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Analysis of the Effects of Blood Purification Combined with Integrated Nursing on Coagulation Function and Organ Injury Biomarkers in Children with Sepsis

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Abstract: **Objective:** To investigate the effects of blood purification combined with an integrated nursing bundle on coagulation function and organ injury biomarkers in children with sepsis. **Methods:** Children treated in January 2024 – January 2025 received the same CRRT protocol plus an integrated nursing intervention (observation group, n=75). Coagulation parameters, organ injury biomarkers, inflammatory indices, and CRRT-related adverse events were compared between groups. **Results:** At 72 h after CRRT initiation, PT and APTT were significantly shorter and D-dimer was lower in the observation group than in the control group (all P<0.05). Cys-C and cTnI decreased more from baseline to 72 h in the observation group (P<0.05), and ALT at 72 h was lower (P<0.05). PCT decreased more from baseline to 72 h, while CRP, lactate, and pSOFA at 72 h were lower in the observation group (P<0.05). Filter coagulation and unplanned circuit termination occurred less frequently in the observation group (P<0.05). **Conclusion:** Blood purification combined with integrated nursing was associated with improved coagulation status, attenuated inflammatory burden, better organ injury profiles, and enhanced circuit safety/continuity in children with sepsis.

Keywords: children; sepsis; blood purification; integrated nursing; coagulation function

Introduction

Pediatric sepsis is a response to infection that shows systemic inflammation. The condition develops without clear signs at first but progresses rapidly, leading to marked deterioration in clinical condition. Sepsis that occurs in children often involves dysfunction in the process of forming clots and injury affecting multiple organs. This presents a significant threat to survival in the pediatric population and represents a leading cause of death and poor outcomes in pediatric intensive care units. The systems that provide immune function and regulate clotting in children differ from those in adults. These systems show limited development and remain immature. This difference in development makes children more likely to experience excessive activation of the clotting cascade when exposed to intense inflammatory stimulation. The activation produces small clots in vessels, reduces blood flow to organs, and accelerates the progression of disease. Management of pediatric sepsis faces significant challenges, including controlling inflammation early, correcting coagulopathies, and preserving vital organ function.

Techniques that purify blood, particularly continuous renal replacement therapy, can remove mediators of inflammation, endotoxins, and metabolic products continuously while maintaining balance in the internal environment. These effects improve circulation in small vessels and reduce the burden on organs. This makes continuous renal replacement therapy an important treatment approach that provides support in managing severe pediatric sepsis. Implementation of continuous renal replacement therapy in children requires nursing care that maintains high quality and provides meticulous attention. Children exhibit characteristics that differ from those of adults. These include a small volume of circulating blood, rapid fluctuations in physiological measures, and a limited tolerance for circulation outside the body. Management during continuous renal replacement therapy that is insufficient or lacks systematic organization may produce adverse events. These events include filter clotting and unplanned circuit interruptions. Such events compromise the ability to continue treatment and reduce the effectiveness that treatment provides [1-3].

Current clinical studies examining methods for removing substances from the blood in conditions involving widespread infection focus on adults, and data on children remain limited. In particular, findings that examine the approach combining methods for removing substances from the blood with care approaches that provide multiple forms of support in children with widespread infection remain scarce, and data examining effects on the process by which blood forms solid masses and on damage to internal structures are limited [4]. This indicates a clear need for investigations using careful design to examine the possible benefits that this approach, combining multiple methods, may provide for children. The present study uses this context to compare outcomes in children with widespread infection who receive care using conventional approaches and those who receive care using an approach that combines multiple forms of support during treatment and removes substances from the blood. The study examines whether this combined approach adds value by improving the process by which blood forms solid masses, reducing damage to internal structures, and increasing the overall degree to which care meets standards. Findings may provide evidence that supports efforts to improve strategies for managing critical conditions in children with widespread infection.

1. Materials and Methods

1.1 General Information

This single-center before－and－after observational study enrolled 150 children with sepsis who required CRRT in the PICU between January 2023 and January 2025. Children treated in January－December 2023 were assigned to the control group (conventional CRRT + routine nursing, n=75), and children treated in January 2024－January 2025 were assigned to the observation group (conventional CRRT + integrated nursing intervention, n=75). Baseline demographic and clinical characteristics were collected to ensure comparability between groups (Table 1).

Inclusion criteria: (1) meeting the diagnostic criteria for pediatric sepsis; (2) age between 1 month and 14 years; (3) presence of coagulation abnormalities within 24 h after PICU admission (prolonged PT/APTT, decreased fibrinogen, or elevated D-dimer); (4) indication for CRRT; (5) informed consent obtained from guardians.
Exclusion criteria: (1) congenital coagulation disorders or severe underlying diseases; (2) extreme hemodynamic instability precluding CRRT; (3) long-term use of immunosuppressive agents; (4) incomplete clinical data.

Baseline data, including age, sex, type of infection, pSOFA score, blood lactate level, and mechanical ventilation use, were collected to ensure comparability between the two groups (Table 1).

Table 1. Baseline characteristics of the patients

Variable	Control group (n=75)	Observation group (n=75)	t/χ^2	P value
Age (years, mean ± SD)	4.3 ± 3.1	4.4 ± 3.0	0.19	0.850

Sex (male/female)	41 / 34	40 / 35	0.03	0.862
Blood lactate at PICU admission (mmol/L)	3.3 ± 1.1	3.4 ± 1.2	0.52	0.604
pSOFA score (mean ± SD)	6.7 ± 2.3	6.6 ± 2.4	0.25	0.802
Mechanical ventilation, n (%)	38 (50.7%)	40 (53.3%)	0.10	0.754

1.2 Methods

1.2.1 Control Group (Conventional CRRT + Routine Nursing)

The control group received conventional CRRT with systemic heparin anticoagulation. A loading dose of 10 – 20 U • kg^{-1} was administered, followed by a maintenance dose of 8 – 15 U •kg^{-1} •h^{-1}, targeting an ACT of 180 – 220 s. Each session lasted 12 – 24 h and was continued for 3 – 5 days. Routine nursing included standardized circuit maintenance and monitoring, vital-sign and urine-output observation, strict intake/output recording, catheter-site assessment and dressing care, airway management, and timely troubleshooting to maintain circuit patency and patient safety.

1.2.2 Observation Group (Blood Purification + Integrated Nursing Intervention)

The observation group received the same CRRT regimen as the control group, supplemented with an integrated nursing intervention (bundle) as follows:

(1) Multidisciplinary assessment (PICU physicians, surgery, respiratory therapy, and nutrition) to formulate individualized filtration and supportive-care plans; (2) Preferential use of regional citrate anticoagulation when appropriate, with 3% citrate infused proportional to blood flow and calcium supplementation adjusted in real time according to ionized calcium and circuit coagulation grade; (3) Dynamic risk assessment during CRRT, including microcirculation observation, filter clotting scoring, and early warning/management of potential unplanned circuit termination; (4) Structured airway care (e.g., chest physiotherapy and sputum clearance every 4 h for 10 – 15 min per session after contraindication screening); (5) Organ-protection strategies, including precise fluid management and medication review to avoid nephrotoxic/hepatotoxic exposure, with organ-support therapy as prescribed; (6) Closed-loop documentation, team handover, and quality supervision throughout the nursing process to enable early identification and interruption of the inflammation – coagulation – organ injury cascade.

1.3 Outcome Measures

Laboratory indices were recorded at baseline (within 24 h before CRRT initiation) and at 72 h after initiation when available. D-dimer, ALT, CRP, lactate, and pSOFA were analyzed at 72 h based on routine clinical records.

1.3.1 Coagulation Parameters

The study examines the effects of treatment combining methods for removing substances from blood with approaches that address multiple factors. This examination focuses on functions related to processes that form structures that prevent blood loss in children, and on responses to organisms that cause disease across body systems. The work considers limitations in the volume of blood samples that procedures allow for obtaining from children. This consideration leads to selecting measures that show particular features. These measures include use in standard practice across multiple settings, responses showing changes that occur with slight differences in condition, and a form allowing repeated assessment following changes across time：

(1)Prothrombin time (PT): reflecting the function of the extrinsic coagulation pathway and consumption of coagulation factors;

(2) Activated partial thromboplastin time (APTT): indicating intrinsic pathway activity and serving as an important marker of inflammation-related coagulopathy;

(3) D-dimer: assessing microthrombus formation and fibrinolytic activation, suitable for dynamic monitoring in pediatric sepsis.

All parameters are routinely measured in the pediatric PICU, with appropriate testing frequency and minimal blood volume requirements, allowing practical assessment of changes in coagulation balance.

1.3.2 Organ Injury Biomarkers

The study assesses damage across multiple structures that perform different functions in the body. This damage results from responses to organisms that cause disease across body systems. The work also examines the effects of protective approaches that address multiple factors in care. The study selects measures that indicate the function of structures based on development patterns that occur in children and the volume of blood that procedures allow for obtaining in this population：

(1)Cystatin C (Cys-C): a sensitive renal injury marker more suitable than creatinine in children, reflecting early changes in glomerular filtration;

(2) Cardiac troponin I (cTnI): used to identify sepsis-related myocardial

depression and recommended for assessing myocardial injury in children;

(3) Alanine aminotransferase (ALT): indicating hepatocellular injury, routinely measured in children with low blood volume requirements.

This combination balances feasibility and clinical relevance, enabling dynamic assessment of renal, cardiac, and hepatic injury without increasing patient burden.

1.3.3 Systemic Inflammation and Disease Severity

To examine the effects of treatment combining blood purification with an integrated care approach on inflammatory burden and disease severity across the body, the study selected indicators that allow measurement in children on a routine basis and measurement at multiple times：

(1)Procalcitonin (PCT): specifically reflecting bacterial infection severity and a primary marker for inflammatory assessment in pediatric sepsis;

(2) C-reactive protein (CRP): indicating inflammatory activity and serving as an important reference for treatment response;

(3) Blood lactate (Lac): assessing tissue perfusion and circulatory stability, and a critical prognostic and therapeutic parameter;

(4) Pediatric Sequential Organ Failure Assessment (pSOFA) score: a composite scoring system based on pediatric organ function characteristics, quantifying disease severity and multiorgan dysfunction.

The indicators represent standard monitoring items in the pediatric PICU. These measures provide comprehensive information on inflammation, microcirculation, and organ function. The data from these indicators provide objective evidence for examining the effects of the integrated care approach.

1.4 Statistical Analysis

Statistical analyses were performed using SPSS 26.0. Continuous variables are presented as mean ± SD when normally distributed and were compared using independent-samples t tests; non-normally distributed data were compared using the Mann–Whitney U test. Categorical variables are presented as n (%) and were compared using the χ^2 test or Fisher's exact test, as appropriate. For outcomes measured at baseline and 72 h, a repeated-measures ANOVA (group, time, and group×time interaction) was used, with corrections for violations of the sphericity assumption. A two-sided $P<0.05$ was considered statistically significant.

2. Results

2.1 Comparison of Improvements in Coagulation Parameters

Baseline PT and APTT were comparable between groups. At 72 h after CRRT initiation, both PT and APTT improved, and the observation group had significantly shorter PT and APTT than the control group. D-dimer at 72 h was also lower in the observation group (all P<0.05; Table 2 and Figure 1).

Table 2. Comparison of coagulation parameters between the two groups (mean ± SD)

Parameter	Time point	Control group (*n*=75)	Observation group (*n*=75)	*t*	*P* value
PT (s)	Before treatment	18.70 ± 3.60	18.52 ± 3.41	0.341	0.734
	72 h after treatment	15.62 ± 2.80	13.94 ± 2.52	3.711	0.001
APTT (s)	Before treatment	52.30 ± 9.50	51.80 ± 9.10	0.320	0.746
	72 h after treatment	45.10 ± 8.00	40.60 ± 7.40	3.661	0.001
D-dimer (mg/L)	72 h after treatment	3.28 ± 1.21	2.41 ± 0.96	4.750	<0.001

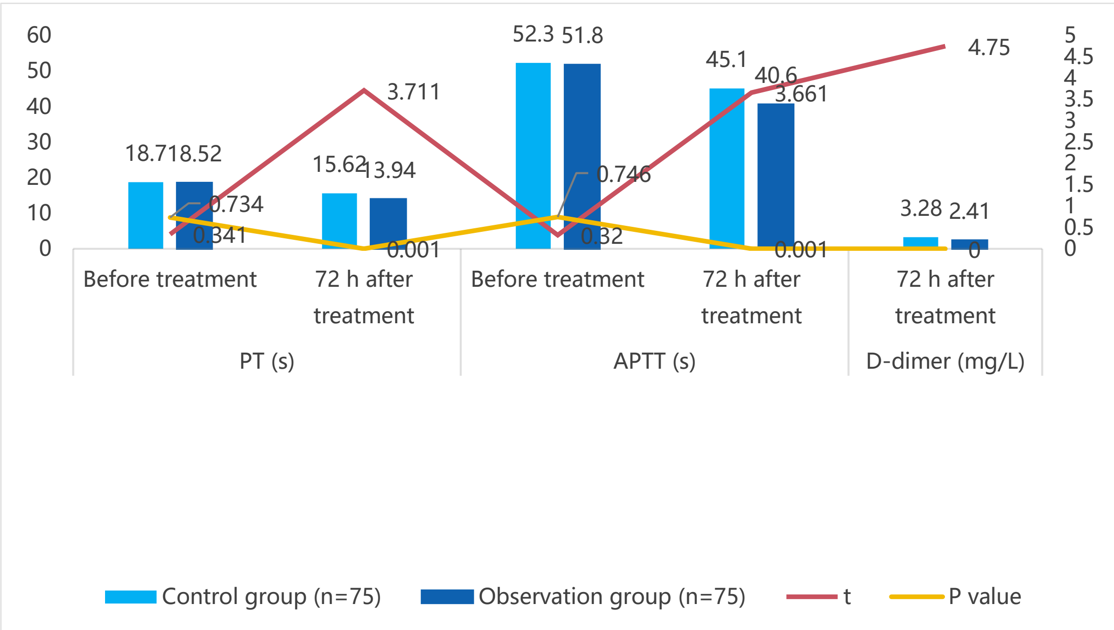

Figure 1 Comparison of coagulation parameters between the two groups (mean ± SD)

2.2 Changes in Organ Injury Biomarkers

Baseline Cys-C and cTnI were comparable between groups. From baseline to 72 h, Cys-C and cTnI decreased significantly in both groups, with a larger decline in the observation group. ALT at 72 h was lower in the observation group than in the control group (P<0.05; Table 3 and Figure 2).

Table 3. Comparison of organ injury biomarkers between the two groups (mean ± SD)

Parameter	Time point	Control group (*n*=75)	Observation group (*n*=75)	*t*	*P* value
Cys-C (mg/L)	Before treatment	2.31 ± 0.64	2.28 ± 0.61	0.280	0.776
	72 h after treatment	1.89 ± 0.52	1.42 ± 0.37	6.320	<0.001
cTnI (ng/mL)	Before treatment	0.46 ± 0.18	0.45 ± 0.17	0.330	0.741
	72 h after treatment	0.33 ± 0.13	0.24 ± 0.09	5.120	<0.001
ALT (U/L)	72 h after treatment	54.20 ± 19.50	42.70 ± 16.30	3.950	<0.001

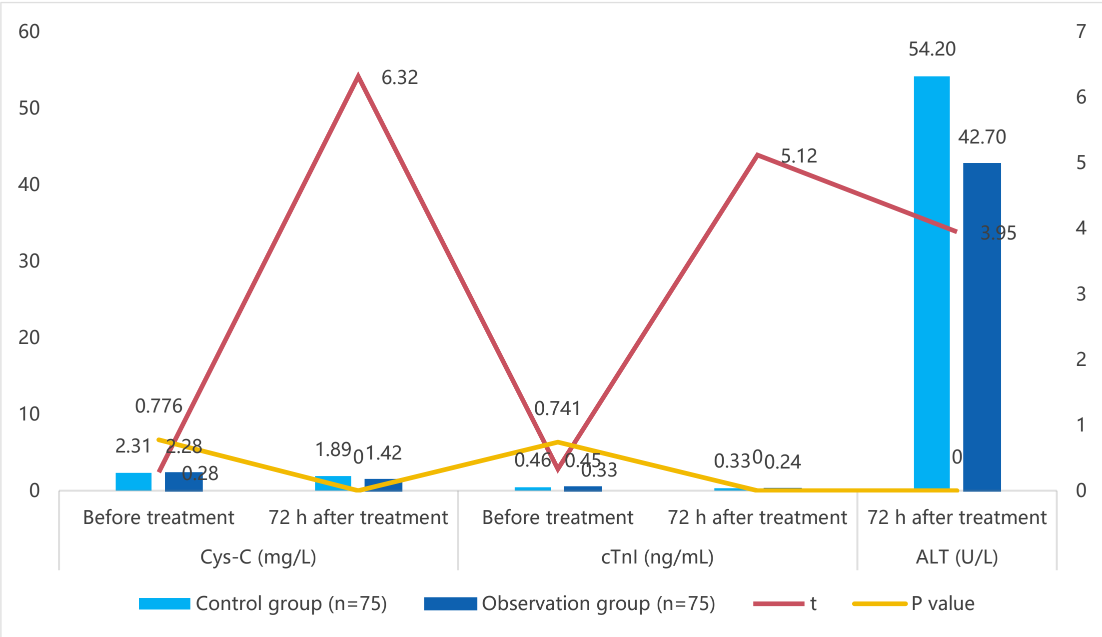

Figure 2 Comparison of organ injury biomarkers between the two groups (mean ± SD)

2.3 Changes in Inflammatory Markers and pSOFA Scores

Baseline PCT levels were comparable between groups and decreased at 72 h in both groups, with a larger decline in the observation group (P<0.05). At 72 h, CRP, lactate, and pSOFA scores were lower in the observation group than in the control group

(P<0.05; Table 4 and Figure 3).

Table 4. Comparison of inflammatory markers and pSOFA scores between the two groups (mean ± SD)

Parameter	Time point	Control group (n=75)	Observation group (n=75)	t	P value
PCT (ng/mL)	Before treatment	8.21 ± 3.45	8.10 ± 3.39	0.200	0.842
	72 h after treatment	5.26 ± 2.41	3.81 ± 1.96	4.230	<0.001
CRP (mg/L)	72 h after treatment	48.50 ± 21.30	36.20 ± 18.90	3.540	0.001
Lactate (mmol/L)	72 h after treatment	2.78 ± 0.91	2.12 ± 0.74	4.670	<0.001
pSOFA score	72 h after treatment	5.30 ± 1.90	3.80 ± 1.70	5.160	<0.001

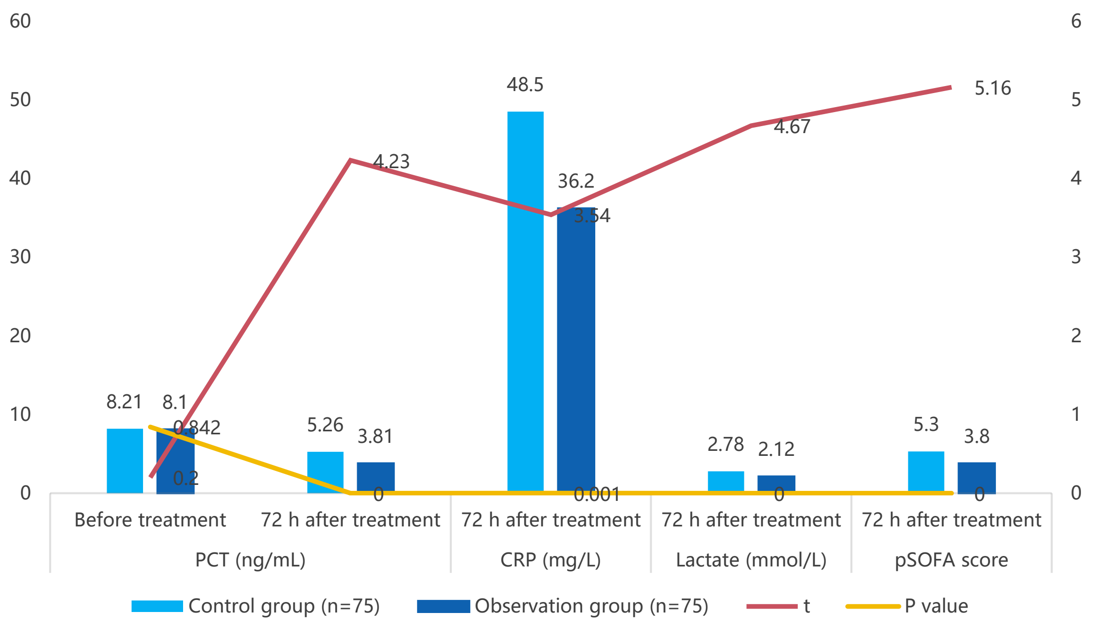

Figure 3 Comparison of inflammatory markers and pSOFA scores between the two groups (mean ± SD)

2.4 CRRT-Related Adverse Events and Nursing Quality Indicators

Nursing quality–related outcomes were significantly better in the observation group than in the control group (P<0.05) , see Table 5.

Table 5. Comparison of CRRT-related adverse events and nursing quality indicators

Outcome	Control group (*n*=75)	Observation group (*n*=75)	χ^2/t	*P* value
Unplanned circuit termination, n (%)	17 (22.67%)	7 (9.33%)	5.120	0.024
Filter clotting rate, n (%)	29 (38.67%)	13 (17.33%)	9.540	0.002
Mean filter lifespan (h)	18.40 ± 5.60	24.70 ± 6.30	6.100	<0.001
PICU length of stay (d)	11.20 ± 4.30	8.60 ± 3.80	3.710	<0.001
Duration of CRRT (d)	4.30 ± 1.20	3.50 ± 1.00	4.510	<0.001

3. Discussion

3.1 Mechanisms and Advantages of Blood Purification in Improving Coagulation Function in Pediatric Sepsis

This study shows that treatment with a blood filtration method significantly improves clotting-related factors in children with blood infection. The data indicate that this approach reduces clotting time and a specific blood marker of clotting activity. These findings suggest that the treatment corrects problems with excessive clotting and the formation of small clots in blood vessels. Problems with clotting in children with this infection develop rapidly. The system that controls clotting in children differs from that in adults because it shows less development. This difference indicates that children experience a more severe loss of factors that allow clotting and also show problems with the process that breaks down clots. These issues occur due to widespread inflammation throughout the body. The treatment that filters blood operates over time to remove substances that promote inflammation and to remove products involved in clotting activation. This removal reduces ongoing excessive activation of the system that controls clotting. The approach also reduces problems with inflammation-induced clotting [5-7].

The method also controls fluid levels, the balance of substances in the blood, and the level of acid in the body. This control supports the flow of blood through tissues and improves circulation in small blood vessels. These effects prevent further clotting when blood flow decreases. These features of the treatment show particular value for children because they have a lower blood volume in circulation, higher rates of bodily processes, and greater sensitivity to changes in blood flow. The approach that filters blood directly addresses problems with clotting by removing substances and indirectly stabilizes internal conditions in the body. This stabilization promotes return to normal balance in the clotting system. These multiple effects indicate that this treatment plays a role that other approaches cannot replace in the care of children with blood infections.

3.2 Role of Integrated Nursing in Enhancing Safety and Organ Protection During Pediatric CRRT

The findings show that the approach using combined care reduces the occurrence of clotting in the device and reduces unplanned treatment interruptions. This approach, which combines care, also extends the device's functional time and shows more substantial changes in measures of function for organs that process waste and support circulation. Children in critical condition exhibit changes that occur quickly, and these changes require high-level care, more frequent assessments, and adherence to more precise procedures. The principal value of the approach that combines care appears in the system that establishes work across different areas. This system involves physicians working in the unit for children in critical condition, individuals who provide respiratory support, and individuals who provide specialized care. This system allows refined management throughout the treatment process. Management occurs through continuous assessment, precise actions, and ongoing observation. The approach that combines care allows changes to the method that prevents clotting. These changes occur in the present time and involve measures of clotting, device pressure, and circulation. The changes reduce the risk of thrombosis and increase the likelihood of continued device use [8-10].

The approach also provides results through changes in fluid management and stronger breathing support, along with actions that use procedures to clear the lungs and corrections that occur quickly for minor circulation problems. These changes increase the delivery of substances to tissues and reduce the burden on the body's responses that cause damage. The changes protect organs that process waste and support circulation. These organs are particularly vulnerable in children with the condition, which causes a widespread response to infection. The approach that combines high-precision treatment with the device for children, immediate response, and design for the individual shows high precision and immediate response. This approach maintains treatment safety and provides comprehensive organ protection.

3.3 Prognostic Implications and Clinical Guidance of the Combined Intervention in Pediatric Sepsis

The study shows that using treatment to remove substances from the blood combined with a particular form of care provides more substantial effects than using standard care alone in reducing factors that indicate processes relating to damage in the body, improving the process by which substances reach different parts of the body, and lowering measures that indicate problems with organ function. These results suggest that the approach allows faster improvement in the function of multiple organs in children with the condition, which involves a systemic response to infection [11-14].

In children, a rapid response to infection can cause damage across different parts of the body, and problems forming substances that stop blood flow can amplify the effects of the other process. This interaction increases the likelihood of problems across multiple organs. The approach that combines different forms of treatment provides a process that follows these steps: removing substances that indicate damage, improving flow in the smallest vessels, and reducing damage to organs. These steps interrupt the process by which the condition develops at multiple points. The approach also reduces events indicating problems with the treatment that removes substances from the blood, thereby improving the duration of uninterrupted treatment. These effects result in shorter time spent in the unit for children with the most significant problems, and the results demonstrate that the approach affects outcomes over time [15-20].

The model provides an approach that can be used across different settings to care for children with the most significant problems. The approach includes treatment that removes substances from the blood as the main component relating to the specific procedures, the particular form of care that combines different elements as the component that provides consistent quality, and observation that occurs repeatedly over time and evaluation that considers individual features as the basis for making changes, and these components form a structure for organizing the overall process that includes reducing factors that indicate processes relating to damage in the body, maintaining appropriate balance in the process relating to forming substances that stop flow in vessels, protecting organs from damage, and managing factors that relate to preventing problems. The study provides evidence that the approach combining different forms of treatment shows value for use with children with the condition characterized by infection spreading throughout the body, and the findings provide a basis for using the approach in studies that include larger numbers of individuals and multiple locations where care is provided.

3.4 Limitations

This study has limitations. It was conducted at a single center with a before–after design, so residual confounding and time-related changes in clinical practice cannot be entirely ruled out. Several outcomes were analyzed at a single post-treatment time point based on available routine records, and longer-term follow-up (e.g., mortality, ICU length of stay, and functional outcomes) was not assessed. Future multicenter randomized studies with standardized time-point measurements are warranted.

Conclusion

The study shows that providing integrated care with continuous treatment using blood filtration produces significant effects in children with sepsis across multiple approaches, including reducing inflammation, correcting blood clotting problems, protecting organs, and maintaining treatment adherence. Children who received integrated care showed greater reductions in measures of blood clotting time and in levels of factors associated with clotting problems compared with those receiving routine care. This suggests that the process involving excessive clotting and the formation of small clots was reduced more in these children.

The group receiving integrated care also showed larger decreases in measures of organ damage, including kidney function, heart muscle damage, and liver function. These findings suggest that recovery of kidney, heart, and liver function occurred more rapidly and in a more coordinated manner in this group. The same group also showed decreases in measures of inflammation, blood lactate levels, and overall disease severity. These changes indicate that the burden of inflammation across the body was reduced, that blood flow to tissues improved, and that the severity of disease decreased.

The integrated care approach uses a specific method to prevent blood clotting in the treatment circuit, ongoing risk assessment, and a closed system for management. This approach reduced problems with filter clotting and unplanned treatment interruptions. It also increased the time that filters could be used and improved the stability and continuity of the blood filtration treatment. These benefits resulted in shorter time in intensive care and shorter duration of blood filtration treatment. The findings indicate that combining blood filtration with integrated care provides a practical and effective approach. This strategy may represent a valuable method for improving care and nursing procedures for children with sepsis in critical care settings.

Declarations

Ethics approval and consent to participate: This study was conducted in accordance with the Declaration of Helsinki. Approved by the Ethics Committee (Institutional Review Board) of Hebei Children's Hospital (Approval No. 202407-71). Written informed consent was obtained from guardians of all participants.

Consent for publication: Not applicable.

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

Authors' contributions

Huifen Zhang (HZ), Yanhe Ma (YM), Lihong Hu (LH), Yuxiang Wang (YW), Na Zhang (NZ), and Meixian Xu (MX) contributed to the study conception and design, data acquisition, data analysis and interpretation, and manuscript drafting and revision. All authors read and approved the final manuscript.

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