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Effect of Different Blood Purification Methods on Residual Renal Function in Maintenance Hemodialysis Patients

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Abstract: *Objective:* This study aims to evaluate the efficacy of different blood purification methods in protecting residual renal function (RRF) in patients with maintenance hemodialysis (MHD). *Methods:* The study selected 50 patients receiving MHD between September 2023 and September 2024. Using the random number table method, patients were divided into the control group and the study group, each with 25 participants. The control group received hemodiafiltration, while the study group was treated with hemodialysis plus hemoperfusion. The RRF measures of the two groups were compared. *Results:* There were significant differences in the RRF measures ($P < 0.05$). *Conclusion:* Combined hemodialysis and hemoperfusion therapy can effectively improve the RRF index of MHD patients with a significant curative effect.

Keywords: Blood purification; Maintenance hemodialysis; Residual renal function

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1. Introduction

Chronic renal failure, also referred to as chronic renal insufficiency, is a condition characterized by gradual and progressive damage to the kidney's parenchymal tissue. Over time, this damage leads to the atrophy of the kidneys, rendering them unable to perform their essential functions. The failure to filter waste products results in the retention of metabolic byproducts, as well as imbalances in water, electrolytes, and acid-base regulation, affecting multiple organ systems. This clinical syndrome, often reaching its advanced stage in uremia, can take several years or even decades to develop from the initial disease to significant renal insufficiency. Chronic renal failure is a severe stage of renal insufficiency [1]. In multiple stages, uremia marks the terminal stage of chronic renal failure, at which time the patient's glomerular and tubular function is severely impaired, resulting in metabolic abnormalities in the body, which often leads to a series of clinical symptoms such as malnutrition and anemia. In the current treatment strategies, maintenance hemodialysis (MHD) has become an important tool in the treatment of uremia [2]. By removing toxins from the blood, hemodialysis not only delays the progression of the disease but also helps to prolong the patient's life. However, the specific effects of MHD on residual renal function (RRF) are still insufficient [3]. Selecting a sample of 50 patients with chronic renal failure receiving different blood purification methods, this study observes and compares the specific effects of two different dialysis regimens on their RRF, and strives to provide a more sufficient reference for further clinical improvement and protection of RRF in the future.

2. Data and methods

2.1. General information

The selection period of this study was from September 2023 to September 2024, including 50 patients on MHD in our hospital. Using the random number table method, the patients were divided into the control group and the study group, with 50 patients in each group. In the control group, there were 16 men and 9 women with an age range from 30 to 70 years, with a mean age of 50.11 ± 3.97 years, dialysis duration from 10 to 50 months, and a mean dialysis duration of 30.19 ± 3.11 months. In the study group, there were 15 men and 10 women with an age range from 29 to 70 years, with a mean age of 49.67 ± 3.88 years and dialysis time from 12 to 50 months, with a mean dialysis time of 31.26 ± 3.55 months. The baseline data between the two groups showed no significant difference ($P > 0.05$), indicating that the data of the two groups were comparable.

Inclusion criteria included (1) patients had a plateau; (2) patients had an indication for blood purification; and (3) patients and their families had fully informed and given consent.

Exclusion criteria were (1) patients with immune dysfunction; (2) patients with abnormal blood coagulation function; and (3) patients who were participating in other research programs.

2.2. Methods

In the control group, hemodiafiltration treatment was given. The blood flow velocity was controlled at 250 ml per minute; the effective area of the acetate fiber membrane was 1.8 m^2; the dialysate speed was controlled at 800 ml per minute, and the posterior replacement and displacement amount was 50–70 ml per minute, once for four hours. Hemofiltration treatment was performed once a week, and hemodialysis was performed twice [4].

In the study group, combined treatment with hemoperfusion and hemodialysis was performed. Heparin (100 mg) was poured into the runner and reversed up and down approximately 10 times, then left to stand for 30 minutes. Saline (2000 ml) was used to flush the runner and line, and the dispenser and dialyzer were cleaned in series [5]. Irrigation was repeated with normal saline (1000 ml). The arteriovenous line was connected, and combined dialysis was performed for 0–2 hours, with the blood flow velocity controlled at 200 ml per minute. The perfusion device was removed after 2 hours, and hemodialysis continued for 2 more hours, with the blood flow controlled at 250 ml per minute. Combined dialysis was conducted once a week, with two additional sessions of hemodialysis [6]. All patients were treated for 6 months. During this period, drug treatment, such as blood pressure-lowering medications, was administered according to patients' actual conditions.

2.3. Observation indicators

For accurate assessment of residual renal function, fasting venous blood samples were taken for relevant biochemical tests, ensuring more reliable data and avoiding inaccuracy caused by food intake [7]. Patients fasted for at least 8 hours before blood drawing to eliminate the potential effects of food and fluid intake on renal function determination values. Thereafter, professional medical staff drew venous blood samples under strict sterile conditions, and the collected blood was immediately sent to the laboratory for analysis.

2.4. Statistical methods

The calculation software used was SPSS25.0; measurement data were expressed as mean ± standard deviation (SD), count data were expressed as [*n* (%)], by *t* value and χ^2. $P < 0.05$ indicated a significant difference.

3. Results

3.1. Comparison of the clinical data

There was no significant difference between the age, disease duration, and primary disease type of each group, thus the groups are comparable, as shown in **Table 1**.

Table 1. Comparison of the clinical data

Groups	*n*	Mean age (years)	Mean course of disease (month)	Primary disease types			
				Chronic glomerulonephritis	Diabetic nephropathy	Hypertension kidney disease	Other
Control group	25	44.50 ± 3.27	15.36 ± 2.14	10	6	7	6
Observation group	25	45.68 ± 3.59	14.68 ± 1.62	9	5	7	7
χ^2/t	-	0.686	0.617	0.068	0.056	0.231	0.281
P	-	> 0.05	> 0.05	0.795	0.812	0.631	0.596

Table 1 presents the comparison of clinical data between the patients in the control and observation groups. Each group had 25 patients, the mean age of the control group was 44.50 years (SD 3.27), and the mean disease duration was 15.36 months (SD 2.14). The primary disease types included 10 cases of chronic glomerulonephritis, six diabetic nephropathy, seven hypertensive nephropathy, and six others. The mean age of the observation group was 45.68 years (SD 3.59), and the mean disease duration was 14.68 months (SD 1.62), including nine cases of chronic glomerulonephritis, five diabetic nephropathy, seven hypertensive nephropathy, and seven others. The statistical differences between the two groups in terms of age, duration of disease, and distribution of primary disease type were not significant ($P > 0.05$), indicating that the data of the two groups were comparable.

3.2. Comparison of RRF index

The data of the two groups were similar before dialysis, the mean values of the study group and the control group were 1.61 ± 0.26 and 1.62 ± 0.33, respectively, and the statistical differences were not significant ($P > 0.05$); after dialysis, the RRF index in the study group was significantly better than the control group ($P < 0.05$), as presented in **Table 2**.

Table 2. Comparison of RRF index (mean ± SD, ml/min)

Groups	*n*	Before dialysis	After dialysis
Study group	25	1.61 ± 0.26	1.09 ± 0.49
Control group	25	1.62 ± 0.33	0.63 ± 0.39
t	-	0.119	3.672
P	-	0.950	0.000

4. Discussion and conclusion

4.1. Factors affecting RRF and its mechanisms

Residual renal function refers to the portion of kidney function that remains intact despite significant damage during the progression of chronic kidney disease. This function includes, but is not limited to, the ability to remove toxins and regulate water and electrolyte balance. These functions are required for kidney health to maintain environmental stability in the body. Although the RRF may have declined substantially, even limited renal function is important for reducing the systemic toxin burden, maintaining the electrolyte and acid-base balance, and supporting other physiological processes such as hematopoiesis [8]. In fact, even a small RRF significantly reduces dialysis needs and improves patient nutritional status and overall prognosis. Therefore, it is crucial to closely monitor and protect patient RRF during the course of hemodialysis treatment.

The loss of RRF is influenced by a variety of factors, including individual physiological differences in the patient, the primary etiology of chronic kidney disease (e.g., diabetic nephropathy, hypertensive nephropathy, or autoimmune nephritis), and the chosen dialysis technique. Hemodialysis itself, although an important treatment to save the patient's life, may cause further damage to the kidney. The materials and methods used during the dialysis process may cause nephrotoxicity, such as certain dialysis membrane materials may trigger inflammatory reactions, and the composition of the dialysate may not be completely suitable for all patients, thus increasing the burden on the nephron. Mechanical pressure and chemical exposure during dialysis frequently trigger the release of inflammatory mediators such as cytokines and free radicals that can further damage kidney tissue, especially when renal function is already impaired. This dialysis-induced inflammation and kidney damage accelerates the loss of RRF, leading to an increased patient dependence on dialysis.

4.2. Protection of RRF by blood purification technology

4.2.1. Hemodiafiltration

Hemodiafiltration (HDF) is an advanced blood purification technology that combines traditional hemodialysis with an efficient filtration mechanism. In this process, special filter equipment is used to simultaneously remove dissolved toxins and excess water from the blood. This technique helps patients maintain a stable fluid state by effectively controlling water retention, thereby reducing complications caused by excessive water accumulation, such as increased heart burden and hypertension. HDF works with the use of a highly permeable filter membrane that allows the passage of larger molecules of toxins and excess water, while retaining essential components in the blood, such as red blood cells and plasma proteins [9].

During dialysis, HDF removes the solutes in a more stable manner, which is extremely important for maintaining the hemodynamic state of the patient. A more gradual solute clearance helps prevent potential blood pressure fluctuations and other hemodynamic instabilities during dialysis, which can otherwise impose additional strain on the heart or negatively impact residual renal function.

4.2.2. Hemoperfusion

Hemoperfusion uses a physical adsorption device to remove toxins from the blood, and its basic principle is adsorption. The filling column is composed of adsorbent and wrapping material. The adsorbent has resin and activated carbon, and has the ability to adsorb dissolved substances and colloidal substances in the liquid. According to the nature of the force between the surface of the adsorbent and the adsorbent, the adsorption can be divided into two basic types: physical adsorption and chemical adsorption. This method is an efficient blood purification technology, which is used through a physical adsorption device, such as activated carbon or special resin, to remove various toxins from the blood. This technique is particularly suited to remove harmful substances with large molecular weight and difficult to pass through conventional dialysis membranes. During hemoperfusion, blood is directed through filters that contain adsorbents that can capture and fix toxins in the blood [10]. By reducing the use of dialysate, the risk of complications related to dialysate quality issues, such as electrolyte imbalance and contamination, is correspondingly reduced. This lessens the burden on the kidneys, allowing the remaining nephrons to better perform their physiological functions, such as regulating body water and electrolyte balance, as well as processing other metabolic waste. Blood perfusion mainly removes harmful substances in the blood through adsorption, especially the aromatic amino acids adsorption capacity. However, it should be noted in the treatment that this technique can also adsorb the thyroid hormones T_3 and T_4, growth hormone, and hormones such as insulin. Therefore, in the long-term application of hemoperfusion, it is necessary to be alert to the possible decline of hormone levels, and timely supplement or adjust according to the need. Due to the adsorption materials, such as improper washing of the irrigation, excessive residual aldehydes or bubbles, may cause a series of adverse reactions, including hemolysis, headache, and even air embolism.

4.3. Comprehensive application and patient benefits

In exploring the effects of different blood purification techniques on RRF in patients with MHD, the comprehensive application of various blood purification methods, such as hemodialysis (HD) combined with hemoperfusion (HP), shows significant clinical advantages. With HD technology, small and medium molecule toxins can be effectively removed, while HP focuses on removing macromolecules and toxins that are hardly dialyzing. This dual clearance mechanism not only enhances the efficiency of toxin clearance but also alleviates the possible physiological burden of relying on a single purification technique. This comprehensive treatment modality promotes the overall health of patients, including improved nutritional status, by reducing toxin accumulation and improving water and electrolyte balance. The above improvements directly enhance the patient's quality of life and have the potential to indirectly prolong patient survival. Although a combination of both purification technologies may increase healthcare costs at early stages, it could in the long run reduce overall healthcare expenditure by reducing complications and prolonging patient survival. Furthermore, the maintenance and improvement of RRF reduces the financial burden and life disturbance associated with frequent dialysis. Future studies should further explore the effect of this combination treatment model in patients with different types of kidney disease to optimize the treatment plan and achieve the goal of individualized medicine.

Disclosure statement

The author declares no conflict of interest.

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