CHAPTER 186

Comparison of Peritoneal Dialysis With Other Treatments for Acute Kidney Injury

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OBJECTIVES

This chapter will:

1. Examine solute and volume control using peritoneal dialysis in critically ill acute kidney injury patients.
2. Compare peritoneal dialysis with other forms of renal replacement therapy in critically ill acute kidney injury patients in regard to outcomes.
3. Examine the differences in cost for peritoneal dialysis in critically ill acute kidney injury patients.
4. Compare the risks and benefits that peritoneal dialysis may have over other forms of renal replacement therapy in critically ill patients with acute kidney injury.

Acute kidney injury (AKI) remains a significant problem among critically ill patients admitted to the intensive care unit (ICU). In the ICU, AKI has been reported to develop in roughly 40% to 50% of such patients and is associated with significant mortality risk.[1–3] Furthermore, the patients with the most severe AKI are at highest risk for death, with mortality rates nearing 50%.[1–3] Although the severity of illness leading to AKI certainly is contributing to these poor outcomes, the metabolic and volume derangements occurring in AKI are also likely playing a role. Many patients ultimately will require renal replacement therapy (RRT) to manage these complications.

Fortunately, a number of different modalities for RRT have been developed to help manage some of these complications, including intermittent hemodialysis (IHD), continuous renal replacement therapy (CRRT), sustained low-efficiency dialysis (SLED), and acute peritoneal dialysis (PD). Despite the inherent differences among these modalities, the superiority of one over the other has not been demonstrated clearly. Nonetheless, physicians tend to favor CRRT over PD among critically ill AKI patients. Although roughly 30% consider PD a viable option, only about 15% prefer or use PD in these patients.[4,5]

Although excellent for metabolic control, the other modalities, particularly CRRT, are not universally available and require significant time and resources. Furthermore, vascular access may be limited, particularly among critically ill infants and small children, or may be difficult to obtain, such as in patients with coagulation disorders or significant vascular disease. The need for anticoagulation, intermittent or continuous, is also a concern because it may raise bleeding risk and is associated with greater utilization of resources for monitoring adequacy of anticoagulation. However, PD is not without risk, including peritonitis, hyperglycemia, protein loss, and mechanical complications (such as fluid leakage or catheter malfunction), and may not be an option in patients with major abdominal surgery.[6]

In centers that lack the resources and expertise in CRRT, acute PD may be a viable option for the management of AKI in critically ill patients. It may be better tolerated than IHD among patients who are hemodynamically unstable or have severe congestive heart failure. Furthermore, the use of continuous PD therapy in AKI appears to provide adequate control of metabolic derangements in catabolic patients and significant solute removal.[7–9]

SOLUTE AND VOLUME CONTROL AND OVERALL OUTCOMES

Many have favored CRRT/IHD/SLED over PD because of presumed superiority in solute, volume, and metabolic control. However, a number of studies have documented excellent solute and volume control with PD. Chitalia et al. compared continuous equilibrated peritoneal dialysis (CEPD) with tidal peritoneal dialysis (TPD) in patients with hypercatabolic AKI.[7] In this study, patients were classified as having mild, moderate, or severe hypercatabolic AKI according to severity of catabolism, which was based on estimation of excess urea nitrogen appearance (UNA). Patients with mildly to moderately hypercatabolic AKI were

subsequently randomly assigned to undergo TPD or CEPD with a total volume of approximately 26 L per session in both arms. TPD was associated with lower postdialysis BUN and creatinine concentrations and higher creatinine and urea clearances than CEPD. The per-session and weekly Kt/V urea achieved with TPD were 0.34 ± 0.14 and 2.43 ± 0.87, respectively—significantly higher than those with CEPD. Ultrafiltration was also superior with TPD as compared with CEPD (3 L vs. 2 L per day).[7] Others have targeted even higher clearances using high-volume peritoneal dialysis.[8,9] Investigators from the same institution in Brazil targeted a per session Kt/V and 0.60 and 0.65 in separate studies, and achieved a Kt/V of 0.51 and 0.55, respectively. In both studies, rapid correction in metabolic derangement while maintaining an ultrafiltration rate of roughly 2L/day occurred.[8,9]

Clearances with continuous-flow peritoneal dialysis (CFPD) may be superior to those in TPD and CFPD and may be particularly useful in AKI.[10] In this modality, large volumes of intraperitoneal fluid are replenished continuously with dialysis solution in constant contact with the membrane. There are two modes of CFPD, continuous infusion and removal of sterile dialysate solution (called single-pass CFPD) and recirculation of the dialysate (in which the peritoneal effluent, and not blood, is "dialyzed" through a hemodialysis or CRRT circuit against an external dialysate and then returned to the patient). Obviously, this technique requires either two catheters or a catheter with dual lumens. Physical separation of catheter lumens is important to minimize recirculation. Urea clearances of 30 to 50 mL/min usually are achieved with this technique, with the potential for even greater clearances.[11] Such clearances are equal or superior to those achieved with CRRT. Unfortunately, no studies have directly compared CFPD with other modalities in patients with AKI. The overall cost of CFPD also may be limiting and may preclude its routine use in AKI, particularly at centers with limited resources. Further studies of the use of CFPD in AKI are required for this promising PD modality.

Volume overload is encountered commonly in critically ill patients with AKI. Hypotension often limits the rate at which fluid can be removed, making IHD less desirable for many nephrologists. Although most clinicians would prefer CRRT in these cases, PD offers an alternative. Exchanges using 4.25% dextrose can yield approximately 1 L per 4-hour exchange and even more with hourly exchanges, so rates of sodium and water removal can be high with PD. Hypernatremia is a risk with rapid PD ultrafiltration, because of sodium sieving, but not with IHD or CRRT. However, low-sodium PD solutions can be prepared to yield very high rates of ultrafiltration with balanced Na and water removal.

Several studies have compared outcomes between patients with AKI managed with PD and IHD or CRRT. One of the first randomized trials comparing PD to continuous venovenous hemofiltration (CVVH) in the treatment of AKI came from Vietnam, and it demonstrated an increased risk of mortality in the group receiving PD (17/36 [47%] vs 5/34 [15%] in the CVVH group).[12] However, the applicability of this study has been questioned for several reasons. The PD techniques used in this study were suboptimal, specifically rigid PD catheters, and open drainage was employed.[6] In addition, the population studied is unique and may not be generalizable because it consisted mainly of patients with AKI in the setting of *Plasmodium falciparum* malaria infection (68%), and the CVVH treated group had a much lower mortality rate than would be expected in this type of population with AKI (only 15%).[6] In contrast to these early findings, subsequent randomized trials did not demonstrate differences in mortality between PD and IHD or CRRT. In 2008 a randomized controlled trial from Brazil comparing high-volume PD (36–44 L/day in 18–22 exchanges/day) to daily HD in 120 patients with AKI from ATN demonstrated similar mortality and renal recovery rates (high volume PD [HV-PD] 58% mortality vs. daily HD [D-HD] 53% mortality $p = .48$, HV-PD 83% renal recovery vs. D-HD 77% renal recovery $p = .84$).[13] Furthermore, in a small study from India randomizing 50 patients with AKI to PD or CVVHDF, mortality was high in both groups, but not significantly different statistically (PD 18/25 vs. CVVHDF 21/25, respectively [$p = .49$]).[14] Most recently, Chionh et al. analyzed these randomized trials along with several other observational cohort studies in a systemic review of studies focusing on PD in AKI.[15] This review found no significant differences in mortality between AKI patients treated with PD and extracorporeal blood purification therapies (i.e., IHD or CRRT). In the seven cohort studies included in this systemic review (270 patients treated with PD and 444 patients treated with HD/CRRT) the odds ratio for mortality was 0.96 (95% CI 0.53–1.71). Similarly, in the combined analysis of the four randomized trials (three of which were discussed above) comparing PD (125 patients combined) to either HD or CRRT (123 patients combined), no significant difference in mortality was identified (OR was 1.50, 9% CI 0.46–4.86). There was significant heterogeneity between the results of the randomized trials ($I^2 = 73\%$, $p = .03$).[15] Although these data suggest clinically significant outcomes in patients with AKI treated with PD are likely similar to those outcomes in patients with AKI treated with HD or CRRT, many of these studies have limitations, including small sample size and methodologic concerns.[6] Consequently, additional larger high-quality randomized controlled trials on PD in AKI would be very useful and informative.

The optimal dose of dialysis for PD in AKI has not been studied extensively. Ponce et al. compared high-intensity PD (target Kt/V of 0.8 per session) versus low-intensity (target Kt/V of 0.5 per session).[16] The investigators found similar metabolic control and mortality at 30 days in both arms. However, the achieved per session Kt/V in the high intensity arm was 0.59, whereas in the low-intensity arm the achieved Kt/V was much closer to prescribed (0.49). Whether the outcomes would have improved if clearances were closer to those prescribed, perhaps using CFPD, requires further study.[16] The achieved weekly Kt/V was similar to that achieved by Gabriel et al. comparing acute PD and intermittent HD.[13] This has prompted some to recommend a minimum weekly Kt/V of 3.5,[6] whereas others feel a weekly Kt/V of 2.1 will be adequate for most patients.[17] Clearly, the metabolic demand of the individual pain will guide therapy until more studies are available to answer these questions.

COST

Chitalia et al. found TPD and CEPD to be relatively inexpensive.[7] They reported that (in 2002) a 12-hour treatment with TPD cost approximately $160 and 48 hours of CEPD cost $175; these figures would yield weekly rates of approximately $1100 for TPD and $600 for CEPD. In comparison, the weekly cost of SLED is about $1200 to $1400, that of CRRT with heparin anticoagulation about $2000 to $2500, and that of CRRT with citrate anticoagulation about $2500 to $3500.[18,19] The significantly higher costs of CRRT are secondary to greater nursing time, higher equipment costs, and larger need for anticoagulation.

DIALYSIS ACCESS

Obtaining venous access may be difficult in some patients, and thus PD may be the only modality that is acceptable in such situations. Such is the case with small children and infants, in whom the central venous system may not be suitable for IHD or CRRT access. Indeed, our clinical experience with acute PD in infants and small children has found it an excellent mode of RRT in such patients. Furthermore, although venous access and peritoneal access can result in infection, central venous access also is associated with the development of venous thrombosis, particularly in the femoral and subclavian veins, putting patients at risk for embolic events. In addition, the placement of central venous access can lead to central venous stenosis, which can have significant long-term sequelae, particularly for children.

Peritoneal access, however, may not be uniformly achievable, particularly in patients who recently have undergone bowel surgery. In such patients, PD probably is contraindicated. In addition, critically ill patients with AKI may have bacteremia, raising their risk for development of peritonitis with the placement of PD access. Having a PD catheter in place is a risk factor for peritonitis, but concomitant bacteremia probably will raise this risk. Given the high rates of hospital-acquired bacteremia, particularly in the ICU, the issue of peritoneal seeding and peritonitis should be considered when PD is being considered for renal replacement therapy.

POTENTIAL BENEFITS FAVORING PERITONEAL DIALYSIS

The use of continuous or extended dialysis usually requires some level of anticoagulation. The use of heparin anticoagulation can lead to bleeding and may be contraindicated in patients with a bleeding diathesis or recent surgery. Monitoring of partial thromboplastin time adds to nursing and laboratory costs. Furthermore, patients treated with heparin sometimes develop heparin antibodies, precluding its use. The use of citrate can ameliorate some of these problems with heparin but adds further to complexity and cost. In PD, anticoagulation is not necessary.

When high volumes of replacement fluid are used in CRRT, hypothermia can develop because the fluid temperature is much lower than the body core temperature. This effect often can be treated with the use of a blood warmer or warming of the dialysate (when dialysis is added in addition to hemofiltration), but hypothermia is much less likely with acute PD. In fact, acute PD using a warmed dialysate has been reported to be a successful treatment for acute hypothermia.[20]

Adequate nutrition is important in critically ill patients, particularly those who are hypercatabolic. Enteral and parenteral feedings can be used for nutritional support. The latter requires additional central access, raising the risk of infection, particularly fungemia. Peritoneal dialysis using dialysate containing amino acids potentially can provide nutritional support and has been shown to enhance nitrogen balance in patients undergoing chronic or acute PD.[21,22] Furthermore, the addition of amino acids may reduce the glucose exposure, and subsequently insulin requirements, in acutely ill hypercatabolic patients with AKI. The high glucose exposure is certainly one of the potential disadvantages of acute PD in AKI.

Dosing of medications is difficult in critically ill patients. Factors such as intestinal edema, liver dysfunction, and renal dysfunction significantly affect the absorption and metabolism of such medications. Clearances for a number of medications via CRRT and IHD have been described and have led to recommendations for dosage and frequency of administration adjustments when these modalities are administered. However, fluctuations in drug levels still probably occur, which may lead to periodic subtherapeutic levels. In PD, a number of medications can be given intraperitoneally, and they have much more steady absorption via this route. This feature may lead to more constant steady-state levels of drugs and possibly greater efficacy.

POTENTIAL LIMITATIONS FAVORING OTHER MODALITIES

Although PD may be able to achieve adequate solute removal and may have additional potential benefits that cannot be provided with CRRT or IHD, it is associated with certain unique complications that are not seen with CRRT or IHD. These complications should not preclude the use of PD in AKI, but their consideration and management are crucial in the planning for acute PD.

Pulmonary function may be compromised in patients undergoing PD owing to an elevation in intraabdominal pressure, particularly in small children and infants. Indeed, Bunchman et al.[23] described the PD treatment of four infants with AKI who were undergoing mechanical ventilation. These investigators found that increased midcycle intraabdominal pressure correlated with reduced pulmonary compliance and increased airway resistance. The increased abdominal pressure may be avoided partially by using more frequent cycling of lower dialysate volumes. Other pulmonary complications are the development of pleural effusions from migration of peritoneal fluid into the thorax, which can be managed with lower dialysate volumes and supine dialysis.

Complications from PD catheter insertion include bowel perforation, intraperitoneal hemorrhage, and peritonitis. Although there is usually some bleeding with catheter insertion, large-volume bleeding also can occur. These complications are seen most often with rigid PD catheters but also can be seen with nonrigid catheters. Peritonitis is a known complication of chronic and acute renal failure. Given the high rate of hospital-acquired infections, particularly in the ICU, proper sterile technique should be adhered to and intensive care nurses should receive focused instruction in its performance, particularly if a cycler is unavailable.

CONCLUSION

AKI injury requiring RRT is associated with significant morbidity and mortality. Although solute clearances and metabolic control are easy to achieve with CRRT and IHD, these modalities are not universally available and require significant resources and a certain technical expertise. Furthermore, the risks of anticoagulation and the need for central access may preclude their use. PD may be an option in these situations. PD can achieve adequate solute clearances in mildly to moderately hypercatabolic AKI and at a lower cost than CRRT and IHD. Current data support the use of PD in the management of AKI. However, many

of these studies do have limitations; therefore additional research in this area is needed.

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Key Points

1. Peritoneal dialysis (PD) is viable renal replacement therapy (RRT) option to treat acute kidney injury (AKI).
2. Although solute clearances are generally less than with other modalities, acute PD can achieve adequate solute clearances in most patients.
3. Most data suggest mortality in AKI treated with PD is not significantly different than AKI treated with other RRT modalities.
4. Acute PD is significantly less expensive than other modalities and requires less technical expertise.
5. Acute PD may be more readily available than other modalities in smaller centers and developing countries.
6. Infectious complications of this modality are a concern, and great care must be taken to adhere to sterile technique.

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A complete reference list can be found online at ExpertConsult.com.

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