Pediatr Nephrol (2010) 25:367–371
DOI 10.1007/s00467-009-1347-y

BRIEF REPORT

Acute peritoneal dialysis in very low birth weight neonates using a vascular catheter

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Received: 5 June 2009 / Revised: 9 September 2009 / Accepted: 14 September 2009 / Published online: 3 November 2009
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Abstract We report on our experience with acute peritoneal dialysis (APD) in 16 very low birth weight neonates ranging from 24.6 to 30.2 weeks' gestation with a birth weight ranging from 630 g to 1,430 g using a 14-gauge Arrow vascular catheter for APD access. The underlying causes of acute renal failure were: sepsis (7), necrotizing enterocolitis (4), patent ductus arteriosus (3), hydrops fetalis (1), intracranial hemorrhage (3), pulmonary hemorrhage (2), pneumonia (1), and perinatal asphyxia (1). Among 12 patients, the APD was successful for the control of hyperkalemia, fluid overload, and metabolic acidosis. The peritoneal permeability and transport were at their maximum at a short dwell time with rapid exchanges. Complications associated with the APD were: peritonitis (2), leakage (2), hemoperitoneum (1), and hernia (1). During the dialysis, four patients died; there were three episodes of catheter-related complications in these patients. At 60 days after the withdrawal of the APD, 10 patients were alive, and had full recovery of their renal function. Therefore, APD in premature neonates with a 14-gauge Arrow vascular catheter was safe and effective. This procedure helped manage the hemodynamic and metabolic imbalance of acute renal failure and was associated with few complications.

Keywords Acute peritoneal dialysis · 14-gauge Arrow vascular catheter

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Introduction

The kidneys of premature neonates are vulnerable to hypoxia, hypoperfusion, and sepsis [1, 2]. For successful treatment of these sick neonates, dialysis should be started early to prevent subsequent complications and to provide adequate time for the recovery of renal function. Peritoneal dialysis (PD) is preferred to hemodialysis in premature patients. This is because PD itself is a simple procedure and can be performed in hemodynamically unstable patients [3–6]. However, it is difficult to find available dialysis catheters for premature neonates due to their small size and inelastic abdominal wall. To minimize the complications associated with PD access, a number of catheters have been tried in small infants including a chest tube and vascular catheter [6–9]. However, there is limited information on the outcome of PD in premature neonates.

Here, we describe the results of a simple acute peritoneal dialysis (APD) procedure in 16 very low birth weight (VLBW) neonates with acute renal failure (ARF) associated with severe systemic illness.

Subjects and methods

Patients

We reviewed the course of 16 premature neonates who received APD as treatment for ARF between January 2004 and December 2008. APD was performed in patients with:

1. An abrupt (within 24–48 h) reduction in kidney function with oliguria of less than 0.5 ml/kg/h without distended bladder, and

2. Failure of conservative treatment (normal saline bolus infusion of 20 ml/kg over 1–2 h, furosemide 2–10 mg/kg/day, dopamine 3 μg/kg/min, and salt and water restriction in some cases with severe edema without hypovolemia), or
3. The signs of uremia (impaired cardiac function or seizures), refractory hyperkalemia, and metabolic acidosis, or
4. Fluid overload with respiratory compromise

Dialysis technique

After preparation of the skin and local anesthesia, 5 ml/kg of normal saline was injected into the peritoneal cavity with a 22-gauge needle in preparation for the safe passage of the catheter. The introduced needle was inserted straight through into the peritoneum, and a "J" tip guidewire was advanced through the introduced needle. A 14-gauge Arrow vascular catheter (Arrow International, Research Triangle Park, NC, USA) was threaded over the wire. We manually made several side holes at the terminal 3–5 cm of the catheter (Fig. 1a). The tip of the catheter was placed in the contralateral iliac fossa, pelvis or subhepatic area. After the catheter was positioned, it was taped flat to the skin and sutured. The catheter was easily advanced and there was no need to make a skin incision. None of the patients required more than one catheter. We confirmed the location of the catheter and occurrence of pleural effusion or pulmonary edema by simple X-ray (Fig. 1b).

Results

Patient characteristics

The characteristics of patients were listed in Table 1. APD was performed within 48 hours of oliguria and the onset of metabolic imbalance. All of the patients had findings compatible with the diagnosis of disseminated intravascular coagulation and seven of the patients had multiple organ failure. None of the patients had a distended bladder or renal vessel thrombosis by ultrasound and Doppler studies.

Complications of dialysis

There were five (31%) episodes of catheter-related complications. Peritonitis occurred in two patients. The organisms isolated were *Candida guilliermondi* and *Enterococcus faecium.* There were no cases of catheter exit-site infections. Immediately after insertion, catheter repositioning was performed in two patients because of kinking and the location of the catheter. Early leakage and poor drainage occurred in these patients. Hemoperitoneum was also noted in one of these patients. Blockage was not documented. Hernia of the omentum was noted in one patient.

Effectiveness of dialysis

Acute peritoneal dialysis was initiated using a Dianeal® glucose solution with different glucose concentrations according to the patient's fluid and metabolic status. One

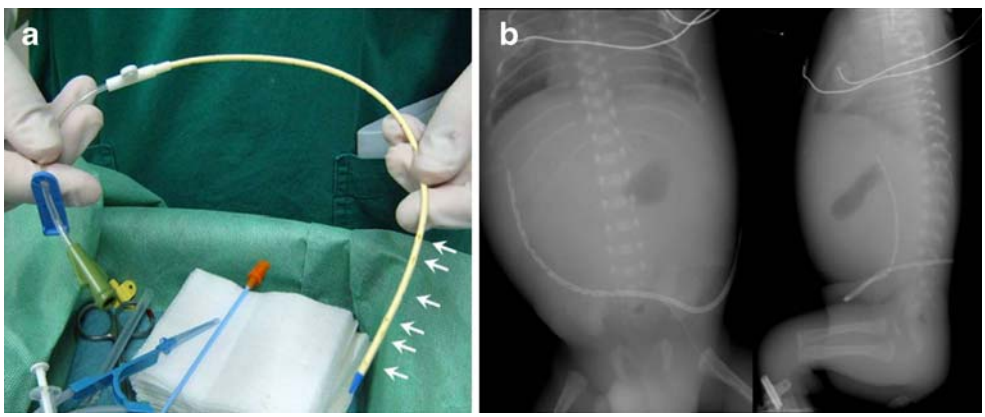

Fig. 1 **a** A 14-gauge Arrow catheter with several side holes that had been made manually (*arrows*) at the terminal 3–5 cm of the catheter. **b** A simple X-ray of the abdomen in very low birth weight neonates was performed after insertion of the dialysis catheter and dialysate was infused before the examination. The tip of the catheter was placed in the right upper quadrant of the abdomen, and the lateral view shows the depth of the intraperitoneal section of the catheter with the tip located in the subhepatic area. No pulmonary effusion or congestion occurred

Table 1 Characteristics and outcomes of peritoneal dialysis in 16 premature neonates following acute peritoneal dialysis

Case	GA (weeks)	BW (g)	Age at onset (days)	Causes of ARF	PD duration (days)	FeNa (%)	Net ultrafiltration (ml/kg/h)	D/P creatinine[a]			BUN (mg/dl)	Cr (mg/dl)	K^+ (mMol/l)	pH	Urine output (ml/kg/h)	Catheter-related complications	Outcome
								at 1h	2h	4h	Pre-/ Post-PD	Pre-/Post-PD	Pre-/ Post-PD	Pre-/ Post-PD	Pre-/ Post-PD		
1	28.2	1,090	29.0	Sepsis	4.0	8.2	−1.4±0.9	0.80	0.98	0.98	48.8/31.2	1.5/1.6	6.1/4.1	7.27/7.33	0.4/5.3		Recovered
2	26.3	930	10.0	Sepsis	2.0	11.3	−0.3±0.1	0.96	0.95	0.95	72.4/42.3	3.0/1.3	7.2/3.7	7.17/7.40	0.2/3.3	Hernia	Recovered
3	28.1	1,020	6.0	Sepsis	10.0	6.8	−6.3±3.0	0.98	0.94	0.95	76.5/19.0	2.1/0.8	4.9/3.7	7.32/7.38	0.8/1.8		Recovered
4	26.5	890	25.0	PDA, ICH	2.0	9.8	−1.2±1.6	0.95	1.00	0.98	7.9/8.1	2.1/1.6	9.2/5.6	7.35/7.38	0.0/2.3	Peritonitis (*Enterococcus faecium*)	Recovered
5	28.6	900	14.0	Pneumonia, sepsis	6.0	12.0	−0.8±0.5	0.98	0.94	0.91	40.4/18.0	2.5/1.7	6.1/5.5	7.30/7.41	0.0/2.0		Recovered
6	28.5	730	26.0	Sepsis, NEC stage IB	3.0	7.8	−0.5±0.5	1.10	1.00	0.94	33.2/21.5	1.7/0.9	6.3/4.3	7.30/7.32	0.0/3.4		Recovered
7	26.0	680	28.0	PDA	6.0	11.3	−0.2±1.0	0.95	1.00	0.95	49.1/32.3	2.1/0.8	3.7/3.2	7.17/7.37	0.2/2.0		Recovered
8	30.2	1,200	3.0	Perinatal asphyxia	6.0	8.4	−2.2±2.1	0.88	0.85	0.80	22.0/19.7	3.7/1.2	6.5/4.3	6.90/7.30	0.3/3.1		Recovered
9	28.5	1,430	9.0	Hydrops fetalis	2.0	13.8	0.4±0.5	1.10	0.98	0.98	22.8/24.5	2.8/1.6	3.6/3.6	7.21/7.44	0.0/2.8		Recovered
10	27.0	690	8.0	Pulmonary hemorrhage	8.0	12.1	−0.6±3.2	0.95	0.91	0.90	23.6/18.3	1.5/0.8	5.1/3.5	7.15/7.32	0.0/2.5		Recovered
11	26.1	1,070	21.0	Sepsis, NEC stage IB	2.0	14.3	0.5±0.2	1.00	0.95	0.96	42.4/48.5	2.1/2.7	6.4/7.4	7.19/7.15	0.3/0.0		Died[b]
12	25.9	700	21.0	ICH	2.0	10.9	0.7±0.7	0.98	0.94	0.94	35.0/ 38.4	2.7/3.1	6.7/9.8	7.12/7.20	0.5/0.0	Leakage	Died[b]
13	28.0	980	32.0	Sepsis, NEC stage IB	3.0	11.7	−0.6±0.3	0.98	1.00	0.94	23.4/25.0	3.0/4.1	7.8/8.7	7.30/7.10	0.3/0.7	Peritonitis (*Candida guilliermondi*)	Died[b]
14	26.4	840	18.0	NEC stage IB, ICH	2.0	10.8	0.7±0.2	1.00	0.96	0.94	46.2/51.2	4.1/5.3	8.1/10.2	7.08/7.25	0.0/0.1	Leakage, hemoperitoneum,	Died[b]
15	26.4	630	27.0	Pulmonary hemorrhage	2.0	11.4	−0.7±0.1	0.94	0.90	0.85	44.8/32.0	2.0/1.6	7.6/2.9	7.24/7.37	0.0/2.3		Died
16	24.6	820	26.0	PDA	3.0	14.5	−1.1±1.0	0.90	0.80	0.81	49.6/33.2	2.7/2.3	8.9/4.1	7.01/7.36	0.0/2.8		Died
Median	26.8	895	21.0		3.0	11.3	−0.6	0.97	0.95	0.94	41.4/28.1	2.3/1.6	6.5/4.2	7.20/7.35	0.1/2.3		
Mean	27.2	913	18.9		3.9	10.9	−0.8	0.97	0.94	0.92	39.9/29.0	2.5/2.0	6.5/5.3	7.19/7.32	0.2/2.2		
SD	1.4	216	9.3		2.5	2.3	1.6	0.07	0.06	0.06	18.2/11.9	0.7/1.3	1.6/2.4	0.12/0.10	0.2/1.4		

GA gestational age, *BW* body weight, *ARF* acute renal failure, *PDA* patent ductus arteriosus, *ICH* intracranial hemorrhage, *NEC* necrotizing enterocolitis, *PD* peritoneal dialysis, *SD* standard deviation, *D/P creatinine* creatinine concentration ratio between dialysate and plasma, *FeNa* fractional excretion of sodium, *BUN* blood urea nitrogen, *Cr* creatinine

[a] Creatinine concentration of the effluent at 1 h, 2 h, and 4 h dwell time was estimated with the plasma creatinine at the same time. 2 ml of effluent and 0.5 ml of peripheral blood was obtained for estimating the creatinine concentration

[b] Patients died during peritoneal dialysis

unit (IU) of low molecular weight heparin was mixed with 1 ml of dialysate. At first, retention of the dialysate was performed over 4 h to evaluate the peritoneal transport and individual equilibration ratio of the creatinine between the dialysate and plasma (D/P Cr). The initial exchange volume was 10 ml/kg, which was increased to 20 ml/kg. Pre-warmed dialysis fluid was delivered by an infusion pump and extension set (with a 3-mm inner diameter) and drained by gravity at a height of 100 cm. The dialysis cycle included 10 min infusion time, 30–90 min dwell time, and 20 min drain time. The dwell time was determined by the time of maximum D/P Cr, electrolyte, metabolic status, and severity of edema. The dialysate dwelled for 90 min in four patients (Cases 1, 4, 7, and 13) and for 30 min in the remaining 12 patients. The D/P Cr at 1-h dwell time was the highest. The repeated measures ANOVA test was used to verify the changes in D/P Cr; the decrease was significant ($P<0.02$) at 1, 2, and 4 h dwell time.

The PD was successful in 12 patients for the control of hyperkalemia, fluid overload, and metabolic acidosis. These 12 patients had diuresis with improvement of the urine output within 48 h of initiating the dialysis. If the patient's renal function improved, the PD cycles were extended up to 6 h and the catheter was removed.

Outcome

Four patients died during the PD; two were extremely low birth weight (ELBW) neonates who remained anuric and had very poor PD functioning. Another two patients were VLBW and ELBW neonates with necrotizing enterocolitis, stage IB. Twelve patients recovered their renal function; however, two of them subsequently died of congestive heart failure and intracranial hemorrhage. At 60 days after the withdrawal from the APD, 10 neonates were alive, and they completely recovered their renal function as defined by normalization of the serum creatinine concentration and electrolytes; none of the patients required long-term peritoneal dialysis (Table 1).

Discussion

Refinement of dialysis techniques has allowed preterm infants to be treated by PD. However, mortality is still high in preterm infants with oliguric ARF. In addition, abnormalities in the glomerular filtration and tubular function can persist in infants following acute kidney injury [4, 6, 10, 11].

The peritoneal surface characteristics can differ in premature infants with severe illness. In infants with poor cardiac output, bowel perfusion is insufficient to permit adequate dialysis exchange. The capillary permeability of the peritoneal membrane is increased in infants with sepsis; this may lead to more rapid solute removal, but may decrease the ultrafiltration [11–14]. In patients undergoing PD, we have to estimate the individual peritoneal equilibration rate for optimal dialysis; however, recurrent blood and dialysate sampling can put small infants at additional risk. Therefore, there are limited available data on the kinetics of PD in this age group.

Several PD access catheters have been used in small infants [6–9]. However, these catheters have been used for short periods and no standard method has been developed. The APD procedure, using a 14-gauge Arrow vascular catheter, was technically safe and effective. Peritonitis occurred in two patients; one of the microorganisms (*Candida guilliermondi*) was confirmed by previously performed blood cultures in the same patients. Leakage with poor drainage and hemoperitoneum occurred in three ELBW patients; these three patients had multiple organ failure with severe systemic inflammatory responsive syndrome. These findings suggest that the success of PD is inevitably related to the overall severity of the patient's condition. Additionally, because side holes that have been made manually have a rough and irritant edge, they may cause complications such as bowel injury and/or infection. It is suggested that an APD device designed in this way might be substituted with a temporary vascular catheter.

Peritoneal dialysis has to balance the dwell time and the dialysate volume to optimize the ultrafiltration and purification of the solute. A large volume of instilled dialysate increases the intraperitoneal hydrostatic pressure and facilitates the ultrafiltration of water. A short dwell time increases the ultrafiltration of water. However, too short a dwell time with a low dialysate volume reduces the peritoneal diffusion capacity and decreases the solute purification from the blood [13–15].

In this study, the D/P Cr was high and rapidly reached equilibration (Table 1). The D/P Cr revealed a significant decrease at 2 and 4 h dwell time and a long dwell time did not cause a large effluent volume. These findings suggested that the creatinine was inversely transported to the plasma. Therefore, at first, the dialysate dwelled for 30 min in 12 severely edematous patients with the maximum D/P Cr at 1 h. We maintained the dwell time for 90 min in four patients (Cases 1, 4, 7, and 13) with the maximum D/P Cr at 2 h; then, the dwell time, the number of exchanges, and the glucose concentration of the dialysate were adjusted according to the patients' status. This technique was effective for the ultrafiltration and purification, and the intraperitoneal hydrostatic pressure did not cause respiratory or hemodynamic compromise.

The biochemical parameters of our patients were compatible with intrinsic renal failure with acute tubular necrosis (ATN), and the overall mortality rate was 37.5%, which is lower than has been reported in prior reviews [3,

4, 6, 10, 11]. In conclusion, early APD was performed successfully even in very small neonates. This procedure could be used in severely ill, very premature newborns with ARF to improve patient outcome and reduce morbidity and mortality.

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