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Examining the progress and implementation of neonatal peritoneal dialysis in the Ningxia autonomous region

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Abstract

Background Neonates are prone to experiencing acute kidney injury (AKI) and metabolic irregularities. Although hemodialysis is a primary treatment for these conditions, its utilization is not prevalent in the Ningxia Autonomous Region in China. Peritoneal dialysis (PD) presents itself as an alternative with benefits such as simplicity, cost-effectiveness, and minimal technical complexity compared to hemodialysis. Nonetheless, the safety and efficacy of employing PD in neonates, particularly in very low birth weight infants, require additional investigation.

Objective In this study, we explored the practical use of PD in neonates in the region of Ningxia.

Methods The retrospective analysis focused on the clinical information of neonates undergoing PD at the neonatal intensive care unit of PKUFH-NINGXIA Women & Children's Hospital, covering the period from January 2021 to August 2023.

Results A total of 7 neonates (3 males and 4 females) were included in the study, including one early preterm infant ($28–31^{+6}$ weeks' gestational age), one moderately preterm infant ($32–33^{+6}$ weeks' gestational age), two late preterm infants ($34–36^{+6}$ weeks' gestational age), and three term infants. The minimum gestational age recorded was 28 + 6 weeks and the lowest body weight was 1,075 g. Among the cases, sepsis was the primary cause of AKI in three cases (43%), with preterm infants accounting for 67% of these cases; genetic metabolic disorder in two cases (28.5%), and twin-twin transfusion syndrome in two cases (28.5%), both involving premature infants; and one of these two involving severe asphyxia. The onset of dialysis occurred between 1 and 24 days of age, and the duration of dialysis ranged from 1 to 5 days. The dialysis procedures for all seven cases were executed smoothly, and there were no complications observed in terms of unsecured catheter leakage at the insertion site, hyperglycemia, hypokalemia, catheter occlusion, peritonitis, or catheter detachment during the peritoneal dialysis treatment.

Conclusion The use of peritoneal dialysis proves to be a safe and efficient approach in addressing neonatal AKI.

Keywords Acute kidney injury, Complications, Neonates, Peritoneal dialysis, Preterm infants

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Introduction

Peritoneal dialysis (PD) stands out as a widely utilized approach to renal replacement therapy in neonates [1], applicable to preterm neonates and those with very low birth weight. Despite advancements in hemodialysis and continuous renal replacement therapy, there is currently no optimal vascular access method for preterm neonates. Consequently, PD remains the preferred treatment for very low birth weight neonates [2]. This method effectively eliminates excess fluid and solutes from the body, thereby rectifying fluid, electrolyte, and acid-base imbalances [3]. In contrast to hemodialysis, PD gradually removes fluid and solutes, successfully sidestepping the hemodynamic instability associated with hemodialysis [3]. Furthermore, PD treatment eliminates the need for anticoagulation and venous access establishment, offering a straightforward procedure with a low cost [3]. This clinical convenience contributes significantly to improving the survival rate of critically ill neonates, particularly in regions or households with limited economic resources.

There have been no previous studies evaluating the use of PD for neonates in Ningxia Autonomous Region, China. Due to its simplicity, affordability, and relatively low technical complexity, however, PD is likely to be extensively used in Ningxia. It can enhance the care and treatment of critical neonates in the region, ultimately lowering neonatal mortality rates. In this study, we reviewed the clinical application of PD in critical neonates in the Ningxia Autonomous Region.

Participants and methods

Participants

Between January 2021 and August 2023, seven cases involving neonates undergoing PD treatment for acute kidney injury (AKI) or hyperammonemia in the neonatal care unit at PKUFH-NINGXIA Women & Children's Hospital were identified.

Methods

Diagnostic criteria and staging of AKI

According to KDIGO Clinical Practice Guidelines for Acute Kidney Injury [4], the diagnosis of AKI met one of the following criteria: (1) An increase in serum creatinine by ≥0.3 mg/dL (≥26.5 μmol/l) within 48 h; (2) An increase in serum creatinine to ≥1.5 times baseline within the previous 7 days; (3) Urine volume≤0.5 mL/kg/h for 6 h.

The staging of AKI are as follows: Stage 1: serum creatinine 1.5–1.9 times baseline, or ≥0.3 mg/dL (≥26.5 μmol/L) increase; urine output<0.5 mL/kg/h for 6–12 h. Stage 2: serum creatinine 2.0–2.9 times baseline; urine output<0.5 mL/kg/h for ≥12 h. Stage 3: serum creatinine 3 times baseline, or ≥4.0 mg/dL (≥353.6 μmol/L) increase, or initial of RRT, or in patients<18 years a decrease in eGFR<35 mL/min/1.73 m^2; urine output<0.3 mL/kg/h for ≥24 h, or anuria≥12 h.

Indications of PD

(1) Respiratory failure accompanied by a substantial fluid overload exceeding 15%; (2) Severe hyperammonemia; (3) Prolonged worsening of azotemia; (4) Diminished kidney function persisting for 24–48 h, characterized by oliguria or a urine volume less than 0.5 $ml \cdot kg^{-1} \cdot h^{-1}$, absence of urinary retention, and inadequate response to intensive medical interventions for severe edema [5].

Dialysis method

The rectus incision guided by ultrasound was utilized for the implantation of the dialysis catheter. Peritoneal dialysis solution with glucose concentrations of 1.25% and 2.5% was chosen. The initial infusion of 10 $ml \cdot kg^{-1}$ of dialysate was administered gradually over 10 min, and the dialysate was retained in the abdomen for 2 h. Subsequently, the volume was increased by a maximum of 30 $ml \cdot kg^{-1}$, based on the ultrafiltration volume, for a preservation period of 3 h. The dialysis sessions occurred 10–12 times per day. Throughout the treatment, various parameters, including hourly intake and outflow, blood pressure, body weight, renal function, electrolytes, blood glucose, and blood gas, were monitored on a daily basis. The PD procedure in our center involves the instillation of dialysate at a rate of 10mL/kg over a duration of 10 min. The dialysate was initially stored in the abdomen for a duration of 2 h during the commencement of dialysis. In cases where the ultrafiltration volume exceeded 10mL per session, there was a gradual extension in the storage time of the dialysate. The maximum increase in ultrafiltration volume did not exceed 30mL/kg, and the duration of abdominal ultrafiltration was limited to no more than 3 h. The frequency of dialysis sessions ranged from 10 to 12 times per day. PD catheter placement: Aseptic bedside procedures were performed by pediatric surgeons at our center. The neonate was positioned supine and marked slightly lateral to the anti-McBurnet point under ultrasound guidance. Standard iodophor disinfection was carried out, followed by the placement of an aseptic hole-towel. The skin incision, approximately 1.0 cm in length, was made at the puncture site, exposing both the anterior and posterior rectus sheaths as well as the peritoneum. With ultrasound guidance, a needle was inserted at a 45° angle to place the PD tube within the abdominal wall, adjusting its position to either uterorectal fossa or vesicorectal depression. A small amount of dialysate was injected for patency testing before suturing and applying postoperative sterile dressing. Wound disinfection occurred every 6 h with regular changes of sterile dressings.

Table 1 General conditions and complications in the seven neonates undergoing peritoneal dialysis

S/*N*	Gestational age (weeks)	Gender	Body weight (g)	Primary disease	Associated complications	Dialysis indications	Dialysis days (d)	Complications
1	38	F	2 900	Sepsis	Capillary leakage, multiple organ failure	Acute kidney injury	3	None
2	41^{+2}	F	2 600	Methylmalonic aciduria	Metabolic encephalopathy	Hyperammonemia	1.5	None
3	39^{+5}	M	2 940	Methylmalonic aciduria	Metabolic encephalopathy	Acute kidney injury, hyperammonemia	1	None
4	36^{+2}	M	2 300	Twin-twin transfusion syndrome	Hypoxic ischemic encephalopathy of newborn	Acute kidney injury	3	None
5	32^{+2}	F	1 280	Sepsis	Multiple organ failure	Acute kidney injury	1	None
6	36^{+5}	M	2 880	Sepsis	Capillary leakage	Acute kidney injury	5	None
7	28^{+6}	F	1 075	Twin-twin transfusion syndrome	Neonatal hyaline membrane disease	Acute kidney injury	1.5	None

Note Case 4 and 7 were different twin pairs

Table 2 Assessing index variations in the seven neonates before and after dialysis

S/*N*	Creatinine (μmol/L)		Blood potassium (mmol/L)		Blood ammonia (μmol/L)		Urine Volume ($ml \cdot kg^{-1} \cdot h^{-1}$)	
	Pre-PD	Post-PD	Pre-PD	Post-PD	Pre-PD	Post-PD	Pre-PD	Post-PD
1	79	57	6.29	4.67	-	-	0.5	2.7
2	45.9	44.7	4.43	4.20	825	40	3.0	2.4
3	21.0	13.7	4.33	3.27	170	117	1.7	Abandon treatment
4	338	126	4.01	5.20	64	49	0.8	1.75
5	93.8	65.0	4.47	3.66	-	-	0.2	3.6
6	95	65	2.98	4.56	-	-	0.1	2.7
7	102.8	95.1	4.04	4.36	-	-	0.0	2.8

Notes PD (Peritoneal dialysis)

Indications for stopping PD

(1) Maintenance of stable circulation; (2) Urine volume > 1 $ml \cdot kg^{-1} \cdot h^{-1}$, with resolution of edema. (3) Normal fluid levels, acid-base balance, and electrolytes [5].

Results

A total of 7 neonates (3 males and 4 females), with gestational ages ranging from 28 + 6 weeks to 41 + 2 weeks, and weights ranging from 1,075 g to 2,940 g, were included in the study. The primary diagnoses were as follows: three cases of sepsis (43%), two cases of genetic metabolic disorder (28.5%), and two cases of twin-twin transfusion syndrome (28.5%, one of which involved severe asphyxia). PD was initiated within 1 to 24 days after birth.

The indications for dialysis included six cases of AKI (manifesting as anuria/oliguria and elevated serum creatinine), one case of hyperkalemia, and two cases of hyperammonemia. The severity of AKI in case 2 and 3 did not warrant the use of peritoneal dialysis; however, their blood ammonia levels exhibited significant elevation. PD was primarily employed for toxin clearance purposes. The duration of dialysis ranged from 1 to 5 days. Following PD treatment, the dialysis procedures for all seven cases proceeded smoothly. Among them, six cases were successfully treated and discharged, while one case (case 3) succumbed to a genetic metabolic disease one day after discontinuing treatment and discharge; further details can be found in Table 1. For the two newborns with methylmalonic aciduria (cases 2 and 3), metabolic support therapy was applied. Case 2 received treatment involving the administration of L-carnitine, vitamin B12, vitamin B1, and arginine. Metabolic support for case 3 was provided through supplementation with L-carnitine, vitamin B12, and vitamin B6.

The creatinine levels in all seven cases exhibited varying degrees of reduction before and after treatment. Notably, the case with hyperkalemia achieved normalization of blood potassium levels post-treatment, and the two cases with hyperammonemia exhibited normal blood ammonia levels after treatment. The urine volume of all neonates returned to normal following treatment, as outlined in Table 2. Importantly, no complications, such as catheter leakage, hyperglycemia, hypokalemia, catheter occlusion, peritonitis, or catheter detachment, were observed in any of the cases.

The acid-base balance of all cases was abnormal prior to PD treatment, and following PD treatment, the neonates exhibited improved acid-base balance. Furthermore, PD treatment did not have any impact on the cardiac function of the neonates, and no infections were observed among them. Particularly in case 1 and case 6,

there was a significant improvement in infection index after undergoing PD treatment (Table 3).

After undergoing PD treatment, a significant reduction in body weight was observed in all cases, accompanied by improved edema. With the exception of case 2 and case 3, the urine output returned to normal levels in the remaining cases (Table 4).

Except for case 3, in which the patient discontinued treatment, the remaining neonates exhibited reduced edema and normalized urea nitrogen levels after undergoing PD treatment. Furthermore, PD did not have a significant impact on platelet count, hemoglobin, or electrolyte levels (Table 5).

Discussion

In a comprehensive study involving a substantial cohort, it was found that the occurrence of neonatal AKI in neonatal intensive care units reached a rate of 29.9% [6]. Research indicates that the leading factor contributing to neonatal AKI is prerenal, constituting approximately 76–80% of cases [7]. Neonatal AKI often emerges as a consequence of conditions such as multiple organ failure, sepsis [8], prematurity, and birth asphyxia. Literature reports underscore concerning mortality rates, indicating that preterm neonates with AKI face a mortality range of 69–80% [9], while those with multiple organ failure may confront an even more alarming 95% mortality rate [10].

PD emerges as a pivotal and effective therapeutic approach for various critical neonatal conditions. It is deemed to be a preferred dialysis method for neonates, particularly those with very low and ultra-low birth weights, due to its efficacy, simplicity, and safety. Compared to hemodialysis and continuous hemofiltration, PD is considered superior, given the higher technical demands of the latter two methods. Establishing vascular access for neonates poses clinical challenges, with issues such as large extracorporeal blood volume, rapid circulation, necessitated heparinization anticoagulation, and potential complications like circulatory disturbance and abnormal coagulation. These complexities make the implementation of hemodialysis and continuous hemofiltration challenging in critically ill or young infants. Consequently, PD therapy is regarded as a secure, efficient, and comparatively straightforward approach for treating neonatal AKI. It not only provides a means to recover renal function but also plays a crucial role in saving the lives of infants [7].

In prior investigations, PD demonstrated positive outcomes in ameliorating AKI. Cao et al. observed the treatment involving PD for AKI in seven infants [11], noting varying degrees of improvement in renal function in five cases. In contrast to their pre-dialysis states, a reduction in edema was observed, and there was an improvement in the equilibrium of fluid intake and output. Studies

Table 3 Changes in acid-base balance, cardiovascular function, and inflammatory markers in pediatric patients pre- and post-peritoneal dialysis

Cases	Arterial blood gas						Cardiac function				Indicators of infection			
	pH		BE (mmol/L)		Lac (mmol/L)		EF (%)		BP (mmHg)		WBC (10^9/L)		CRP (mg/L)	
	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
PD														
1	7.30	7.38	-5.2	8.6	2.3	0.4	59	77	51/31	63/45	16.54	23.4	141.15	<5
2	7.32	7.49	-10.1	-5.9	1.2	4.1	67	70	50/33	66/42	5.4	6.75	<5	<5
3	6.93	7.39	-14.3	0.4	6.8	1.5	55	69	87/52	92/64	4.5	3.24	<5	9.35
4	7.49	7.4	-3.5	5.6	2.5	1.0	68	68	52/34	59/40	9.05	6.42	5.02	<5
5	7.16	7.31	-5.5	1.7	6.9	4.3	70	68	51/35	55/37	6.0	4.0	<5	<5
6	7.33	7.38	-4.8	-3.8	2.5	1.2	69	67	60/34	68/41	39.96	13	38.35	<5
7	7.38	7.36	-3.2	0.6	2.1	0.6	65	66	54/47	56/38	11.78	5.72	<5	<5

Notes BE (base excess); EF (ejection fraction); BP (blood pressure); WBC (white blood cell count); CRP (C-reactive protein); PD (peritoneal dialysis)

Table 4 Alterations in body weight, fluid amount, and urine output pre-, during, and post-peritoneal dialysis

Cases	Body weight (g)			Fluid amount (mL/kg)			Urine output (mL/kg.h)		
	Before	During	After	Before	During	After	Before	During	After
1	3250	2980	2880	100	98	86	0.5	1.2	2.7
2	2740	2720	2600	134	126	108	3.0	4.9	3.4
3	3300	3212	Abandon	108	81	Abandon	1.7	2.5	Abandon
4	2930	2850	2700	132	103	75	0.8	1.1	1.75
5	1360	1280	1200	135	126	117	0.2	1.5	3.6
6	3660	3320	2990	120	115	66	0.1	1.1	2.7
7	1075	1050	1000	100	94	80	0	1.2	2.8

indicate that early PD administration to infants with or developing AKI not only reduces fluid burden but also leads to significantly shorter stays in the neonatal intensive care units [12]. The renal function, urine volume, electrolytes, acid-base balance, and infection indexes of 6 infants with AKI showed significant improvement after 1–5 days of PD treatment in our study. During the treatment, PD had no impact on cardiac function and there were no instances of infection observed. The prognosis was favorable, which aligns with previous research findings.

Nevertheless, the uniformity of PD efficacy for hyperammonemia lacks consensus in literature. Owing to limited pediatric literature on the role of PD in hyperammonemia treatment, there is a lack of consensus on treatment recommendations and effects [13]. Further confirmation through multi-center and large-sample studies is imperative. Tang et al. reported relatively slow and inefficient reduction of blood ammonia with PD [14]. Nevertheless, within our study, encompassing two cases of hyperammonemia—one of which was complicated with anuria—we observed a substantial decrease in blood ammonia levels after 1–1.5 days of dialysis, signifying a discernible therapeutic impact. These results suggest that with active evaluation and early intervention, PD exhibits efficacy in hyperammonemia treatment. Nevertheless, the limited sample size of the study (only two infants with hyperammonemia) may introduce bias, necessitating validation through larger multi-center studies.

Historically, the infrequent utilization of PD in neonates, especially in preterm and low birth weight infants, can be ascribed to the constraints posed by their limited abdominal body surface area. Challenges and complications in establishing indwelling peritoneal access stem from the difficulty associated with the small surface area, making the placement of a PD catheter for an extended duration a formidable task. Factors such as the inflexible texture of the catheter, challenges in achieving prolonged catheter placement during PD, risk of side hole misplacement outside the neonates' abdominal cavity, and susceptibility to concurrent infections contribute to the inability to sustain the catheter for an optimal duration. Additionally, the repeated injections and drainage of dialysate during dialysis may lead to perforation of abdominal organs. A hose PD catheter was carefully chosen for neonates and positioned under ultrasound guidance in this study, ensuring the absence of any adverse consequences to the neonates throughout the entire PD treatment process.

Common complications in PD treatment include bleeding, dialysate leakage, catheter occlusion, and skin and catheter infections. The most severe complications, notably peritonitis, have been well-documented in literature. In this study, the dialysis process for the seven infants proceeded smoothly, with no observed adverse reactions or complications. The positive outcomes in this study are closely linked to proficiency in PD catheterization, disease assessment, and nursing skills. This affirms the safety of neonatal use of PD in this population and underscores the availability of preventive and treatment measures for potential complications [3].

Similar findings were reported by He et al., who identified the primary cause of death during dialysis treatment as the underlying disease, with no occurrences of serious life-threatening complications during PD operations [1]. This suggests the safety and effectiveness of PD, with complications being rare. For the seven infants in this study experiencing AKI, hyperammonemia, hyperkalemia, and so on, proactive decision-making, early initiation of PD when indicated, and timely removal of excessive fluid overload significantly improved their survival rate even in critically ill conditions.

Moreover, two out of the four preterm infants in this study were characterized as very low birth weight infants. Their PD treatment lasted for 1.0–1.5 days, demonstrating not only positive clinical outcomes but also the absence of adverse reactions. This suggests that PD is a feasible and effective intervention for preterm infants experiencing AKI, particularly those with very low birth weight [15]. This study marks the first instance of PD application in very low birth weight infants in Ningxia Autonomous Region. The cost-effectiveness of PD helps alleviate the economic burden on affected families [16].

Given the constraints of medical resources and technology in Ningxia compared to more advanced regions, timely intervention is crucial for critically ill neonates.

Table 5 The variations in blood urea nitrogen, serum sodium, hemoglobin, platelet count, and ultrafiltration volume during PD

Cases	Ultrafiltration volume (mL)			Urea nitrogen (μmol/L)			PLT (10^9/L)			Na (mmol/L)			Hb (mmol/L)		
	12 h	24 h	48 h	12 h	24 h	48 h	12 h	24 h	48 h	12 h	24 h	48 h	12 h	24 h	36 h
1	70	123	176	9.7	11	4.7	140	123	159	141	136	140	123	114	133
2	75	-58	49	8.9	7.5	5.6	270	230	181	142	178	135	147	125	105
3	10	/	/	10.9	/	/	158	/	/	146	/	/	136	/	/
4	61	65	31	8.5	9.5	7.6	39	14	93	127	132	136	87	104	87
5	3	10	-	4.1	1.7	-	75	88	-	136	145	-	167	113	-
6	35	65	55	17.	12.	4.0	76	211	407	139	137	137	136	150	127
7	4	45	34	4.7	4.7	3.5	201	113	115	133	148	149	173	150	148

Notes The case3 has been discontinued from further treatment

In this context, PD emerges as a vital factor in achieving favorable prognoses, emphasizing the importance of swift treatment for neonates facing life-threatening conditions.

Conclusion

In summary, PD emerges as a straightforward, cost-effective, and safe method for addressing neonatal AKI [17]. Given the less advanced state of medical and economic development in Ningxia, the adoption and promotion of PD in the region hold considerable merit. It is important to note that the limited sample size in this study may introduce some bias into the findings. To address this limitation, ongoing efforts will focus on collecting additional relevant cases to expand the sample size and validate the conclusions drawn from this research.

Abbreviations

AKI Acute kidney injury
NICU Neonatal intensive care unit
PD Peritoneal dialysis

Author contributions

Yong-Jia Ji conceived the idea and conceptualized the study. Zhen Tian, Juan Yang, Xiu Luo and Hua Yang collected the data. Hua Yang, Zhi-Mei Ma and Juan Yang analyzed the data. Yong-Jia Ji and Xiu Luo obtained the finance. Zhen Tian and Yong-Jia Ji drafted the manuscript, then Yong-Jia Ji reviewed the manuscript. All authors read and approved the final draft.

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Data availability

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was conducted with approval from the Ethics Committee of PKUFH-NINGXIA Women & Children's Hospital. This study was conducted in accordance with the declaration of Helsinki. Written informed consent was obtained from all participants' legal guardians.

Consent for publication

All participants' guardians signed a document of informed consent.

Competing interests

The authors declare no competing interests.

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