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Modalities of renal replacement therapy in acute kidney injury

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Abstract

Impaired renal function artificial support development massively contributed to increased life expectancy and quality of life improvement. The first steps in this direction were made in the beginning of the 1900s, nowadays existing a variety of methods of renal replacement therapies that could be customized to each patient depending on the associated complications and comorbidities. Considering these aspects and that acute kidney injury (AKI) could represent a life-threatening condition, the present review will present different options of renal replacement therapies suitable to be initiated in emergency.

Keywords: acute kidney injury, continuous renal replacement therapies, intermittent therapies, hybrid treatment

INTRODUCTION

A major breakthrough that contributed to prolong survival and improve life quality was the development of artificial support of the impaired renal function, later known as renal replacement therapy (RRT) [1]. The first documented data related to this procedure are since 1913, when Kolff WJ and Abel JJ presented the initial form of hemodialysis (HD) procedure [1,2], that represented the background for creating the HD apparatus [1,3]. In 1923, the first attempt of peritoneal dialysis (PD) was performed [1,4], but the technique gained more interest and was widespread once Tenckhoff and Quinton improved the peritoneal catheter [1,5,6]. In the 60s, continuous renal replacement therapies were developed, and continuous veno-venous hemofiltration (CVVH) for adults was presented by Canaud B in 1988 [1,7], and for children in 1990 by Dr. Yorgin [1,8].

Over the years, all these procedures have been further developed, and nowadays there are different forms of RRT (Figure 1) [9], recommended in acute kidney injury (AKI) or end-stage renal disease (ESRD) – Table 1 [1,10-14].

As already discussed, there are several methods to perform RRT in AKI patients with severe and life-threatening forms: continuous renal replacement therapies (CRRT), hybrid therapy or intermittent HD (IHD) / PD (IPD), the latter types (IHD / IPD) being preferred to hemodynamically stable AKI patients [9].

Special attention should be paid to the burned patient, when the risk of developing early AKI is very high, being one of the most life-threatening complication [15]. Until now, the severity of AKI was related to rhabdomyolysis onset, electrical burns, full-thickness burns, burn injuries > 40% of total body area surface, and the presence of significant comorbidities [16-18]. Although

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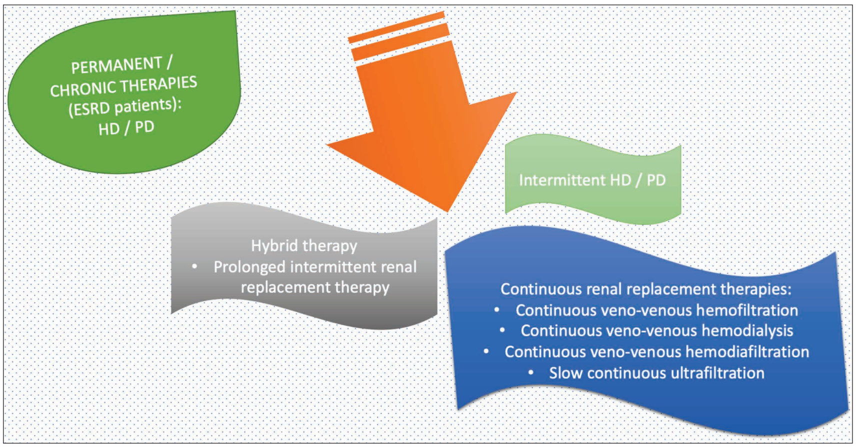

FIGURE 1. *Available renal replacement therapies for clinical use [9]*

TABLE 1. *Renal replacement therapies major indications in acute kidney injury*

● Severe hyperkalemia ($K^+ > 6.5$ mEq/l)
● Severe metabolic acidosis (pH < 7.1)
● Refractory hypervolemia
● Increased uremia – signs: pericarditis, encephalopathy, unexplained decline in mental status, etc.
● Drug / alcohol intoxications

K^+ = potassium

the literature is scarce about the optimum time of starting or the type of RRT in this subgroup of patients, various reported studies have shown that early initiation is associated with decreased morbidity and mortality [19].

CONTINUOUS RENAL REPLACEMENT THERAPIES

Continuous veno-venous hemofiltration (CVVH) [9]

CVVH is a form of RRT based on hydrostatic pressure to ultrafiltrate plasma water through the hemofilter membrane and on convection to remove the solutes, such as small and middle-sized molecules. Due to increased ultrafiltration rate (almost 20-25 ml/body weight/h) [20], replacement fluid is required in order to prevent hypovolemia. Therefore, depending on the net fluid that will be removed, an equal quantity of fluid will be replaced. As no dialysate fluid is used, the fluid replacement is recommended to be administered before the hemofilter in order to induce a predilution state that, for example, will decrease plasma urea concentration and consequently the serum urea will diffuse into the plasma water [21,22] – in this manner, serum urea could be removed using this technique.

Continuous veno-venous hemodialysis (CVVHD) [9]

CVVHD is a technique based on diffusion for solutes removal, and it uses dialysis fluid with a rate flow of 20-25 ml/body weight/h (in countercurrent to the blood flow direction). In contrast with CVVH, CVVHD has a lower ultrafiltration rate (2-8 ml/min) [20] and fluid replacement is not necessary.

Continuous veno-venous hemodiafiltration (CVVHDF) [9]

CVVHDF is a form of RRT based on diffusion and convection in order to remove solutes, and it uses dialysis fluid and also fluid replacement to prevent hypovolemia. As in CVVH, the required fluid replacement used during CVVHDF depends on the net fluid amount which will be removed.

Slow continuous ultrafiltration (SCUF) [9]

SCUF is a form of RRT with minimal solutes removal that does not use dialysate fluid, being recommended to hypervolemic patients (i.e. severe heart failure, cirrhosis, etc.), but without signs of impaired renal function (i.e. uremic syndrome, severe electrolytes disorders etc.) The ultrafiltration rate is between 2 and 8 ml/min, with a blood flow of 100-200 ml/min.

These types of CRRT are performed using a double-lumen tunneled or non-tunneled dialysis catheter that could handle a blood flow rate of 200-250 ml/min. Furthermore, due to the increased risk of technique-related complications (i.e. injury, bleeding etc.) during these procedures, catheter placement is recommended even in patients that already have an arteriovenous fistula / graft [9].

Regarding anticoagulation, it is preferrable to attempt CRRT without anticoagulation, but filter and circuit survival are reduced, therefore, when it is necessary, regional citrate or unfractionated heparin are frequently used [23,24].

HYBRID THERAPY – PROLONGED INTERMITTENT RENAL REPLACEMENT THERAPY (PIRRT) [25]

PIRRT is a type of RRT usually performed 3 times/week, but in contrast to hemodialysis for a longer period of time per session (6-18 hours) [26]. It is recom-

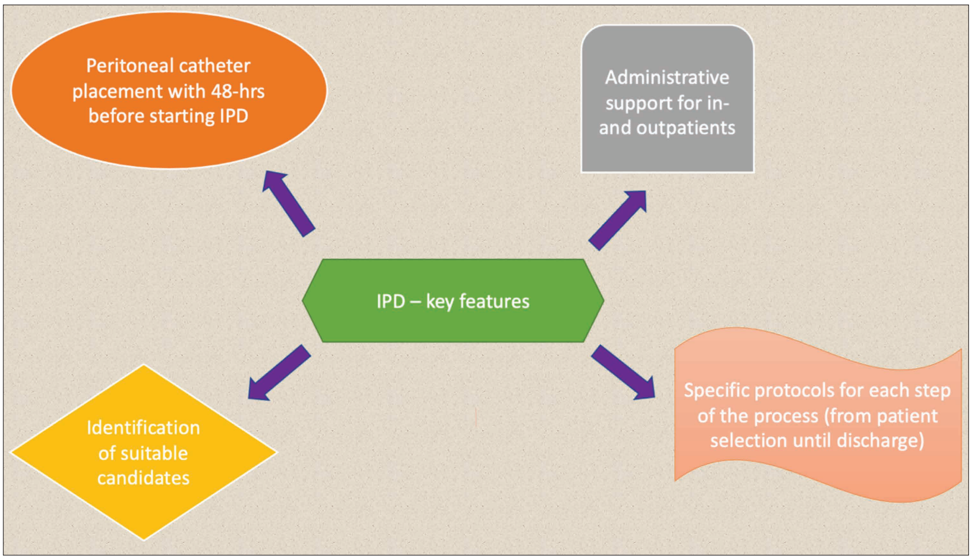

FIGURE 2. *Key features to a successful IPD*

mended to hemodynamic unstable patients, similar to CRRT. The technique is based on convection and diffusion [26], and dialysis fluid is used, with a flow rate of 100-300 ml/min. The ultrafiltration rate depends on patient hemodynamic state and, of course, the plasma water that should be removed. Therefore, in hemodynamic unstable patients, the initial rate is of almost 50 ml/h that could further be increased, and in hemodynamic stable patient the rate could be higher (the rationale in this case is to avoid intubation). As in CRRT, the preferrable vascular access is a double-lumen tunneled or non-tunneled dialysis catheter (even in patients that already have an arteriovenous fistula / graft – for the same reasons mentioned above), and the anticoagulation therapy can include regional citrate or unfractionated heparin (initially, it is preferable to start RRT without anticoagulation) [27].

INTERMITTENT THERAPIES

Intermittent HD (IHD) [28]

IHD is a technique based on convection, diffusion, and ultrafiltration, using dialysis fluid. It can be initiated in emergency in patients presenting hemodynamic stability, using a vascular access, and depending on the frequency of the sessions' requirement, a double-lumen tunneled or non-tunneled dialysis catheter could be recommended instead of using the preexistent arteriovenous fistula / graft. It is recommended to slowly increase the blood flow rate, starting initially with 200 ml/min. In the beginning, the length of the session is approximately of 2 hours that will be gradually increased up to 4 hours sessions, 3 times/week. Initially, IHD is preferable to be started without anticoagulation therapy.

Intermittent DP (IDP) [29]

IDP could be started in patients requiring emergency RRT, but not sooner than 24-48 hours (the period of time recommended after the placement of the peritoneal catheter to be safely used). As IHD, it is suitable for hemodynamic stable patients. IDP is recommended in patients with a temporary or permanent impossibility for a vascular catheter placement [30]. There are several aspects that should be considered when IDP is proposed as a viable form of urgent RRT – described in Figure 2 [31].

CONCLUSIONS

AKI patients that require urgent initiation of RRT could benefit from a variety of techniques that should be elected depending on their hemodynamic state, excess fluid and/or quantity of solutes recommended to be removed, the severity of electrolytes and/or acid-base imbalance, with special consideration regarding the burned patient. Each method presents specific limitations, complications and contraindications, and therefore, this group of patients should benefit of an adequate and careful assessment, including daily evaluation of clinical and bioumoral parameters, and accordingly adjusting the prescription of the RRT.

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