Chapter 8

Is Peritoneal Dialysis a Suitable Method of Renal Replacement Therapy in Acute Kidney Injury?

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Additional information is available at the end of the chapter

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Abstract

Research focus: The role of peritoneal dialysis (PD) in the management of acute kidney injury (AKI) is not well defined, although it remains frequently used, especially in low-resource settings. A review was performed to ascertain its suitability as the "first choice" in AKI patient treatment and to compare PD with extracorporeal blood purification (EBP), such as hemodialysis (HD). *Research methods used*: Design, setting, participants, and measurements of MEDLINE, CINAHL, and Central Register of Controlled Trials were searched. The review selected eligible adult population studies on PD in the setting of AKI. *Results/findings of the research*: This paper suggests that PD should be considered as a valuable method for AKI since it offers several advantages over HD, such as technical simplicity, no extracorporeal circuit, and no bleeding risk. It offers good cardiovascular tolerance and less cardiovascular instability, thus reducing kidney aggression by ischemia and hydroelectrolytic imbalance. *Main conclusions and recommendations*: Finally, not only in developing countries but also in developed countries, PD is relatively simple and inexpensive and is more widely used. Various techniques of PD have been developed, and these have been adapted for use in AKI. There is currently no evidence to suggest significant differences in mortality between PD and HD in AKI. There is a need for further good-quality evidence in this important area.

Keywords: acute peritoneal dialysis, acute kidney injury, extracorporeal blood purification, suitability, renal recovery

1. Introduction

Peritoneal dialysis (PD) was initially used in the 1920s to treat acute kidney injury (AKI), but it was not until 1946 that it was first described in saving the life of a patient. In the 1970s, acute

PD was widely accepted for AKI treatment, but its practice declined in favor of hemodialysis (HD). It is frequently used in developing countries because of its lower cost and minimal infrastructural requirements. The role of peritoneal dialysis in the regimen of patients with AKI is not well defined. In a recent review on the dose of dialysis in AKI, PD was not even mentioned as a potential modality [1].

The use of PD for AKI, then, became somewhat limited and did not receive much attention until 2008. In the year 2008 has rekindled interest in PD for AKI with a series of publications in which they used a randomized trial design. They confirmed efficacy of PD to demonstrate that results with PD are at least as good as those with HD [2, 3].

AKI is defined as an abrupt decline in glomerular filtration rate (GFR) resulting in progressive elevation of plasma urea and creatinine and is an important cause of morbidity and mortality worldwide [4]. AKI is a major cause of morbidity and mortality in critically ill patients and in aging populations. About 30% of patients admitted to intensive care units (ICUs) develop hemodynamic instability, cardiorenal syndrome, and sepsis [5].

The epidemiology of AKI is faintly documented, especially in developing countries. Primarily, this is because of variable definitions of AKI [6]. Nonetheless, it can be safely assumed that AKI is an associated high mortality and morbidity. It is therefore important to continue to evaluate PD as a modality of renal replacement therapy (RRT) in AKI. This is particularly so for centers in countries which often lack the technical support to effectively perform extracorporeal blood purification (EBP). In these settings, PD may be the most practical form of RRT.

2. The use of peritoneal dialysis in AKI

Dialysis modalities used in AKI are hemodialysis (HD), continuous renal replacement therapy (CRRT), and acute PD either manually or with automated machines in advanced centers. PD is practiced for AKI treatment mostly due to its cost-effectiveness and the minimal infrastructure required, important considerations in many developing countries. PD is an accessible and effective method for AKI treatment mainly because it's quite simple. At times of major disasters, PD could be a lifesaving therapy. For example, the second most frequent cause of death after direct trauma during disasters is crush injury, and it could be treated with PD [7, 8].

The recent consensus guidelines published by International Society of Peritoneal Dialysis (ISPD) on PD for AKI are an important step in providing RRT uniformly [9, 10]. PD is still an underutilized modality in developed countries for reasons that are unclear, and CRRT is more widely used [11]. However, CRRT requires multiple accesses to bloodstream in critically ill patients, which predisposes them to blood-borne infections and possible circulatory complications. PD is hemodynamically friendly and requires only a single access to the peritoneal cavity, and fluid removal can be smoothly achieved by altering the concentration of glucose in the dialysis fluid. Continuous glucose absorption provides nutritional benefits to the critically ill patient.

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The use of PD was associated with a shorter time to renal recovery in the research of Kilonzo et al. [7]. PD is a more physiological and less inflammatory mode of dialysis than HD and better preserves residual renal function [12]. It is likely that the same is true in AKI, although further studies are needed to assess the effect of PD on survival [13]. However, the use of PD for AKI in adults has not attracted much attention from researchers with just few randomized controlled trials in adults in the past 40 years. However, the paucity of literature on PD does not imply that its use is waning. PD is often the only method of supporting a patient with AKI, particularly in developing countries.

2.1. Techniques: dosing and adequacy of acute PD

Various techniques (**Table 1**) of peritoneal dialysis have been described in the literature, and these have been adapted for use in AKI. These different techniques are used according to patient requirement and facility preference. The urea clearance is 8–12 mL/min for acute intermittent peritoneal dialysis (AIPD), 15 mL/min for tidal peritoneal dialysis (TPD), and 30–35 mL/min for continuous flow peritoneal dialysis (CFPD) [14].

Technique	Description
Acute intermittent peritoneal dialysis (AIPD)	Most often used in the past. Frequent and short exchanges with volumes 1–2 L and dialysate flows of 2–6 L/h. Each session lasts 16–20 h, usually tri-session per week. The solute clearance is likely inadequate due to its intermittent nature
Tidal peritoneal dialysis (TPD)	Typically involves an initial infusion of 3 L of dialysate into the peritoneal cavity. A portion of dialysate, tidal drain volume (usually 1–1.5 L), is drained and replaced with fresh dialysate (tidal fill volume). The reserve volume always remains in the peritoneal cavity throughout the tidal cycle
Continuous flow peritoneal dialysis (CFPD)	Inflow and outflow of dialysate occur simultaneously through two access routes. By inflow of 300 mL/min, it is possible to achieve a high-peritoneal urea clearance
High-volume peritoneal dialysis (HVPD)	Continuous therapy proposed to increase high small-solute clearances. Frequent exchanges, usually with cycler (18–48 exchanges per 24 h, 2 L per exchange). The total dialysate volume ranges from 36 to 70 L a day
Continuous equilibrated peritoneal dialysis (CEPD)	Long dwells of 2–6 h with up to 2 L of dialysate each (similar to CAPD). The clearance of small molecules may be also inadequate, but clearance of middle molecules is possibly higher due to the long dwells

Table 1. Techniques of PD for AKI treatment.

This raises the question, why is the use of PD for AKI declining? The use of PD is precluded in some circumstances, such as after major abdominal surgery or trauma. Patients with AKI are hypercatabolic and require adequate clearance of toxins to avoid complications. Part of the reason for underuse of PD may be related to the perception that PD is not adequate for

treatment of AKI. The ultrafiltration (UF) volume could be better controlled with current machines for EBP than with PD. However, published studies report efficient fluid removal and metabolic control in patients on PD. With the decline in the use of PD for AKI worldwide, the clinical experience of the physician as well as the supporting staff in the use of this modality becomes limited due to the lack of exposure.

Recent data from randomized and observational studies on EBP have indicated that, beyond a certain threshold, further increments in dose had no benefits [15, 16]. Low doses and inadequate dialysis contribute to poor outcomes, and augmenting dose may reap increasing benefits until a certain limit is reached. In uremic patients who receive no dialysis, mortality is close to 100%. The probability of survival improves with dialysis. The data on recovery of both the patient and the kidney in those treated with PD are lacking. So far, the dose of dialysis that should be targeted for AKI is unknown.

2.1.1. Clearance of small solutes

This is most often represented by urea clearance which had been developed for the assessment of chronic dialysis patients, and this model is often applied to AKI as well. However, urea kinetic modelling (UKM) is not held true in an unstable patient and not validated for use in AKI [17, 18]. It continues to be utilized in AKI only due to a lack of alternatives.

To date, there has been very limited data on the effect of dose of PD on AKI. There are no studies which have directly compared various dosing levels in PD and its effect on outcomes.

Studies on EBP [17, 19, 20], which reported dose in terms of Kt/V_{urea}, were selected for inference of PD dose in this review even if there are some limitations. The standardized (std)-Kt/V_{urea} minimum target for chronic PD is 1.7 which is lower than weekly std-Kt/V_{urea} of 2.1 in chronic HD.

Patients with AKI are generally catabolic, and adequate clearance of toxins and electrolytes is necessary. It remains to be determined if it is necessary to aim for similar small-solute clearance targets as for HD in the management of AKI.

Inadequate small-solute clearance in dialysis is known to be detrimental. The optimal dose of dialysis for AKI remains uncertain. The minimum dose of peritoneal dialysis that should be achieved according to EBP studies is a std-Kt/V_{urea} of 2.1. It must be emphasized that this is not a fixed dose target for all patients. Higher small-solute clearances may be necessary for patients with more complex catabolic illnesses. But if the small-solute clearance target is met, then clinicians can focus on other aspects of adequacy which may result in improvement in patient outcomes.

2.1.2. Clearance of larger molecules

The clearance of middle-molecular-weight (MMW) substances is important in certain clinical scenarios such as sepsis-related AKI, where clearance of pro-inflammatory cytokines may attenuate the inflammatory response [16, 21]. There is currently no established method of

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prescribing dialysis based on middle molecular clearance. No recommendations can be made with regard to any minimum targets of clearances of MMW substances.

2.1.3. Other aspects of adequacy

The removal of uremic toxins is not the sole aim in renal replacement therapy. Fluid status and other homeostatic mechanisms of the kidney are important aspects that encompass dialysis adequacy.

Fluid balance may possibly act as a biomarker of severity in critical illness [22]. A neutral fluid balance has also been shown to improve outcomes in acute lung injury. PD is usually well tolerated with better hemodynamic stability, and it is therefore often recommended as a form of RRT for subgroups such as the elderly or patients with congestive heart failure [23]. Besides removal of uremic toxins, dialysis must also remove fluid and salt from the patient. With a properly functioning PD catheter, exchanges of 2 L of dialysate with 2.5 or 4.25% glucose concentration provide daily fluid removal at the same or greater rate than other regimens without causing hypotension in most patients.

Adequacy of dialysis dose is controversial since many authors believe that there is no satisfactory marker for dialysis adequacy in AKI. Some authors reported that intermittent peritoneal dialysis was not adequate for treating AKI patients [24, 25]. Phu et al. showed that PD failed to keep optimal control of blood urea nitrogen (BUN) and creatinine levels compared with continuous venovenous hemodialysis, the latter having significantly lower mortality rate [24]. However, this study was frequently commented by others since their PD technique was not optimal: they produced PD solutions locally by using acetate buffer, used rigid peritoneal catheter, and performed manual PD exchanges with short procedure time leading to inadequate solute clearance and dialysis adequacy. The adequacy of PD in AKI was evaluated in a prospective, randomized, crossover trial that included 87 hypercatabolic patients [15]. This study showed that tidal PD and continuous equilibrated PD (CEPD), which is similar to but more intensive than continuous ambulatory peritoneal dialysis (CAPD), were adequate methods of maintaining BUN levels at about 65 mg/dL in mild and moderate hypercatabolic AKI patients in developing countries. Tidal PD provided better clearances at the same dialysis volume for a lower inpatient cost, and the only limitation was greater protein loss. In a prospective study, Gabriel et al. treated 30 AKI patients who received 236 dialysis sessions of PD with encouraging results for metabolic, electrolytic, and acid-base control [26]. They showed that high doses and PD using flexible catheter and cycler were an effective treatment of AKI providing high solute removal and sufficient dialysis dose with higher values than described in previous literature. An old but good method is the use of continuous flow PD (CFPD) [27]. This variant of PD utilizes two access points: one for inflow of dialysate and the other for outflow. Since there is no interruption of inflow to outflow, flow rates are determined only by the rate at which the draining catheter can efficiently drain the abdomen. With CFPD dialysate flow rates of up to 300 mL/min can be maintained through the peritoneum.

We believe that there are some important conclusions which can be derived on the basis of recent publications. First, the optimal treatment of AKI remains uncertain. Second, studies have shown the different therapeutic approaches to AKI. Third, in terms of PD, the optimal

dose of dialysis is unclear. High-dose PD (weekly $Kt/V_{urea} > 3$) provides results comparable to those with HD. Whether lower doses in the range of 2.1, as suggested by some authors [28, 29], provide results comparable to those achieved with the higher doses remains to be determined, but data suggest that such a result may in fact be true. However, published studies have conflicting results (**Table 2**). In a recent review on PD dose in AKI [10], it was recommended that continuous forms of PD should be prescribed, with a minimum standardized Kt/V_{urea} of at least 2.1 per week. Intermittent PD is the more commonly used modality in clinical practice with high level of uncertainty among professionals regarding the appropriate PD dose in AKI. This uncertainty is likely because of the paucity of strong evidence or consensus on this aspect. A systematic review of Chionh and coworkers showed that variable measures were used to represent dose and PD [29]. The total volume of peritoneal dialysate used was reported in eight studies as ranging from 13 to 70 L/d. Additional analysis of the relationship between PD dose and mortality was not possible.

Reference	Std-Kt/V_{urea} (per week)	K_{urea} (mL/min)	K_{Cr} (mL/min)	PD volume (L/d)
Ponce [27]	3.5 ± 0.68	NA	NA	32.0–44.0
Kilonzo et al. [7]	NA	NA	NA	7.5
Ponce et al. [30]	3.6	NA	NA	NA
George [29]	NA	9.4 ± 4.9	10.5 ± 6.1	NA
Gabriel et al. [2]	3.6 ± 0.6	16.1 ± 4.0	NA	42.8 ± 5.72
Gabriel [25]	3.9 ± 0.6	17.3 ± 5.0	15.8 ± 4.2	43.2 ± 5.1
Arogundade [31]	NA	NA	8.1 ± 2.8	8.0 ± 0.6
Phu [24]	NA	NA	NA	70
Chitalia et al. [15]	1.8–2.4	10.6–19.8	5.8–6.8	13.0–26.3
Thongboonkerd [32]	NA	29.6	23.9	26.7
Sonnenblick [33]	NA	NA	NA	48.0

Note: Dose is represented by the standardized weekly Kt/V_{urea} (std-Kt/V_{urea}), urea clearance (K_{urea}), creatinine clearance (K_{Cr}), and volume of PD effluent per day (PD volume). The dose is listed according to how the original article had presented the data: mean, mean ± SD, or range. PD, peritoneal dialysis; NA, results not available.

Table 2. Indicators of dose of PD.

In the absence of precise data, the clinician needs to exercise practical judgment in defining the optimal dose of PD. PD needs to be considered a reasonable treatment for AKI. The dose of PD that needs to be targeted for AKI remains uncertain and presents a challenge that is not different from the challenge presented in defining the optimal dose of HD or hemofiltration in the same situation. Clinical trials have not shown any advantage of increasing the dose of RRT above that obtained with alternate-day HD achieving a Kt/V_{urea} of 1.2 per treatment.

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Importantly, a Kt/V_{urea} in that range can easily be reached with PD without the use of large volumes of solution. The authors emphasize the need to individualize therapy for each patient based on the clinical circumstances, severity of illness, hemodynamic stability, catabolic state, and so on [1, 10].

2.2. Types and methods of insertion of PD catheter

Peritoneal dialysis catheters could be divided in two groups, due to their placement and duration of use.

Acute peritoneal catheters have the same basic design: straight or slightly curved with holes at the distal end. These types of catheters are relatively rigid with an average diameter of 3 mm. By using wire or stylet, these catheters could be inserted, usually at the bedside. Also, these catheters are used immediately after the implantation procedure. They do not have cuffs and could be placed in the patient for three days. If longer use is anticipated, it is recommended that chronic catheter is to be inserted [34]. Because there are no protective cuffs, migration of bacteria from the skin to the subcutaneous tissue increases after three days. Since accidental dislodgments of acute catheter are quite common, care should be taken to provide proper catheter position once it is implanted [35].

Stylocath (Abbott Laboratories, North Chicago, IL) and the Trocath (Baxter Healthcare Corporation, Deerfield, IL) are the most used acute catheters with stylets. Guidewire an acute catheter designed to be inserted over a flexible catheter is available from Cook Co. (Bloomington, IN). The possibility of dialysis solution leak and high frequency of peritonitis are the main reasons why some centers prefer the use of the Tenckhoff catheter. Tenckhoff recommended the use of a single-cuff catheter for acute cases [36].

Chronic peritoneal catheters are usually constructed from silicone rubber or polyurethane. Adult catheters have outer diameter of 5 mm and three internal diameters: 2.16, 3.1, and 3.5 mm. They have two cuffs as a protection from infections. These cuffs will provoke local inflammatory response after formation of scar tissue. As a result, this tissue will be an anchor for catheter. The catheter should function for several years [37]. Peritonitis could be treated without removal of these catheters [38].

In resource-poor settings, some improvised devices could be used: nasogastric tube, rubber catheter, and intercostal drainage catheter. All of these devices must be inserted surgically and are more prone to different complications due to their design [10]. Intraperitoneal part of PD catheters has four basic designs: straight Tenckhoff with side holes on distal end, coiled Tenckhoff with coiled portion with side holes, straight Tenckhoff with perpendicular silicone disc also known as an Oreopoulos-Zellerman or Toronto Western Hospital catheter, and T-shaped catheter with grooved limbs that position against the peritoneum.

Latest guidelines recommend the use of flexible peritoneal catheters for acute PD in cases where resources and expertise exist [39]. Otherwise, rigid stylet catheters or improvised catheters could be used as a lifesaving device. Wong et al. compared flexible Tenckhoff catheters and rigid stylet catheters in children who underwent acute PD. They found fewer complications with flexible catheters and significantly longer catheter survival [40]. Good

function of catheter demands several specifications: the tip should be placed in the pelvic cavity; catheter is implanted in the paramedian lower abdomen. Several methods of placement are used. Percutaneous non-visualized method is a blind method, and fluoroscopy could be used. Methods with direct visualization are surgical minilaparotomy, peritoneoscopy, or open surgical dissection. Some procedures could be done as a bedside procedure. Catheters should be tunneled in order to reduce peritonitis and peri-catheter leaks [10] **(Table 3)**.

Type	Advantage	Disadvantage
Rigid stylet catheter	Cheap	More dysfunctions
	Bedside procedure	Flow-related problems
	Easily removed	Risk of abdominal organ injury
Flexible	Better flow	Expensive
	Less chance for organ perforation, less infection and leaks	Necessary training prior to implantation Easily migrated
	Bedside procedure	
Improvised devices	Inexpensive	Infections, leaks, flow-related problem
	Easily available	Difficult to connect

Table 3. Main characteristics of flexible, rigid, and improvised devices for acute PD.

No method of insertion is superior overall to the others [41]. Choice of method will depend on patient conditions and skills and expertise of medical staff. It is worth to mention that ISPD recommends that "insertion by nephrologists is safe and functional results equate to those inserted surgically." Also, the same guideline recommends "that nephrologists receive training and be permitted to insert these catheters to ensure timely dialysis in the emergency setting." In their survey, Sampathkumar et al. show that with a skilled nephrologist subcutaneous placement could be used very effectively to provide fast dialysis approach [42]. Similar results were found in several studies elsewhere [43].

Kumar et al. described a case from a large-scale disaster in which human life was saved by a relatively inexperienced doctor who had basic skills in catheter insertion [8].

The most common used methods for insertion of PD catheter are surgical, laparoscopic, peritoneoscopic, and blind techniques (**Table 4**). In 1968, Tenckhoff and Schechter were the first to describe a percutaneous non-visualized method of catheter placement. Brewer in 1972 invented open placement as a mini-surgical laparotomy. Since that, several new approaches

were described, namely, laparoscopic as the newest one. Blind techniques include the Seldinger technique, the trochar method, and the fluoroscopic guidance.

Name	Advantage	Disadvantage
Percutaneous	Bedside	Risk of abdominal injury
	Minimal skill	Not suitable for patients with previous interventions
Open surgical	Available in most hospitals	Surgical scheduling
	Relatively cheap compared to laparoscopic	
Laparoscopy	Ability to reach pelvis under vision	Skilled personnel
	Low leak	Expensive
	Additional procedures possible	

Table 4. Different implantation techniques of PD catheter.

Prior to implantation, the patient is advised to empty the bladder, and antibiotics are administered. Adequate procedure will eliminate surgical complication and reduce risk for transfer to HD. The most important determinants of catheter outcome are placement technique and skill of operator. There are strong recommendations from several international scientific bodies that antibiotics should be used prior to implantation of catheter.

Protocols for antibiotic prophylaxis prior to catheter insertion should be guided by the local infectious disease guidelines. The UK Renal Association and ERA-EDTA stated that antibiotics should and must be used. ISPD in its 2010 guidelines recommends that "renal units should have clear protocols for perioperative catheter care, including the use of antibiotic prophylaxis" [44]. The usual approach is single-dose intravenous route prior to insertion. Gadallah and colleagues in their research included several groups of patients who were given cefazolin and vancomycin and a control group without any drugs. The vancomycin group had the least infectious complications, and the protocol they recommended was 1 g vancomycin i.v. single dose 12 h before peritoneal catheter placement procedures. This dosage was superior to cefazolin in preventing possible early infection due to catheter placement [45]. Later, Strippoli et al. conducted meta-analysis which included four studies with 335 patients in total. They concluded that perioperative antibiotic prophylaxis reduced infection significantly compared to nonantibiotic group. There was no significant difference in the risk of exit site/tunnel infection [46]. Based on mentioned research, ISPD guidelines recommend that vancomycin should be part in any protocol according to potential risk and benefits of patient [47].

2.3. Indications and contraindications of acute PD

The indications for acute PD can be divided into two groups: renal and nonrenal (**Table 5**).

Indications of acute PD		PD is contraindicated in the following clinical situations
Renal indications	**Nonrenal indications**	
RRT in the treatment of AKI in children Hemodynamically unstable patients The presence of bleeding diathesis or hemorrhagic conditions contra indicating placement of vascular access for hemodialysis or anti coagulation Patients with difficult vascular access placement Removal of high-molecular weight toxins (10 kDa)	Acute pancreatitis Clinically significant hypothermia or hyperthermia Refractory heart failure Liver failure Infusion of drugs and nutrients as a supportive therapy in critically ill patients	Recent abdominal surgery Pleuroperitoneal communication Diaphragmatic severe respiratory failure Life-threatening hyperkalemia not responding to medical therapy Extremely hypercatabolic state Severe volume overload in a patient not on a ventilator Severe gastroesophageal reflux disease Low peritoneal clearance Fecal or fungal peritonitis Abdominal wall cellulitis AKI in pregnancy

Table 5. Renal and nonrenal indications and contraindications of PD in AKI.

2.3.1. Renal indications

Peritoneal dialysis is an advantageous modality for RRT in AKI (**Table 5**). In many of the studies of PD versus HD for AKI, the reason for improved survival in the PD group was related to an increased rate of renal recovery. It is already known that in patients with ESRD, treatment by PD resulted in better preservation of intrinsic renal function than treatment by intermittent HD. This preservation of renal function is important because it maintains endocrine function of the kidneys, diminishes the clearance requirements for dialysis, and minimizes ultrafiltration and physiologic stress during dialysis. On the other hand, hemodialysis has several known nephrotoxic effects such as generation of inflammatory mediators by extracorporeal circuit, rapid decrease in osmolality, and vascular volume, diminishing renal perfusion. All of the above may influence renal recovery during the course of AKI. PD can easily meet treatment goals for AKI patients, maintaining adequate fluid, electrolyte, and acid base balances. It also allows the use of other supportive measures without limitation until the recovery of renal function. However, as compared to HD, PD is less effective in severe acute illnesses like pulmonary edema, poisoning, or drug overdose, and hypercatabolic states. Several reports suggest that patients with AKI secondary to atheroembolic renal disease may have a better chance of recovery if PD is used over HD [48]. It has also been reported that PD has a beneficial role in recovery of renal function in patients with renal failure due to malignant hypertension [49]. In resource-poor countries, the cost, practicability, and feasibility of CRRT may be limiting factors, whereas peritoneal dialysis is relatively simple and inexpensive and is more widely used. Simplicity of PD permits interns and postgraduate students to be trained to manage AKI earlier at primary care centers, thus avoiding the delay caused by referring critically ill patients to nephrologist or ICU. Finally, even in developed countries, a major catastrophe can cause

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severe damage to the infrastructure. PD is an alternative when reliable power, clean water supply, and facilities for water treatment are unavailable.

Small molecular clearance is lower with PD than that achieved with conventional HD due to characteristics of peritoneal dialysate. However, the clearance of higher molecular weight solutes is higher with continuous PD than with HD. Ultrafiltration rate gradually decreases during PD due to continuous fall of glucose in dialysate fluid [30].

2.3.1.1. Nonrenal indications for acute PD

PD can be used in various extrarenal conditions (**Table 2**). In acute hemorrhagic pancreatitis, hypothermia or hyperthermia, and congestive heart failure, PD could be used if patient does not respond to conventional therapy [39, 50]. In patients with fulminant liver failure, PD has been used because it avoids the need for anticoagulation [51]. Finally, PD may help in the removal of toxins like ammonia, bilirubin, and free fatty acids. On the other hand, PD may be used as route for delivery of nutrients like glucose and amino acids and certain drugs in severely ill patients admitted to intensive care unit [52].

2.3.1.2. Contraindications to acute PD

There are several relative contraindications to acute PD (**Table 3**): recent operation with abdominal drainage, peritonitis (fecal or fungal), and known pleuroperitoneal fistula (after cardiothoracic surgery). The presence of abdominal hernia or intra-abdominal adhesions might make PD difficult. PD may be relatively contraindicated in the presence of abdominal wall cellulitis or severe gastroesophageal reflux disease, adynamic ileus, and recent aortic graft (<6 months). PD is noneffective in treatment of life-threatening hyperkalemia. The use of PD in hyperkalemia should be employed in situations when HD is not available. Also, PD is not the best treatment modality in patients with a high load of azotemia [53].

2.4. Limitations of PD in AKI

Though easy and reliable, PD has some limitations in the treatment of AKI [54], and one of them and the most important is less efficacy for severe acute pulmonary edema and in life-threatening hyperkalemia as well as being its need for an intact peritoneal cavity with adequate peritoneal clearance capacity. Unlike HD, ultrafiltration and clearance cannot be exactly predicted in PD patients. The major criticism of PD is the low clearance of uremic toxins; the clearance of low-molecular weight toxins is lower than for other therapies (continuous arteriovenous hemofiltration, continuous venovenous hemofiltration, and daily HD). It is apparent that PD with a modest dialysate use of 1 L/h is less efficient than other modalities for urea and creatinine but is similarly efficient in removal of larger molecules such as vitamin B12. It is likely that larger-molecular weight toxins are the real cause of uremic illness, and PD is quite effective in removing various anionic organic compounds that function as middle molecules. Small molecular clearance may be increased by increasing flow rate of dialysate to 1.5–1.0 L/h or more. Tidal peritoneal dialysis can easily deliver 2 L/h into and out of the peritoneum. Infectious, mechanical, and metabolic complications may be major problems. The

incidence of peritonitis in PD therapy of AKI is much different than in PD therapy. Previous studies have reported a 12–25% incidence of peritonitis. If peritonitis is detected during therapy of AKI, it usually occurs within 2 or 3 days of starting therapy [39]. This indicates that PD may detect contamination of the peritoneum that predates the implementation of PD. There is predominance of *Staphylococcus epidermidis* and *Candida* (in debilitated patients undergoing antibiotic therapies) but also mixed infections [55]. Peritonitis during PD therapy does not result in septicemia in AKI patients. This is a much different outcome than catheter-related infections during hemodialysis or continuous therapies which frequently result in septicemia. The increasing use of automated PD via flexible catheter has led to a reduction in peritonitis frequency. Studies have shown that mechanical complications occur in fewer than 10% of patients due to immediate use just after catheter insertion [26]. Also, there is controversy about abdominal distension leading to reduced diaphragm mobilization and consequently about pulmonary compliance. Protein losses may play an important role, mainly during peritonitis. It may exacerbate conditions in undernourished, critically ill patients with AKI. It was measured that total weekly protein losses were around 45 g in intermittent and 62 g in continuous peritoneal dialysis (CPD); albumin accounted for approximately half of this loss. Despite this depletion, plasma albumin and total protein levels were not decreased [56]. However, large variability among individuals was seen, and peritonitis was the only factor influencing these losses. This observation was reported by Gabriel et al. who reported no significant difference between median plasma albumin values obtained before and after CPD session (median 2.6 g/dL) despite considerable losses in protein (median 21.7 g/day). The authors concluded that dialysate protein loss, although significant, was not a limiting factor for using CPD. In these situations, it is necessary to increase patient's protein ingestion which should be 1.5 g/kg/day. The fact that PD results in protein loss is generally considered a nutritional problem. However, this loss may contribute to the chemical effectiveness of the PD. In patients with hemolytic uremic syndrome, PD significantly reduces plasminogen activator inhibitor type 1 (PAI-1) which inhibits fibrinolysis in hemolytic uremic syndrome [57]. Most of the organic anions removed by PD in uremic patients are in fact strongly bound to protein, so protein loss increases their clearance. These protein-bound organic anions act as middle molecules, and the presence of protein within the dialysate facilitates the transfer of these compounds into the peritoneum. The peritoneal transfer of proteins can be increased by application of hypertonic solutions; the globulin removal by PD on a daily basis could equal or exceed daily therapeutic plasmapheresis [58]. Hyperglycemia is another metabolic complication resulting from PD with glucose-based solutions. Therefore, it is necessary to closely monitor glucose metabolism even by using insulin via continuous infusion pump [15]. When comparing the overall risk of each type of therapy for AKI, there are marked differences between continuous venovenous hemofiltration, continuous venovenous hemodialysis, HD, and PD. The blood treatment therapies have a significant risk of septicemia, low flow from blood access, hypotension, membrane clothing, and bleeding. PD therapy includes risk of PD catheter outflow failure, hyperglycemia, and asymptomatic peritonitis. There are controversies about the influence of PD on respiratory system in critically ill patients. In ICU settings where patients are on ventilation, PD using high volume may impair diaphragmatic movement, and this should be taken into consideration while profiling the patient. As a result,

pulmonary compliance and ventilation are impaired. Venous return is also reduced leading to hypotension and consequently to organ and tissue hypoperfusion which favor acidosis. The effective peritoneal blood flow in uremic patients during dialysis is 100 mL/min [39] and cannot be increased as in the case of CRRT and HD. Leblanc et al. [59] showed that although it reduces pulmonary volume, characteristics of vital capacity and expiratory volume remain unaltered. They concluded that PD is rarely associated with ventilatory impairment in patients without pulmonary pathologies. However, it must be emphasized that in nearly all the abovementioned situations, PD may be tried as the initial RRT modality and prescription adjusted to get optimum dialysis and ultrafiltration.

2.5. Prescription of PD in AKI

After the insertion of an acute or chronic peritoneal catheter (preferably chronic if possible), PD orders need to be individualized depending upon the hemodynamic status of the patient, laboratory work, and volume status. The components of PD orders are multiple and involve the following: length of the dialysis session, dialysate composition, exchange volume, inflow and outflow periods, dwell time, number of exchanges, additives, and monitoring of fluid balance.

The length of a PD session can vary depending on the cause and duration of AKI, the need for water and solute removal, and the risk of infection although usual dialysis session lasts for 48–72 h, and each exchange is done over 1 h. PD fluid is available in different glucose concentrations and various electrolyte concentrations (**Table 6**). It should be warmed to body temperature prior to infusion to avoid enhanced solute transport.

Type	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	Lactate	pH	Osm.
Stay safe 1.5%	132		2.5	0.5	95		40	5.5	344
Dianeal 1.5%	132		2.5	0.25	95		35	5.2	344

Note: Na = sodium; K = potassium; Ca = calcium; Mg = magnesium; Cl = chlorine; HCO_3 = bicarbonate; osm. = osmolarity

Table 6. Typical composition of commercially available PD fluid.

Glucose (g/dL)	Fluid osmolarity (mOsm/L)	Ultrafiltrate volume (mL per exchange over 1 h)
1.5	346	50–150
2.5	396	100–300
4.25	485	300–400

Table 7. Dialysis fluid glucose concentration.

To obtain better ultrafiltration, it is reasonable to initiate acute PD in most patients with the 2.5 g/dL PD fluid. Using standard regimen, different amounts of fluid can be removed over a

24-h period: 2.5 L with 1.5 g/dL glucose, 4.5 L with 2.5 g/dL glucose, and 8.5 L with 4.25 g/dL glucose. Various types of glucose concentration are available to be used in acute PD prescription (**Tables 6** and **7**).

(1) 1.5 g/dL PD fluid contains 27.2 g of glucose in 2 L bag (ultrafiltration of 50–150 mL/h / 2 L, 60 min exchange time). It is the most commonly used fluid in acute PD; (2) 2.5 g/dL PD fluid contains 45.4 g of glucose in 2 L bag (ultrafiltration of 100–300 mL/h/2 L, 60 min exchange time); (3) 4.25 g/dL PD fluid contains 77.2 g of glucose in 2 L bag (ultrafiltration of 300–400 mL/h/2 L, 60 min exchange time). This hypertonic fluid is usually used in patients with volume overload like congestive heart failure. But its longer use can induce hemodynamic instability due to massive ultrafiltration. Usually, this degree of UF is not required and can use combination of glucose concentrations to attain level of UF desired.

PD orders need to be individualized depending upon hemodynamic status of the patient and volume status. After confirmation that PD catheter is adequately inserted and has no problems with flow of the fluid [35], PD orders need to be reviewed and written daily (**Table 8**).

Nursing orders	Renal physician to be notified immediately for the following situations
Dialysis session length … hours	Poor dialysate flow
Dialysis volume per exchange … L	Severe abdominal pain or distention
Dialysis dextrose concentration, %	Change in color of dialysate, bloody, or cloudy drainage
Inflow time … min dwell time; outflow time…	Dialysate leak or purulent drainage around catheter exit site
Vital signs q … hours	Blood pressure of … mm Hg
Weigh patient q … hours	Respiratory rate of ≥ … per minute or severe shortness of breath in non-ventilated patient
Warm dialysate fluid to body temperature	Temperature of ≥ … C
Maintain strict intake and output	Two consecutive positive exchanges
Additives to dialysate: heparin, yes/no; insulin, yes/no; potassium, yes/no	Single-positive exchange balance if negative balance exceeds … L over … hours
Vancomycin … mg/L of exchange, other … mg/L of exchange; other antibiotic … mg/L	Notification of abnormal laboratory values
Catheter care and dressing change everyday	
Full chemistry panel including blood glucose level to be done every 12 h each day during dialysis	
15 ml of dialysate fluid from catheter every morning during dialysis and send it for cell count with differential, gram staining, and culture; yes/no	

Table 8. Acute PD orders.

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The most practical way to achieve fluid removal is by mixing and matching low- and high-glucose concentration adequate fluid. Exchange volume is the amount of PD fluid instilled into the peritoneal cavity during an exchange. The volume instilled depends on the intraperitoneal pressure (IPP), the presence of pulmonary disease or mechanical ventilation, and the presence of abdominal hernia. An average-sized adult can tolerate 2 L exchanges, but in smaller patients, those with pulmonary disease or those with abdominal or inguinal hernias, the exchange volume should be reduced.

The intraperitoneal pressure rises linearly with higher volume of intraperitoneal fluid used. Intraperitoneal pressure is higher in patients with higher body mass index. Age, gender, weight, height, body surface area, and diabetes mellitus do not correlate with IPP [60]. Low-PDF volume is used after the PD catheter placement to avoid leakage. The volume is gradually increased over the next three or four days as tolerated by the patient. Inflow time is the time required to instill the PD fluid into the peritoneal cavity under the effect of gravity. The time is usually 10–15 min. It should be kept to minimal to maximize efficiency of peritoneal dialysis.

Dwell time is the time period for which the exchange volume stays in the intraperitoneal cavity which is usually 30 min in the single acute peritoneal dialysis exchange. A dwell time of less than 30 min is usually not adequate [61]. The dwell time for patients on acute CPD is about 3–6 h which can be shortened to increase the total number of exchanges to improve solute clearance.

Outflow time is the time required to drain effluent dialysate after dwell which takes place under the effect of gravity. It is usually takes 20–30 min to complete [62]. If incomplete, drainage can cause a rise in intra-abdominal pressure causing respiratory embarrassment or abdominal discomfort. The usual number of exchanges is about 24/day with standard acute PD and approximately 4–6/day with CPD.

Some drugs can be added to the PD fluid to treat certain specific conditions. Some of these drugs are the following:

Potassium. Normally, there is no potassium in the dialysis fluid, but potassium can be added to the PD fluid in hypokalemic patients. Usually 3–4 mmol/L is added to maintain normokalemia [10].

Insulin. Usually insulin is used in diabetic patients on PD for glycemic control. Intraperitoneal insulin is usually added to the PD fluid, and the dose is adjusted based on frequent blood glucose monitoring. It should be avoided in last 2–3 exchanges to prevent postdialysis hypoglycemia.

As glucose concentration rises, an increasing insulin dose in the dialysis bag is needed as follows: 4–5 units/L for 1.5 g/dL PD fluid, 5–7 units/L for 2.5 g/dL PD fluid, and 7–10 units/L for 4.25 g/dL PD fluid.

Anticoagulants. Heparin is used to prevent clot formation. Usually a dose of 500 units/L is given after plugs, or strands of fibrin are visible on the drained fluid [10]. There is no systemic absorption of heparin through peritoneum and there is no systemic anticoagulation risk when heparin is used intraperitoneally.

Antibiotics. Intraperitoneal administration of antibiotics is efficient with a huge variety of antibiotics which can be administered intraperitoneally. This route is preferred to intravenous dosing for treating peritonitis. Both intermittent and dosing of antibiotics are equally efficacious. Empiric treatment of peritonitis should start immediately and should have both gram-positive and gram-negative coverage. Results of culture and sensitivity should be followed, and antibiotics should be changed based on sensitivity of the organism. Most patients show considerable clinical improvement within 48 h of initiation of antibiotic treatment. The reader should refer to the International Society of Peritoneal Dialysis guidelines regarding doses of various antibiotics used intraperitoneally in PD for treatment of peritonitis [10, 63].

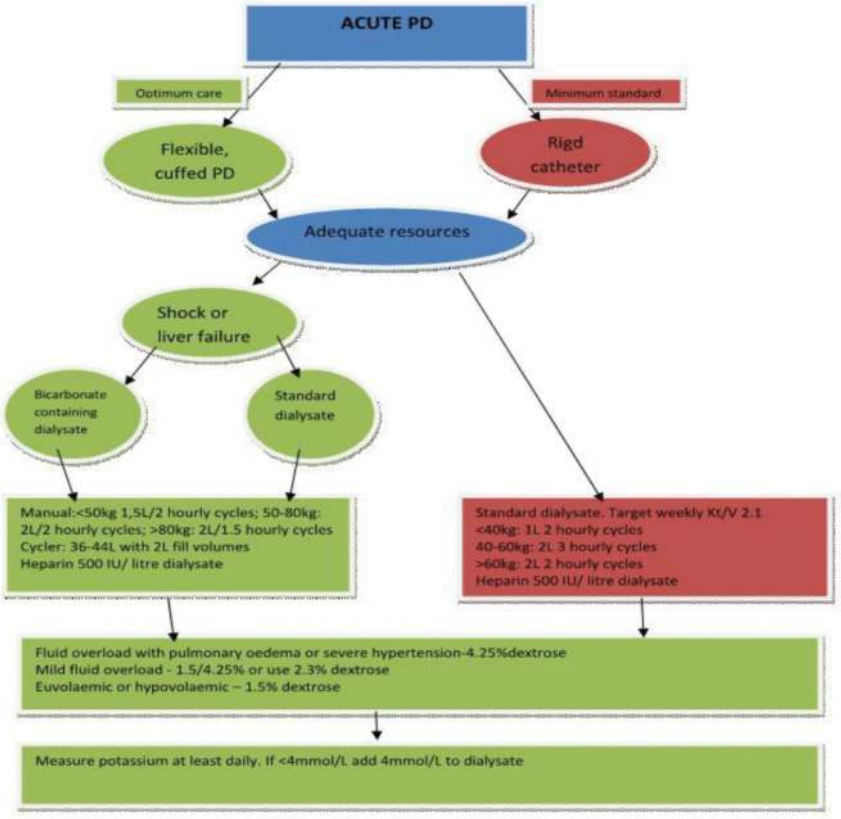

Figure 1. The proposed dosing algorithm for PD in AKI.

2.6. ISPD guidelines for PD in AKI

ISPD guidelines [10] state that PD should be considered as a suitable method for RRT in AKI. Flexible peritoneal catheters should be preferred. Catheter insertion by a nephrologist is safe

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and functional results equal that of surgical insertion. Preoperative prophylactic antibiotics such as first-generation cephalosporins or vancomycin reduce the incidence of peritonitis among PD patients [46]. ISPD recommends the use of PD fluids with bicarbonate as the buffer in patients with shock or liver failure. Fluid overload is to be avoided, and ultrafiltration can be increased by raising the concentration of dextrose and shortening the cycle duration (**Figure 1**).

2.7. Complications of PD for AKI

There are a number of potential complications associated with the use of acute PD.

Peritonitis is the most common complication in PD, in AKI, as well as in chronic kidney disease (CKD), so the treatment of peritonitis is different: due to more rapid exchanges generally performed with acute PD than chronic PD, antibiotics should be given intraperitoneally and with every exchange.

Another important complication is mechanical or catheter-related problems. Mechanical complications are abdominal pain, discomfort, intra-abdominal hemorrhage, bowel perforation, catheter malfunction, and peritoneal fluid leakage. Perforation of abdominal organs, namely, bladder, is a rare complication. It is made by using the blind methods. Frequency of perforation reported in previous percutaneous studies is very low (around 1%) [43].

In their study, Mittal and all reported of 2% bleeding complication mainly connected with anticoagulation therapy. So, they recommended withdrawal of this drug at least 24 h prior to intervention [64].

Catheter obstruction may be a result of fibrin blockage of the catheter or tubing or displacement ± omental wrapping of the catheter. Leakage of peritoneal fluid is most often seen in the older patients and also in those who are obese and with previous abdominal operation. Other factors that can contribute to peritoneal fluid leakage are diabetes mellitus, steroid use, and multiparity.

Pulmonal complications in acute PD could be atelectasis, pneumonia, aspiration, and pleural effusion. All these complications are due to increased intra-abdominal pressure. Rinsing the catheter with sterile saline using sterile technique may remove the blockage. Once flow is reestablished, 1,000 units of heparin will be added to each liter of PD fluid. Methods for manipulating displaced PD catheters could include the use of guidewire manipulation and laxatives. If these methods fail, the catheter should be replaced using the original catheter way into the peritoneum. Loss of protein from the peritoneum in patients on chronic PD varies in different studies from 6.2 to 12.8 g/day or even 48 g during episodes of peritonitis.

Care should be taken to ensure that adequate protein intake occurs aiming for approximately 1.2 g/kg of protein per day. Protein loss is in association with increased mortality in those patients with a negative protein balance.

Due to the high glucose concentration in PD fluid, there is a tendency to hyperglycemia in acute PD which decreases osmotic gradient. It should be treated to enable optimal ultrafiltration. In diabetic patients who are treated with insulin in peritoneal solution, hypoglycemia

could occur. Acid-base imbalance could be the result of simultaneous therapy with bicarbonate with the aim of fast correction of metabolic acidosis. On the other hand, hypernatremia is the result of high ultrafiltration rate due to hyperosmotic solutions. Hypokalemia is the result of using solutions without potassium [10].

Study (authors)	Type	Country	Period	ICU pts (%)	Causes of AKI	*N*	Mortality (%)
Ponce et al. [30]	Pros.	Brazil	2004/2014	66.8	Sepsis (53.2%), ATN (26.9%), others (19.9%)	301	59.8
Ponce [27]	Pros.	Brazil	2004/2011	NA	Sepsis (41.1%), ATN (34.1%)	150	57.3
Kilonzo et al. [7]	Retr.	Tanzania	2009/2011	NA	ATN (40.0%), GN (20.0%)	14	21.4
Ponce [30]	Pros.	Brazil	2005/2007	NA	Sepsis (49.5%), heart failure (23.5%), postsurgery (12.5%)	61	54.1
Hayat et al. [66]	Retr.	India	2004/2005	NA	Gastroenteritis (75.0%)	43	10.0
Gabriel et al. [26]	Pros.	Brazil	2004	76.0	Ischemic (67%), mixed (33%)	30	57.0
Chitalia et al. [15]	Pros.	India	NA	NA	Prerenal (30.0%), leptospirosis (17.2%), others (13.8%)	87	1.1
Thongboonkerd [32]	Pros.	Thailand	NA	100.0	Shock (50%), nonshock (50%)	20	15.0
Howdieshell et al. [67]	Retr.	USA	1989/1990	100.0	Trauma-related (100%)	5	40.0
Sonnenblick [33]	Retr.	Israel	1975/1986	100.0	Sepsis (38.6%), prerenal (36.4%), others (25%)	44	70.5
Ojogwu [68]	Pros.	Nigeria	NA	NA	Hypertensive crisis (100%)	20	100
Cameron et al. [69]	Retr.	UK	1965/1967	NA	Postcardiac (33.3%) and postaortic surgery (33.3%)	9	66.7

Table 9. AKI patients treated with PD only.

2.8. PD and renal outcome in patients with AKI

In many of the studies of PD versus HD for AKI [10, 61], the reason for improved survival in the PD group was related to an increased rate of renal recovery (**Tables 9** and **10**). It is already known that in patients with end stage renal disease (ESRD), treatment by CAPD resulted in better preservation of intrinsic renal function than treatment by intermittent HD. This preservation of renal function is important because it maintains endocrine function of the kidneys, diminishes the clearance requirements for dialysis, and minimizes ultrafiltration and physiologic stress during dialysis. On the other hand, hemodialysis has several known

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nephrotoxic effects such as generation of inflammatory mediators by extracorporeal circuit and rapid decrease in osmolality and vascular volume, diminishing renal perfusion. All of the above may influence renal recovery during the course of AKI. By contrast, CAPD may help to maintain renal perfusion by smaller daily variation in body weight, more constant blood pressure and continuous mild overhydration, persistent high blood osmolality, and continuous removal of proteins from the blood including β_2-micoglobulin, albumin, plasminogen activator inhibitor type 1 (PAI-1), and immunoglobulins [65]. These some physiologic and chemical benefits may account for the highest recovery of renal function in most studies, in patients with AKI treated by PD than HD.

The characteristics of the relevant studies are summarized in **Tables 9** and **10**. The number of patients, results, and percentages represents only patients who had RRT. Thirteen studies were descriptive in nature, in which PD was the only mode of RRT including 597 patients. Three studies (Ponce, Thongboonkerd) compared different subtypes of PD. In 11 studies, there was a comparing group treated with EBP (**Table 9**): seven studies were cohort studies, whereas four studies were prospective randomized clinical trials (RCTs). One study (Chow YW) described two distinct cohorts of patients in 1994 and 2004, and the data from each cohort were analyzed separately. In one RCT (Arogundade), only 8 of 40 patients had AKI; only these patients were included in the analysis. Details of the PD technique were often not reported. Where data were available, the studies used either rigid catheters or flexible Tenckhoff catheters. The automated cycler was used in four studies, and closed drainage systems were commonly used. As buffer, lactate (10 studies), acetate (3), and bicarbonate (1) were used. The majority (19 of 24) of these studies came from low-resource regions, such as Asia, Africa, and South America. From the developed countries such as Canada, the United States, the United Kingdom, and Australia, there was only one study research. Over one-half of the studies were published in the year 2000 or later; six studies were published before 1990. The last study by Ponce et al. has been published from 2004 to 2014 [30, 75]. The predominant cause of AKI is sepsis, and mortality is 59.8%. In the studies that used PD only, fourteen studies were analyzed, and from this number, five studies have been conducted predominantly in the ICU setting. The mortality was 39.3%, whereas reported mortality in the individual studies ranged from 1.1 to 100%. However, in the studies that used PD or EBP, four studies have been conducted only in the ICU, and studies were RCTs. In the present studies, 392 patients underwent PD, whereas 567 patients underwent EBP. For PD patients, mortality rate is ranged from 25 to 75.8%, except for two studies with 0% mortality. On the other hand, mortality for EBP patients ranged from 15 to 84% in individual studies. The total mortality was 58% for PD and 56.1% for EBP. Chionh and colleagues [29] have found among the observational studies that there was no significant difference in mortality between PD and EBP (odds ratio, 0.9 confidence interval, 0.53–1.71).

Finally, on the basis of this research, we could have several important findings. There is an evident lack of good-quality data, and studies showed no difference in mortality between PD and EBP. PD dose and some important outcomes (renal recovery, PD-related complications) were underreported.

Study (authors)	Type	Country	Period	ICU pts (%)	EBP used	Causes of AKI	*PD*	*EBP*	Overall mort. (%)
							Mort. (%)	Mort. (%)	
Watcharotone et al. [11]	Retr.	Thailand	2005/2009	69.7	Int. HD	NA	75.8	62.7	68.3
George [29]	RCT	India	2005/2008	100	CVVHDF	Sepsis (38%), prerenal (34%), leptospirosis (10%), snake bite (6%)	72	84	78
Gabriel et al. [3]	RCT	Brazil	2004/2006	77.4	Daily HD	Sepsis (44.5%), prerenal (39.2%), postsurgery (22.5%)	58	53	55.5
Chow et al. [70]	Pros.	Malaysia	2004/2005	13.3	Int. HD, CVVHDF	Prerenal (53.5%), sepsis (37.9%), toxins (6.2%)	12	75	46.7
Mahajan et al. [71]	Retr.	India	2000/2004	NA	Int. HD	Prerenal (33%), sepsis (21.6%), toxins (16.1%)	46	67.6	53.8
Arogundade [31]	RCT	Nigeria	1998/2001	NA	Int. HD	Sepsis (87.5%), obstruction (12.5%)	0	0	0
Chow et al. [70]	Pros.	Malaysia	1994	29.5	Int. HD, CVVHDF	Prerenal (43.6%), sepsis (41%), toxins (10.3%)	66.7	66.7	66.7
Phu [24]	RCT	Vietnam	1993/1998	100	CVVHDF	Malaria (68.6%), sepsis (31.4%)	17	15%	31.5
Kumar et al. [8]	Retr.	India	1987/1998	NA	Int. HD	Diarrheal illness (100%)	25	66.7	60
Bellomo et al. [72]	Retr.	Australia	1983/1993	100	HDF, Int. HD	Sepsis (66%)	12	63.8	64.5
Hadidy et al. [73]	Retr.	Syria	1980/2006	NA	Int. HD	Obstruction, surgery, trauma 64%; pregnancy	0	33.8	30.9
Werb and Linton [74]	Retr.	Canada	1974/2006	100	Int. HD	Sepsis (28%), prerenal (17%)	69.2	65	65.5

Table 10. AKI patients treated with either PD or extracorporeal blood purification.

Possible confounders are identified in this chapter. Time span and different epidemiologies of AKI were most visible. The studies last over four decades in which approach and technical issues evolve significantly. HD was changed from imprecise machines with low efficiency and

flux bioincompatible membranes that were with those dialyzers with high efficiency and high flux for EBP. PD evolved from manual exchanges at low doses to automated PD and higher doses. We now tend to see older patients with multiple comorbid conditions who have undergone interventions, such as radiocontrast procedures, high-risk surgery, and invasive ICU care [29]. Also, selection bias is likely among the nonrandomized studies. Physician's personal opinion and experience on different treatment modalities are the main base for patient's selection in studies.

3. Conclusions

Adequate treatment for most AKI patients without contraindications for PD use is based on careful prescription and accurate measurement of efficiency, which allows adequate metabolic and fluid control. Age and sepsis were risk factors associated with death, whereas follow-up time, urine output, UF, and nitrogen balance were protective factors against mortality.

Recently, interest in using PD to manage AKI patients has been increasing. It is frequently used in developing countries because of its advantages for this surrounding. However, in those countries, the infrastructure for quality research is often lacking. There is lack of evidence on important information for standardized treatment such as indications, dosing, volumes, technical failure, and mortality. But, so far, results have shown that critically ill patients can be successfully treated by PD.

PD is an acceptable form of treatment in patients with AKI. Recent studies have suggested that outcomes with PD are as good as with extracorporeal RRTs. While the ISPD guidelines as well as the recently published "Update on PD" [76] focus on optimal treatment algorithms, it is important to keep in mind that treatment patterns need to be developed in accordance with individual patient needs. In low-resource settings, flexibility and appropriate adjustments in treatment patterns may need to be made. According our national renal patient registry, PD was only 2.6% in 2015 to treat ESRD patients only. We have very little experience in using PD for AKI. Our center had been using AIPD even though rarely. We hope this chapter will encourage the application of this method not only in chronic kidney disease but also in AKI.

Looking globally, the majority of the world population lives in developing countries with two-thirds or below the poverty line. AKI is common in such populations due to a variety of causes. Dialysis modality should be available to save lives. Based on available information, we may conclude that PD is as suitable as EBP to treat AKI.

PD may be a viable option for treatment because there is no significant difference in outcomes between PD and EBP. In the absence of precise data, the clinician needs to exercise judgment in selecting a dialysis modality. The choice should depend on the clinical status of the patient as well as the expertise and resources of the center. Well-designed and powered randomized trials are needed to evaluate clinically important outcomes as well as cost. Standardized reporting of technique, dose, complications, and cost like the Utstein style should be encouraged for observational studies.

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