Hepatorenal Syndrome Treated for Eight Months with Continuous-Flow Peritoneal Dialysis

The case documented here represents the longest course of continuous-flow peritoneal dialysis (PD) reported in the literature. A 61-year-old man with hepatorenal syndrome type 1 and ascites presented with hypotension and bright red blood per rectum and was found to be in acute renal failure with severe anemia. Continuous-flow PD was initiated, and the patient improved clinically. The patient died of a jejunal bleed 8 months later, before discharge. Acute PD or continuous-flow PD is a viable alternative in the setting of hemodynamic instability and ascites, can be used as a chronic modality, and addresses many of the weaknesses of continuous ambulatory and automated PD.

Key words
Continuous-flow peritoneal dialysis, acute kidney injury, hepatorenal syndrome

Case description
A 61-year-old man with alcoholic cirrhosis, chronic kidney disease (baseline creatinine 3 months before admission: 1.5 mg/dL), and tophaceous gout presented with hypotension and bright red blood per rectum. He denied recent use of alcohol and nonsteroidal anti-inflammatory drugs. Physical exam revealed hypotension, altered mental status, tense ascites, anasarca, spider angiomata of the abdomen, large tophi of both upper extremities, muscle wasting, and cachexia.

Laboratory data on admission were significant for creatinine 5.24 mg/dL and hemoglobin 5.6 g/dL. Paracentesis was negative for spontaneous bacterial peritonitis, and 4.6 L ascites were drained. Upper endoscopy demonstrated no evidence of bleeding or varices, only chronic gastritis.

Hypotension was managed with a combination of blood transfusions, albumin, and vasopressors. The acute kidney injury (AKI) initially responded to resuscitative measures as listed, but then oliguria and acidemia worsened, with creatinine increasing to 8.65 mg/dL. The patient became more obtunded; the anasarca worsened, including reaccumulation of the ascites post paracentesis; and the patient became dyspneic at rest.

By the 5th hospital day, palliative care was consulted because of the poor prognosis of hepatorenal syndrome and the patient’s ineligibility for liver transplantation secondary to alcohol abuse. The renal team discussed the risks and possible benefits of peritoneal dialysis (PD) and continuous-flow PD (CFPD) with the family, who agreed to a trial. On hospital day 12, a dual-lumen Ronco PD catheter (Figure 1) was placed at bedside, and 8 L ascites was drained.

The patient required intravenous albumin and dopamine infusion to support his blood pressure. On hospital day 13, standard acute PD was initiated (with dopamine infusion) using 4 exchanges of 1.5% dextrose solution. With a daily net negative fluid balance of 4 – 7 L, a combination of albumin, blood transfusions, saline, and dopamine were needed. On hospital day 21, dopamine was switched to midodrine, and the patient was transferred to the general medical ward. Serum albumin was consistently below 1.8 g/dL.

Because of persistent hypotension after 24 days of intermittent PD, CFPD was started once radiographic verification had been obtained that the diffuser portion of the Ronco catheter was located in the peritoneal cavity. A Fresenius 2008H hemodialysis machine with a F180NR dialyzer was used in continuous renal replacement therapy mode to dialyze ascites with a peritoneal fluid flow ($Q_p$) of 300 mL/min and a dialysate flow of 500 mL/min. The ascitic fluid was dialyzed against a standard dialysate with 2.5 mEq/L Ca and 4.0 mEq/L K. During each session, 2 – 4 L
ascites was removed by ultrafiltration (UF). Each session lasted 4 – 6 hours, and 4 – 6 sessions were delivered per week. Clearances were calculated by the Daugirdas equation using pre- and post-treatment blood chemistries (Table I).

The patient improved clinically over several weeks, with clearing of anasarca (20 kg net weight reduction), control of ascites and acidosis, and withdrawal of pressors. The CFPD was continued, with a few missed treatments because of melena, worsening anemia, and punctate leaks in the external portion of the catheter near the Luer connector (fixed by trimming the tubing and inserting a new Luer connector).

Four months into the admission, the patient developed an elevated white blood cell count of 15.6×10⁹/L, but was asymptomatic. The cell count in his peritoneal fluid was 3060/μL with 85% neutrophils, and a culture grew Streptococcus mitis and S. oralis sensitive to ceftriaxone. The white blood cell count in ascites decreased promptly with antibiotics.

The patient’s Kt/V urea averaged 0.25 per treatment (Table I) with a mean urea clearance (K_U) of 46 mL/min. Mean creatinine clearance (K_Cr) was 44 mL/min, mean phosphorus clearance (K_Pph) was 52 mL/min, and mean uric acid clearance (K_Uric) was 47 mL/min (Table II).

The patient remained cachectic, and sessions were increased to 6 hours. The K_U declined after 6 – 8 months to a mean of 24 mL/min (Table I). The K_Cr was 21 mL/min, K_Pph was 17 mL/min, and K_Uric was 22 mL/min (Table II). Seven months into the hospital admission, an attempt was made to add hemodialysis to enhance clearance, but because of worsening symptomatic hypotension, hemodialysis was stopped.

Eight months into the hospital admission, the patient developed recurrent gastrointestinal bleeding. Sigmoidoscopy was negative, and a bleeding scan revealed a jejunal bleed. The bleeding proved refractory, and the patient died 236 days after hospitalization.

Discussion

Review of CFPD

The principle of CFPD is to maximize transperitoneal solute transport by maintaining a constant infusion of solute-free dialysate. The process requires a dual-lumen catheter (or 2 catheters), and either large volumes of fresh, sterile dialysate (single-pass, used in pediatric AKI), or external regeneration of dialysate using a hemodialysis circuit or sorbent.

Continuous-flow PD was first reported by Shinaberger et al. in 1965, with urea clearances in the range 46 – 125 mL/min (1). Those authors used 2 peritoneal catheters with 3 L sterile dialysate refreshed by an external Kil dialyzer and a Q_p in the range 120 – 300 mL/min. During the subsequent two decades, other groups (2–5) reported urea clearances of 30 – 50 mL/min using various means of peritoneal access.

Since the start of the 1990s, enhanced solute clearance with CFPD has been confirmed (6–9). There have also been improvements in catheter design to prevent “streaming”—that is, channeling of dialysate causing a maldistribution of flow (10). The newer catheters enhance intraperitoneal (IP) dialysate mixing and
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Contact with the peritoneal membrane. The Ronco dual-lumen catheter used in our patient has a thin-walled silicone diffuser that is implanted in the upper abdomen and that enables dialysate to exit from multiple pores, thus reducing trauma to the peritoneal walls and also improving IP mixing of the dialysate (11). The second lumen is positioned inferiorly in the pelvis to minimize streaming.

Along with others, we have reported the successful use of CFPD for AKI (12,13). We have also used CFPD in patients with refractory dialysis ascites (14). Other potential applications include home dialysis and a wearable artificial kidney device.

Our patient benefited from use of PD and CFPD for AKI leading to end-stage renal disease and management of ascites. We were in the process of

<table>
<thead>
<tr>
<th>Date</th>
<th>Weight (kg)</th>
<th>Volume (L)</th>
<th>Treatment time (min)</th>
<th>Qp (mL/min)</th>
<th>UF volume (L)</th>
<th>BUN (mg/dL)</th>
<th>Urea (mL/min)</th>
<th>Kt/V (mL/min)</th>
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<td>246</td>
<td>286</td>
<td>2362</td>
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Qp = peritoneal fluid flow; UF = ultrafiltration; BUN = blood urea nitrogen; Kt/V = urea clearance.

<table>
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<th>Date</th>
<th>Creatinine (mg/dL)</th>
<th>KCr (mL/min)</th>
<th>Phosphorus (mg/dL)</th>
<th>Kph (mL/min)</th>
<th>Uric acid (mg/dL)</th>
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KCr = creatinine clearance; Kph = phosphorous clearance; KUric = uric acid clearance.

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<th>KCr (mL/min)</th>
<th>Phosphorus (mg/dL)</th>
<th>Kph (mL/min)</th>
<th>Uric acid (mg/dL)</th>
<th>KUric (mL/min)</th>
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KCr = creatinine clearance; Kph = phosphorous clearance; KUric = uric acid clearance.
preparing the patient for home CFPD, with the family providing support.

**CFPD in AKI**

Like standard acute PD, CFPD benefits patients with AKI who are too hemodynamically unstable to tolerate intermittent hemodialysis, those for whom blood access is unavailable, and those in whom anticoagulation is contraindicated (15,16). Our patient was extremely unstable, with large fluid shifts and hypotension even on standard acute PD. Those circumstances forced the transition to CFPD, which was then maintained for the duration of his hospitalization.

**CFPD in dialysis ascites**

Continuous-flow PD can be used in end-stage renal disease patients with dialysis ascites, obviating the need for recurrent large-volume paracentesis. Dialysis patients can accumulate ascites secondary to cirrhosis, heart failure, or previous PD (15). Repeated ascitic drainage causes continuous protein loss and malnutrition; in contrast, the proteins are retained with CFPD (15). If ascitic fluid is circulated against sterile, urea-free dialysate, then urea clearance lags by about 30 – 60 minutes depending on the volume of ascites and the efficiency of the extracorporeal circuit, because the external dialyzer must first lower the urea level in the ascitic fluid to facilitate transperitoneal urea transport (15). Another benefit of dialysis of ascites is that the proteins become concentrated as water exits the dialyzer membrane, creating a favorable gradient for transperitoneal UF (15). On chronic CFPD, our patient no longer required vasopressors or intravenous saline support, and we were easily able to maintain volume homeostasis by UF of ascites.

**CFPD in daily home dialysis**

Obstacles to daily home CFPD include machine design and UF management. In patients who do not generate ascites, several options for volume control are available. Diuretics can be used to maximize natriuresis from the native kidneys in patients with residual function. An overnight or day dwell with hypertonic dextrose or icodextrin might be sufficient in some patients.

To incorporate volume management into a CFPD machine, the dextrose concentration in the external circuit would have to be boosted to 1% – 1.5%. Because the circuit would maintain that level, lower concentrations would likely be successful. The machine would need to balance internal UF with external UF to allow for gradual removal of the IP volume, a task that might be accomplished using IP pressure monitors.

The 2008K2 machines are designed for blood use and therefore require disabling of the optical blood-sensing alarms. For patients with significant ascites and volume overload, setting UF goals and checking weight before and after should suffice for management. Our patient rarely had abdominal pain, because the IP volume was decreasing; however, the few times such pain occurred, it resolved with either a decrease in the Qp or with the IP addition of normal saline. However, patients without significant hypervolemia may suffer from volume depletion or failure of ascitic recirculation (or both) as ascitic fluid is depleted (15).

Advantages of CFPD over standard PD include removal of inefficiency from the fill–dwell–drain cycles (17), absence of glucose degradation products in the dialysate, improved biocompatibility of fluids (bicarbonate), minimal protein loss (18), and lower cost of online production of dialysate from purified water.

**Discussion**

Our patient presented with hepatorenal syndrome and AKI in the setting of a gastrointestinal bleed. He benefited from multiple applications of CFPD, including management of AKI, ascites, and daily dialysis. This case reinforces the potential for CFPD in such settings. Our patient survived and experienced improved functional status (he attended his daughter’s wedding) on chronic CFPD. However, he remained cachectic throughout the course of his hospitalization, despite dietary measures and anabolic steroids. We attribute the cachexia to end-stage liver failure. The decrease in clearance over time was likely the result of membrane failure (19). The reduced urea clearance might still have been adequate if we had been able to extend treatment time to 8 – 10 hours, which was our plan after discharge to home.

There are still barriers to a successful home dialysis implementation, which this patient never had the chance to experience. The Ronco catheter represents a major advance in peritoneal access technology, and CFPD continues to address many of the weaknesses of continuous ambulatory PD and automated PD. Currently, projects using CFPD technology to develop a
wearable artificial kidney are ongoing (20). As more solutions to the technical challenges develop, CFPD should become a viable competitor to home hemodialysis, particularly considering the inherent safety of peritoneal compared with blood-based renal replacement therapies.

Disclosures
The authors have no financial conflicts of interest to declare.

References

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