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Chapter

Dialytic Treatment of Acute Renal Failure in Children

Djamila-Djahida Batouche, Djilali Batouche and Kamel Elhalimi

Abstract

Renal replacement therapy (RRT) ensures the removal of water and solutes that are not or no longer sufficiently ensured by the kidneys: Acute renal failure (AKI) remains the oldest indication, regardless of the patient's age. All the methods of extracorporeal purification (peritoneal dialysis, conventional hemodialysis, and continuous extracorporeal purification) have been developed in children to compensate for renal function when it becomes totally or partially inadequate, and primarily or secondarily the RRT must be initiated without delay in life-threatening situations (hyperkalemia, metabolic acidosis, lysis syndrome, pulmonary edema refractory to medical treatment...). There are insufficient data to define the optimal time for initiation of RRT outside of life-threatening situations. Despite the lack of specific studies, the benefit of ERA in life-threatening situations seems reasonable, which is why most experts recommend its use in these situations. The CRRT has proven its effectiveness in pediatrics. The continuous and progressive nature of CRRT, particularly hemofiltration, makes it the therapy of choice for unstable ICU patients. The choice of the RRT method in a given center is therefore based on the type of patient to be treated, but also on technical availability, experience, and local skills.

Keywords: child, neonate, peritoneal dialysis, salt and water depletion, hemodiafiltration, continuous extrarenal therapy

1. Introduction

Kidney failure, currently called acute kidney injury in children and adults alike, is growing daily and can be life threatening if associated with organ failure. The substitutive treatment of this renal failure is the renal replacement therapy (RRT). This ensures the removal of water and fluids that are not or are no longer sufficiently supplied by the kidneys: Acute renal failure (ARF) remains the oldest indication, regardless of the age of the patients [1]. Our objective will provide a synthesis in the area of RRT in children through a few literature reviews. The incidence of the use of RRT varies in the published series from 0.7 to 2.4% of admissions, that is, a maximum of 20 cases per year for the largest units [1–5] and its occurrence worsens the life-threatening. Overall fluid overload is a factor associated with mortality [1–6].

2. Principles modalities of renal replacement therapy

Prior to the late 1980s, RRT was limited to peritoneal dialysis (PD) and hemodialysis (HD). In intensive care, all the renal therapy methods (peritoneal dialysis, conventional hemodialysis, and continuous extracorporeal purification, such as hemofiltration (HF) and hemodiafiltration (HDF)) have been developed in children to supplement renal function when it becomes insufficient in all or part, whether in primary or secondary way. These methods became quickly very popular, especially in Europe, and gradually gained prominence in intensive care units. HD is based essentially on diffusion, hemofiltration on convection, and hemodiafiltration on the diffusion/convection combination.

The advent of hemofiltration (HF) methods has provided resuscitators with therapies that they have been able to appropriate more easily while reducing hemodynamic complications but at the cost of reduced efficacy (clearance), thus justifying their continued use [7].

For the convective modality, the exchanges take place through a semipermeable membrane according to a hydrostatic pressure gradient. An ultrafiltrate is then removed from the patient's blood, composed of plasma water and molecules of a molecular weight less than the diameter of the pores of the membrane. A large quantity of plasma water is thus withdrawn from the patient, requiring replacement with a replacement liquid, either upstream of the filter (predilution) or downstream (post-dilution).

The DP, therefore, does not require an extracorporeal blood circuit, the peritoneum acts as a semi-permeable membrane, and the exchanges between the blood and the dialysis solution (infused into the peritoneal cavity by a catheter placed by the resuscitator in the peritoneal cavity) take place through the walls of the rich vascular network of the peritoneal membrane, according to the concentration gradients. Water extraction is possible by adding glucose polymers to the dialysate, creating an oncotic pressure gradient that generates water transfer from the vascular sector to the dialysate.

PD is the most commonly initiated technique in infants and newborns because of the hemodynamic stability it provides, and the age and weight of the child.

The advantages and disadvantages of each method are summarized in **Table 1**.

Variable	CRRT	PD	IHD
Continuous therapy	Yes	Yes	No
Hemodynamic stability	Yes	Yes	No
Fluid balance achieved	Yes, pump controlled	Yes/no, variable	Yes, intermittent
Easy to perform	No	Yes	No
Metabolic control	Yes	Yes	Yes, intermittent
Optimal nutrition	Yes	No	No
Continuous toxin removal	Yes	No/yes, depends on the nature of the toxin—larger molecules not well cleared	No
Anticoagulation	Yes, requires continuous anticoagulation	No	Yes/no, intermittent anticoagulation

Variable	CRRT	PD	IHD
Rapid poison removal	Yes/no, depending on patient size and dose	No	Yes
Stable intracranial pressure	Yes	Yes/no, less predictable than CRRT	Yes/no, less predictable than CRRT
ICU nursing support	Yes, high level of support	Yes/no, moderate level of support (if frequent, manual cycling can be labor intensive)	No, low level of support
Dialysis nursing support	Yes/no, institution dependent	Yes/no, institution dependent	Yes
Patient mobility	No	Yes, if IPD used	No
Cost	High	Moderate. Increases with increased dialysis fluid used	High/moderate
Vascular access required	Yes	No	Yes
Recent abdominal surgery ^a	Yes	No	Yes
VP shunt	Yes	Yes/no, relative contraindication	Yes
Prune belly syndrome	Yes	Yes/no, relative contraindication	Yes
Ultrafiltration control,	Yes	Yes/no variable	Yes, intermittent
PD catheter leakage	No	Yes	No
Infection potential	Yes	Yes	Yes
Use in AKI-associated inborn errors of metabolism	Yes	No	Yes
Use in AKI-associated ingestions	Yes	No	Yes

^a*Omphalocele, gastroschisis, frequent or extensive abdominal surgery.*

IPD intermittent peritoneal dialysis, VP ventriculoperitoneal, ICU intensive care unit.

Table 1.

Comparison of the advantages and disadvantages of continuous renal replacement therapies (CRRT) and peritoneal dialysis (PD) and intermittent hemodialysis (IHD).

3. Indications for initiating acute dialysis in children

The decision to initiate acute dialysis depends first on fluid balance, degree of azotemia, electrolyte disturbances, and acid-base metabolism.

In addition to renal causes (e.g., hemolytic uremic syndrome) or hemodynamic causes (after cardiac intervention for congenital heart disease), in rare cases indications for acute dialysis are also intoxication (ethylene glycol, barbiturates) or a metabolic disorder (urea cycle deficits and hyperammonemia).

For HD, HF, and HDF a central venous access with a large light is placed by the resuscitator. The size of the central catheter depends on the weight of the child (**Table 2**).

In low-weight newborns with problems getting blood to them, using two single-lumen catheters in two different veins is an efficient alternative [8].

Weight	Catheter size
3–5 kg	6,50 F (frequent surgical denudation)
5–20 kg	8 F
20–30 kg	10 F
> 30 kg	11–13 F

Table 2.
Choice of bilumeric dialysis catheter size by child's weight.

4. Peritoneal dialysis

It is a relatively simple technique, which can be used regardless of the age or weight of the child, including the newborn or the premature because of the difficulties of vascular access, the risk of bleeding, and hypotension in an extracorporeal circulation [9].

In case of respiratory distress, the child should be intubated and ventilated.

Access to the peritoneum may be possible by placing a rigid catheter near the resuscitator at the patient's bedside or by placing a Tenckhoff catheter that is surgically introduced with subcutaneous tunneling and positioning control, under cover of antibiotic prophylaxis (2nd-generation IV cephalosporin, 20 mg/kg); it is heparinized at 500 IU/L.

The initial cycles last approximately 1 hour, with a volume of 10 mL/kg (at the beginning to avoid leakage), with a 30-minute break to reach in 2 to 3 days an optimal volume of recruitment of the peritoneal exchange surface, of the order of 30 to 50 mL/kg/cycle and according to the clinical needs and the patient's tolerance. Industrial solutions of neutral pH (bicarbonate buffer) are preferred, with iso-osmolality at first, and then use the intermediate osmolality solution if necessary. A glucose concentration of 3.8 to 4.2% is required in the case of a high water overload. Risks of PD: leakage around the catheter, migration, catheter dysfunction, and peritonitis. Hemodynamic tolerance is generally correct; occasionally there is pain with abdominal filling.

5. Continuous hemofiltration (HF, HDF, continuous HD)

These techniques are preferred in respiratory and/or hemodynamic failure situations; they require the placement of a dialysis catheter), an HF machine, and a biocompatible filter. The preferred ultrasound insertion site is the right internal jugular vein in terms of purification quality [10, 11].

The femoral site is a perfectly acceptable alternative in the context of extreme urgency and remains the most used in the English literature [12].

Machinery pumps (blood, dialysate, restitution) guarantee the accuracy of the water balance. Pediatric filters with areas ranging from 0.2 to 1.2 m² are available in all commercial markets depending on the brand of dialysis generator used (**Figure 1**).

A wide range of pediatric and neonatal Hemofilters, made of MediSulfone® proprietary membrane, has been developed to create the best treatment for low-body-weight patients.

Frequently, the circuit must be de-coagulated with heparin therapy (10 to 20 IU/kg/hour to achieve an activated cephalin time between 50 and 65 seconds) or with regional citrate anticoagulation (ionized calcium monitoring).



Figure 1.
 Diagram of a pediatric hemofilter.

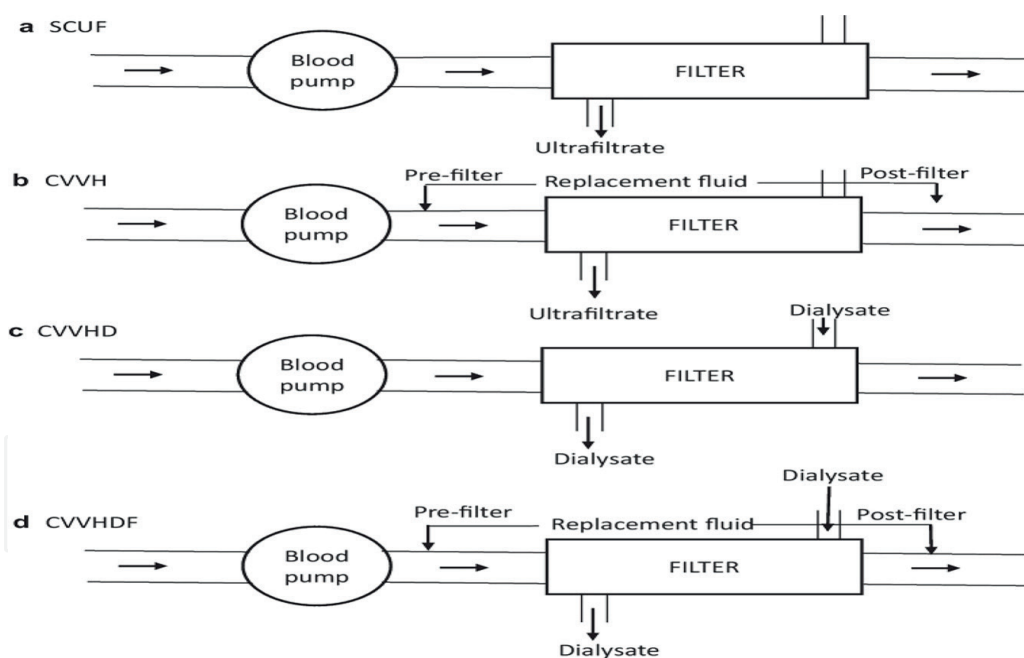


Figure 2.
 Circuit diagrams for the various modes of continuous kidney replacement therapy (CKRT) by ref. [14] in *Indian J Pediatr*. Blood flows from left to right from the patient to the blood pump and then to the filter, from which it is returned to the patient. (a) Slow continuous ultrafiltration (SCUF): In this modality, there is no diffusive clearance and only ultrafiltrate (UF) is generated across the filter; this method is preferred for isolated UF removal when kidney function is normal, (b) Continuous venovenous hemofiltration (CVVH): Replacement fluid is run either pre- or post-filter in a volume to replace the effluent; excess effluent is removed to ensure the UF desired for negative fluid balance; clearance is convective rather than diffusive. (c) Continuous venovenous hemodialysis (CVVHD): Blood flows across the filter in a countercurrent fashion with the dialysate fluid, and the effluent predominantly consists of dialysate fluid with minimal, if any, UF, as in intermittent hemodialysis. (d) Continuous venovenous hemodiafiltration (CVVHDF): This modality combines CVVH with CVVHD, such that the blood and dialysis fluid run in counter-current directions, the replacement fluid is either pre- or post-filter, and the effluent comprises the dialysate and replacement fluids.

Blood flow (BF) ranges from 3 to 10 mL/kg/minute. The blood pump flow rate should be at least 50 mL/min to maintain a filtration fraction <20%, which is easily achieved with a functioning 8 Fr catheter and HF of 0.3 m² [13].

This corresponds approximately to 2000 mL/h for 1.73 m² (in HDF, it is necessary to take into account the dialysate flow rate, or QD: total dose = QUF + QD).

In all cases, a filtration fraction (FF = QUF/[1 - Ht] x QS) of less than 15–20% should be maintained to avoid coagulation of the filter.

In pure continuous hemofiltration (CVVH, CAVH) and in the course of the derived methods which are the techniques without restitution (SCUF), the clearance is ensured by convection (**Figure 2**).

The following table describes the advantages and disadvantages of each treatment modality.

6. The choice of the therapeutic modality

6.1 Intermittent hemodialysis

Like HF, it requires a dialysis catheter, dialysis machine, and filter as well as a water treatment system. It may be preferred for hemodynamically stable patients with acute poisoning or acute decompensation of CKD to avoid costly and time-consuming continuous use.

In children with intermittent hemodialysis lasting <6 hours, blood flow should start at 3 ml/kg per minute and reach 5 ml/kg per minute in subsequent sessions, and dialysate flow should be at least 300 ml/min up to twice the blood flow in ml/min [15].

Another method, sustained low-efficiency dialysis (SLED), is a form of prolonged intermittent renal replacement therapy (PIRRT), combines the advantages of intermittent hemodialysis and CKRT, although the literature on the use of PIRRT in children is limited [16].

6.2 When to start a dialysis session?

EER should be initiated without delay in life-threatening situations (hyperkalemia, metabolic acidosis, lysis syndrome, pulmonary edema refractory to medical therapy [17]).

In children, water and sodium overload of more than 10% and most likely more than 20% should be considered as a criterion for initiating an ERA.

Several series published in the literature have shown that water overload before RRT is a risk factor for mortality [12, 17–22].

However, despite the absence of specific studies, the benefit of ERA in acute prognostic situations seems reasonable, which explains why most experts recommend using RRT in these situations [15, 23, 24].

The best time to start an RRT remains an unresolved question. Very few studies have assessed the potential benefits of an early start to RRT.

The study of Gettings [25] in polytrauma patients treated with continuous techniques shows greater survival when ERA was started before urea reached 20 mmol/l.

The beneficial impact of the dialysis dose on prognosis would be to start very early. However, a start after relative hemodynamic stability has been achieved might be more reasonable. Whatever the situation, the only certainty is that it is not necessary to wait for the complications of nitrogen retention before starting the purification [26].

A prospective randomized study by Bouman [27] compared an early onset of hemofiltration within 12 h of diagnosis of AKI to a later onset (urea greater than 40 mmol l⁻¹, serum potassium greater than 6.5 mmol l⁻¹, presence of pulmonary edema).

Time from diagnosis of ARF to onset of hemofiltration averaged 6 h in the early group and 42 h in the late group. Survival between the two groups was identical.

A meta-analysis of 12 studies with 4880 participants of all ages found no significant difference between early or late-onset dialysis in terms of survival but in terms of cost [28].

7. Impact of choice of dialysis modality

The choice of continuous therapy varies widely in the pediatric literature [29].

HDI has the obvious advantage of rapid ultrafiltration or solute removal over the DP or RRTC.

In hemodynamically stable patients, no RRT modality is better suited than HDI for rapid removal of an offending solute. This method of treatment is particularly important in the following cases: cases of ingestion of drug toxicity, tumor lysis syndrome, and hyperammonemia observed in the pediatric population [30–32].

For the ability to adjust the composition of the dialysate to treat various electrolytes (i.e., hyperkalemia, hyponatremia) HD is a major advantage over DP or RRTC [33].

In some literature series, most hypernatremic dehydration in children was treated with PD [34, 35].

Bunchman et al. [36] reviewed survival outcomes in 226 pediatric patients receiving various forms of RRT, including PD, IHD, and CRRT, over 7 years. Patients were treated with CRRT (n = 106), IHD (n = 61), or PD (n = 59).

The survival rate is 54% of the overall population studied: 40% survival in the group treated with hemofiltration, 49% in the group treated with peritoneal dialysis, and 81% survival in the group treated with intermittent hemodialysis. (P < 0.01 HD vs. HF or PD).

In a series of 62 children with organ dysfunction syndrome (22-fold related to septic shock), continuous hemodiafiltration was more effective in controlling fluid overload than peritoneal dialysis (Lowrie) [37].

The hemodynamic tolerance of intermittent hemodialysis has been studied in adults [38, 39] but not in children, but in the Maghreb countries personal experience has led us to take into consideration what the literature has offered us by taking specific measures (with respect to volume, reduction of the temperature of the dialysis baths and sodium enrichment of the dialysis bath in particular, and daily dialysis session [40]).

A new machine can perform KRT in neonates and young infants using low extracorporeal blood volume and a slow blood flow rate while permitting precise calibration of ultrafiltration (CARPEDIEM) NIDUS developed in French and countries developed and confirming their safety and feasibility in infants with AKI [41, 42].

These machines are not marketed in India [43] and in the Maghreb and in our country we use Prismaflex®, to deliver CKRT to infants.

8. Conclusion

The data for RRT modality choice in the treatment of pediatric AKI are limited. At the present time, there have been no randomized clinical trials comparing PD vs.

IHD vs. CRRT for the treatment of children with AKI and no prospective studies have evaluated the effect of dialysis modality on the outcomes of children with AKI in the ICU setting.

The decision about dialysis modality should therefore be based on local expertise, resources available, and the patient's clinical status.

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