particularly in cases involving idiopathic or multi-organ dysfunction, underscores the need for individualized treatment approaches. Given the retrospective nature of this study, the findings suggest an association between the intervention and the observed improvements, though definitive conclusions regarding causality cannot be drawn.

Comparison with existing evidence

Plasma exchange (PE) is widely used in liver failure management to improve coagulation by removing hydrophilic toxins and replenishing plasma proteins [20], with studies such as those by Xiang et al. showing its efficacy in reducing mortality in adult acute-on-chronic liver failure (ACLF) [21]. However, PE is less effective in clearing lipophilic toxins, which are crucial in liver failure pathophysiology. In contrast, DPMAS effectively removes bilirubin, DAMPs, and inflammatory mediators, addressing the limitations of PE [22]. As shown in research by Gao et al., DPMAS significantly improves hyperbilirubinemia, although its impact on coagulopathy is minimal [15]. Additionally, continuous veno-venous hemodiafiltration (CVVHDF) is another widely used artificial liver support method, providing stable support by continuously removing hydrophilic toxins and replenishing essential components [23]. However, CVVHDF has limitations in removing lipophilic toxins. The combination of DPMAS and PE offers complementary toxin removal, particularly in patients with multi-organ failure, showing more significant effects. While most studies focus on adult patients, our research highlights the potential of this combination therapy in pediatric populations.

Clinical implications

The combined DPMAS and PE therapy demonstrated clear advantages in treating PALF, particularly in cases with viral or autoimmune etiologies [24]. DPMAS was highly effective in rapidly reducing bilirubin levels and

mitigating inflammation, while PE improved coagulopathy by replenishing clotting factors [25–27]. However, patients with idiopathic liver failure or severe multi-organ dysfunction showed limited response, suggesting that the timing of therapy initiation and patient selection are crucial for success. Despite the promising results, the therapy's dependency on plasma availability and specialized equipment poses challenges, especially in resource-limited settings [28]. These findings emphasize the need for well-defined protocols to maximize the benefits of combined therapy.

Clinical comparison of multiple scoring systems

The LIU, MELD, MELD-Na, and MELD 3.0 scoring systems are widely used to assess liver function, with higher scores indicating poorer prognosis [29–31]. MELD-Na and MELD 3.0, which incorporate parameters like sodium concentration, offer enhanced accuracy in cases with water and electrolyte imbalances, with MELD 3.0 being particularly effective in predicting mortality [31]. A MELD 3.0 score > 19 correlates with higher 30-day mortality. In this study, the consistency of these scores with treatment outcomes in cases 1, 3, and 7 highlights their clinical value, though differences in the predictive accuracy of MELD 3.0 and MELD-Na remain, warranting further research with larger datasets.

Future directions

This study underscores several areas for further investigation. Prospective, multicenter trials with larger sample sizes are essential to validate the efficacy and safety of DPMAS and PE in pediatric patients. However, one limitation of this study is that it is a retrospective observational study of the non-controlled experience of a small number of patients in a single institution. Our experience has shown that the dual plasma molecular adsorption system and plasma exchange are effective for acute liver failure, but whether this combined treatment can reduce the number of plasma exchange sessions needs to be confirmed in a larger sample in the future.

Conclusion

The combination of DPMAS and PE represents a promising approach to managing pediatric acute liver failure, showing a relationship with improvements in liver injury scores and coagulation profiles. While the therapy suggests potential benefits, its limitations in resource requirements and varying efficacy for certain patient groups highlight the need for further refinement. By addressing these challenges and expanding the evidence base, this combination therapy may contribute to advancing the treatment landscape for pediatric liver failure.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12887-025-05520-z .

Supplemental figure 1: The rest cases of treatment outcomes

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Not applicable.

Author contributions
Study design: Geng JH, Liu SL, Dou BF, Zhao JL, Ma HK, Wang ZY, Li SJ. Data acquisition: Geng JH, Liu SL, Dou BF, Zhao JL, Ma HK, Wang ZY, Li SJ. Data analysis and interpretation: Geng JH, Liu SL, Dou BF, Zhao JL, Ma HK. Manuscript preparation: Geng JH, Liu SL, Dou BF, Zhao JL, Ma HK, Wang ZY, Li SJ. Critical revision of the manuscript for intellectual content: Li SJ. Manuscript review: Geng JH, Liu SL, Dou BF, Zhao JL, Ma HK, Wang ZY, Li SJ. Obtaining financing: Li SJ.

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Data availability
Data will be available upon request.

Declarations

Clinical trial number
Not applicable.

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki and approved by the Research Ethics Committee of The First Affiliated Hospital of Xinxiang Medical University, and informed consent for the use of anonymous data had been obtained from the guardians of all patients upon admission. All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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