Use of continuous-flow peritoneal dialysis for the treatment of acute renal failure in an adult horse

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A 15-year-old Paso Fino gelding was admitted to Purdue University Veterinary Teaching Hospital because of acute renal failure that was refractory to conventional fluid therapy. The renal failure had developed following an episode of exertional rhabdomyolysis, and myoglobin-induced nephropathy was believed to be the inciting cause. During the preceding 3 days, the horse was azotemic and had reportedly been treated sporadically with IV administration of fluids and diuretics, but this had achieved only a minimal decrease in the degree of azotemia.

On initial evaluation (day 1), the horse had mild signs of depression and a decreased appetite. The horse was in good body condition (body condition score, 3/5) and weighed 388 kg (854 lb). Findings of a physical examination (including transrectal examination of the abdomen and pelvis) were unremarkable with the exception of mild tachycardia (52 beats/min). An abdominocentesis was attempted, but no fluid was retrieved. Blood and urine samples were collected for analysis. Abnormal serum biochemical findings included marked azotemia with a BUN concentration of 136 mg/dL (reference range, 73 to 124 mg/dL); therefore, 500 units of lente insulin was administered SC. The horse remained normoglycemic during the remainder of the period of treatment with total parenteral nutrition, which continued for 11 days. An ultrasound-guided renal biopsy specimen of the right kidney was also obtained on day 3, but no histopathologic abnormalities were detected, and there was no bacterial growth on culture of the tissue sample. Because the horse was still severely azotemic (serum BUN concentration, 98 mg/dL; serum creatinine concentration, 14.5 mg/dL) and suspected to be oliguric, treatment with dopamine via constant cuff to monitor the effects of dopamine.

Despite treatment directed at increasing the horse's glomerular filtration rate, azotemia persisted; therefore, intermittent peritoneal dialysis was initiated on day 3. After application of local analgesia to facilitate placement, a 24-F pezzar catheter was placed in the ventral aspect of the abdomen of the horse while it was standing. Intermittent peritoneal dialysis was performed...
once daily. Ten to 15 L of warmed sterile parenteral fluid\textsuperscript{d} was infused into the abdomen via gravity flow, and the catheter was clamped; the horse was then walked during a 30-minute fluid dwell time, after which the catheter was unclamped and the fluid was allowed to drain out of the abdomen. On the first day of intermittent peritoneal dialysis, 65\% of the fluid administered was recovered from the abdomen during drainage. Creatinine concentration in the fluid collected subsequent to dialysis was 3.3 mg/dL. On the second day of intermittent peritoneal dialysis, only 26\% of the 10 L of fluid administered was recovered from the abdomen during initial drainage and a Heimlich 1-way valve was placed on the end of the abdominal catheter to allow continuous drainage. Cytologic examination of the recovered peritoneal fluid revealed signs of inflammation (228,000 WBCs/µL; reference limit, < 5,000 WBCs/µL). The cells in the fluid were mature nondegenerate to minimally degenerate neutrophils along with low numbers of activated macrophages, reactive lymphocytes, and reactive mesothelial cells; protein concentration in this fluid was 4.5 g/dL (reference limit, < 2.0 g/dL), and no bacteria were detected microscopically. Bacterial cultures of the recovered peritoneal fluid yielded no growth. On that day, results of a CBC also indicated mild neutrophilia with a left shift and hyperfibrinogenemia. Although cytologic examination of the peritoneal dialysis outflow fluid did not reveal septic peritonitis, the horse was administered ceftriaxone sodium\textsuperscript{e} (2.2 mg/kg [1.0 mg/lb], IV, q 12 h) to prevent peritoneal infection as a consequence of the indwelling catheter. The horse remained azotemic (serum BUN concentration, 85 mg/dL; serum creatinine concentration, 16.1 mg/dL) and anorexic after 6 days of treatment, including 4 days of intermittent peritoneal dialysis.

Because administration of fluid therapy, diuretics, and dopamine and intermittent peritoneal dialysis were not deemed sufficient to resolve the azotemia in the horse of this report, \textit{continuous-flow peritoneal dialysis (CFPD)} was initiated on day 7. Compared with other techniques, CFPD has been reported to increase clearance of toxins that accumulate as a result of uremia in humans.\textsuperscript{1,2} The catheter in the ventral aspect of the abdomen was removed and replaced blindly with a 28-F indwelling thoracic tube to allow continuous outflow of peritoneal fluid. By use of a surrounding catheter guide,\textsuperscript{1} a 2.2-mm-diameter, 15-cm-long, T-fluted catheter\textsuperscript{2} was placed in the left flank via peritoneoscopy to allow inflow of dialysate.\textsuperscript{3,5} On transrectal examination of the abdomen, the catheter was detected in the retroperitoneal space. The catheter was removed, and a spiral fenestrated catheter\textsuperscript{6} was placed in the left flank by use of the peritoneoscope.

A standard dialysate solution of 1.5\% glucose in sterile parenteral fluid was continuously infused through the catheter into the left flank at a rate of approximately 3 L/h; fluid was collected into a sterile closed collection system from the catheter in the ventral midline region of the abdomen. The quantity of intraperitoneal fluid was regulated by positioning the collection bags at the level of the withers to maintain a constant and modest intraperitoneal pressure (Figure 1). All treatments initiated prior to CFPD were continued as well. On day 1 of CFPD, the serum creatinine and peritoneal fluid creatinine concentrations were nearly at 100\% equilibration (Figure 2). The creatinine clearance achieved by use of CFPD was calculated by dividing the creatinine concentration in the peritoneal dialysate outflow fluid by the serum creatinine concentration and then multiplying that value by the outflow volume in milliliters per minute; the creatinine clearance was 40.9 mL/min. Continuous-flow peritoneal dialysis was continued for 72 hours, and by that time, serum BUN concentration was 33 mg/dL and creatinine concentration was 7.4 mg/dL (Figure 2). The horse tolerated the CFPD and the closed collection system well. While receiving CFPD, the horse's appetite increased slowly and it began to drink some water. Throughout the treatment period, the horse maintained body weight to within 20 kg (44 lb) of its weight at the initial evaluation. On day 2 of CFPD, results of cytologic examination of the peritoneal...
dialysis outflow fluid indicated signs of ongoing (albeit much less severe) inflammation (23,300 WBCs/µL); the cells identified in the fluid were mainly nondegenerate neutrophils, and there were no detectable bacteria. Results of bacterial culture of a sample of this fluid were negative. Five days after cessation of CFPD, the horse had a mild episode of acute laminitis characterized by increased digital pulses in both forelimbs, reluctance to move around the stall, and lying down more frequently. Lateral radiographic views of the forelimbs revealed no rotation or sinking of the distal phalanx, and the episode was resolved by use of frog pressure pads and bilateral application of nitroglycerin® patches to the palmar digital arteries (12 hours on and 12 hours off) for 5 consecutive days.

Overall, the horse remained at the hospital for 23 days. At discharge, serum BUN concentration was 23 mg/dL and serum creatinine concentration was 3.0 mg/dL. Three months after discharge, serum BUN (20 mg/dL) and creatinine (1.5 mg/dL) concentrations had returned to within the reference ranges and the horse had resumed normal activity.

Causes of renal failure in horses are numerous, yet some of the goals of treatment remain constant. Conventional treatment involves increasing glomerular filtration rate and providing supportive care to the affected horse along with removal or correction of the inciting cause. Intravenous administration of large volumes of fluids (except in instances of urinary tract obstruction or postrenal azotemia) is often required in horses with renal failure, and diuretics and renal vasodilators may be necessary to establish diuresis.

Other aspects of treatment include relief from uremic syndrome with the use of antitussive medications and oral or parenteral administration of nutritional support. However, in refractory cases of renal failure in horses, the treatment options are limited. In small animals, renal replacement treatments such as hemodialysis and peritoneal dialysis have had limited success. To our knowledge, use of CFPD has not been reported in an adult horse with renal failure, nor has return of renal function in an adult horse treated with peritoneal dialysis been reported.

Hemodialysis requires specialized equipment and is fraught with potential complications. In large animals, hemodialysis would be both time and cost prohibitive. In humans with renal failure, survival rate is 10% higher among patients receiving peritoneal dialysis, compared with patients receiving hemodialysis.

In veterinary medicine, the results of peritoneal dialysis are not as promising; only 30% of dogs and cats with renal failure receiving peritoneal dialysis improved and were discharged from hospital in 1 study. In large animals, more favorable results of intermittent peritoneal dialysis have been obtained in horses and ruminants with peritonitis or uremia and urethral obstruction.

Peritoneal dialysis has been used in human medicine since the early 1920s and, at present, is the most commonly used form of dialysis in human intensive care units. The peritoneum acts as a dialyzer membrane that allows passage of toxins out of and nutrients into the blood. Diffusive and convective forces move substances down their concentration gradient to achieve correction of electrolyte and acid-base abnormalities and toxin removal, and ultrafiltration facilitates normalization of fluid balance. Peritoneal dialysis can be safely used in patients in which vascular access is difficult or volume overload is detrimental.

One of the drawbacks of peritoneal dialysis is that it has a slower clearance of toxins, compared with that achieved via hemodialysis. However, because of the large surface area of the equine peritoneum (approx 6.3 m² in the horse of this report vs 2 m² in humans) along with continuous flow of dialysate (3 L/h), we were able to obtain creatinine clearance of 40.9 mL/min in the patient on the first day of CFPD. This rate represents 5.7% of normal renal creatinine clearance. The highest creatinine clearance achieved with intermittent peritoneal dialysis in the horse of this report was 12.5 mL/min (ie, 1.7% of normal renal creatinine clearance), compared with creatinine clearance of 8 mL/min that is achieved via intermittent peritoneal dialysis in humans. In the horse of this report, the higher creatinine clearance with CFPD was achieved with higher dialysate flow, which was provided through continuous flow of fluid into the abdomen and continuous drainage of fluid from another catheter.

In veterinary medicine, dialysis of any type is often considered a last resort procedure. This may be responsible for the poor outcomes observed. The success rate of peritoneal dialysis in the treatment of acute renal failure might improve if it was instituted earlier in the disease process. Most of the common complications, such as catheter failure, subcutaneous edema as a result of leakage of fluid around the catheter, and aseptic peritonitis, are minor and easily dealt with. In the horse of this report, there were more catheter-related problems during intermittent peritoneal dialysis (eg, catheter failure, which was probably as a result of occlusion by the omentum) than during CFPD. During CFPD, we used a large-bore (28-F) thoracic tube as the outflow port and a T-fluted and a spiral fenestrated catheter as our inflow ports; by keeping a modest amount of fluid in the abdomen, the omentum was probably raised above the outflow catheter (thereby avoiding catheter occlusion) and most of the peritoneum was available for chemical transport. Also, during intermittent peritoneal dialysis, the horse developed an aseptic peritonitis, probably as a result of multiple handlings of the port when connecting or disconnecting dialysate bags and during abdominal drainage with the Heimlich valve. These interruptions in the system were decreased considerably with CFPD. All of the acute complications were minor and easily dealt with, although long-term complications, such as intra-abdominal adhesions, still remain undetermined.

Patient selection is critical to the success of CFPD. In small animals, peritoneal dialysis is indicated in patients with severe azotemia that remains refractory to conventional treatment (ie, administration of fluids and diuretics) for 24 hours. Peritoneal dialysis can also be used to aid in exogenous toxin removal, correction of acid-base disturbances, hypothermia, and stabilization of the patient prior to surgical correction of uroabdomen. Contraindications of peritoneal dialysis would include abdominal surgery or trauma.
abdominal adhesions, and hypoalbuminemia. Not only does peritoneal dialysis need to be clinically warranted, but the animal's temperament along with owner, clinician, and staff dedication are also essential for successful outcome of CFPD in horses.

Acute renal failure is a potential complication of many conditions in horses, such as colic, ileus, excretional rhabdomyolysis, and nonsteroidal anti-inflammatory drug treatment, among others. In many horses, conventional treatment with IV administration of fluids and diuretics may be enough to resolve acute renal failure. Nevertheless, some horses remain refractory to such interventions and have severe azotemia that persists more than 24 to 36 hours despite treatment. Traditionally in veterinary medicine, peritoneal dialysis has been considered a "last resort" treatment that is associated with a high mortality rate. Intermittent peritoneal dialysis has been used with some success in the treatment of uremia and urethral obstruction in ruminants and for presurgical stabilization of foals with uroperitoneum. In the horse of this report, intermittent peritoneal dialysis was ineffective and associated with complications; CFPD was attempted and successful. By allowing continuous flow of dialysate into the abdomen through an inflow catheter in the left flank, maintaining modest intra-abdominal fluid pressure via placement of the fluid collection bags, and allowing continuous drainage through a catheter on the midline of the ventral aspect of the abdomen, we were able to utilize more of the peritoneum as a dialyzer membrane and maintain a high flow of dialysate (3 L/h) to improve the diffusive and convective forces of dialysis. In the horse of this report, marked improvement was seen within the first 24 hours of CFPD; not only was there a decrease in serum BUN and creatinine concentrations but also clinical evidence of improvement. In our experience, CFPD appears to be a useful treatment for refractory acute renal failure in adult horses.

**References**


