10.5152/turkjnephrol.2019.3360

Original Article

Turkish Journal of Nephrology

Therapeutic Plasma Exchange in Renal Diseases: A Three-Year Retrospective Analysis

Sibel Ersan[1], Fatma Liv[2], Sibel Demiral Sezer[3], Hülya Çolak[1], Alper Alp[1], Cengiz Ceylan[4], Harun Akar[3]

[1]Department of Nephrology, University of Health Sciences, İzmir Tepecik Training and Research Hospital, İzmir, Turkey
[2]Therapeutic Apheresis Unit, University of Health Sciences, İzmir Tepecik Training and Research Hospital, İzmir, Turkey
[3]Department of Internal Medicine, University of Health Sciences, İzmir Tepecik Training and Research Hospital, İzmir, Turkey
[4]Division of Haematology, University of Health Sciences, İzmir Tepecik Training and Research Hospital, İzmir, Turkey

Abstract

Objective: The aim of the study was to analyze the indications, efficacy, and complications of therapeutic plasma exchange (plasmapheresis) applied for renal diseases in three years retrospectively.
Materials and Methods: This study included 47 patients with nephrological disorders (41.5%, 28 men and 19 women). We analyzed data including demographic characteristics, underlying renal disease, and outcomes of the patients as well as the procedural characteristics and safety profile regarding the type and amount of the replacement fluid, number of sessions, and complications.
Results: The mean age of the patients was 48±14.68 years. A total of 251 sessions were performed, and the mean number of sessions per patient was 5.61±2.79. Nephrological diseases treated with plasmapheresis were rapidly progressive glomerulonephritis in 17 (36.4%) patients, thrombotic microangiopathies in 13 (27.6%) patients, renal transplantation in 9 (19%) patients, focal segmental glomerulosclerosis in 4 (8.5%) patients, and multiple myeloma in 4 (8.5%) patients. The most common complications were muscle cramps in 8.5% of patients, minor allergic reactions and pruritus in 6.3% of patients, hypotension in 6.3% of patients, and hematoma in catheter insertion site in 2.1% of patients. Six patients (12.7%) treated with plasmapheresis died because of primary disease.
Conclusion: Plasmapheresis has place as a therapeutic modality in nephrology practice with a minor adverse reactions.
Keywords: Plasmapheresis, renal diseases, therapeutic apheresis

Corresponding Author: Sibel Ersan ersansibel1@gmail.com
Received: 05.05.2018 **Accepted:** 12.09.2018

Cite this article as: Ersan S, Liv F, Demiral Sezer S, Çolak H, Alp A, Ceylan C, et al. Therapeutic Plasma Exchange in Renal Diseases: A Three-Year Retrospective Analysis. Turk J Nephrol 2019; 28(2): 114-9.

INTRODUCTION

Therapeutic plasma exchange or plasmapheresis is based on the centrifugation or membrane path separation of plasma outside the body (extracorporeal) and replacement with fresh frozen plasma or albumin solutions (1). Plasmapheresis removes large molecules such as antibodies, immune complexes, lipoproteins, cryoglobulins, or endotoxins from plasma or replaces the missing material in plasma (1-3). With a single change of total plasma volume, 50%-60% of the target substance can be removed from the intravascular compartment (4).

The efficacy of plasmapheresis has been demonstrated in many immunological, hematological, neurological, metabolic diseases, and intoxication conditions (4, 5). In nephrology practice, it has a place in the treatment of rapidly progressive glomerulonephritis (RPGN), renal-associated vasculitis, thrombotic microangiopathies (TMAs), paraproteinemias, and transplantation rejections (4-7). In the finally published guide of the American Apheresis Society (ASFA) in 2016, new indications have been added to the extracorporeal blood purification therapies by the modern techniques (such as immunoadsorption, rheopheresis, lipopheresis, selective cytapheresis) in addition to the classical plasmapheresis (8).

In this study, we retrospectively evaluated demographic features, indications, efficacy, and safety of plasmapheresis in nephrological diseases that were treated with plasmapheresis.

Table 1. Indications and categories of plasma exchange in renal diseases*

Disease	Category
ANCA-associated RPGN	
Dialysis dependent	I
Diffuse alveolar hemorrhage (DAH)	I
Dialysis independent	III
Anti-glomerular basement membrane disease (Good-pasture syndrome)	
Dialysis dependent, DAH (-)	III
DAH	I
Dialysis independent	I
Systemic amyloidosis	IV
Cryoglobulinemia (symptomatic/severe)	I
Focal segmental glomerulosclerosis (relapse in transplant kidney)	I
Atypical hemolytic uremic syndrome (aHUS) (*Complement-mediated thrombotic microangiopathy-TMA*)**	
Complement factor gene mutations	II-III**
Factor H autoantibodies	I-I**
Membrane cofactor protein (MCP) mutations	IV-III**
HUS-infection related (*İnfection related TMA***)	
Shiga toxin related, *severe neurological symptom***	IV-III**
S. pneumoniae related	III
*No severe neurological symptom***	IV**
Henoch-Schonlein purpura (crescentic)	III
Severe extrarenal disease	III
Monoclonal gammopathy with	
Symptomatic hyperviscosity	I
Rituksimab prophylaxis	I
Immune-complex RPGN	III
Immunoglobulin A nephropathy	
Crescentic	III
Chronic progressive	III
Myeloma cast nephropathy	II
Nephrogenic systemic fibrosis	III
Renal transplantation, ABO compatible	
Antibody mediated rejection	I
Desensitization, live donor, positive cross-match based positive donor specific HLA antibody	I
Desensitization, high PRA, cadaveric donor	III
Renal transplantation, ABO incompatible	
Desensitization, live donor	I
Humoral rejection	II
From A2/A2B group to B transplantation, cadaveric donor	IV
Sepsis and multiorgan dysfunction	III
Systemic lupus erythematosus	
Severe	II
Nephritis	IV
Drug related thrombotic microangiopathy	
Cyclosporine/Tacrolimus	III
*Vasculitis***	
Hepatitis B related polyarteritis nodosa (HBV-PAN)	II
Idiopathic PAN	IV
Eosinophilic granulomatosis with polyangiitis (EGPA)	III
Behçet's disease	III

* American Society of Apheresis guideline-2013 (8)
** The new indications included in ASFA-2016 guideline were expressed as italic
Categories imply;
I; Disorders for which apheresis is accepted as first-line therapy, either as a primary standalone treatment or in conjunction with other modes of treatment,
II; Disorders for which apheresis is accepted as second-line therapy, either as a standalone treatment or in conjunction with other modes of treatment,
III; Optimum role of apheresis therapy is not established,
IV; Disorders in which published evidence demonstrates or suggests apheresis to be ineffective or harmful.

MATERIALS AND METHODS

Data of 47 patients (19 females, 28 males) who had plasmapheresis because of kidney disease between January 2015 and December 2017 were reviewed. The data of these patients were obtained by entering the plasmapheresis procedure code in the hospital registry system. Age, gender, plasmapheresis indications, total number of sessions, type and amount of replacement fluid, anticoagulation, complications, and in-hospital outcomes of the patients were investigated.

In this retrospective study, data were collected with the patient protocol number without questioning the identity information; and an ethical committee approval was not obtained because of the lack of an interventional procedure.

Plasmapheresis was performed by the MCS+system (Haemonetics, Braintree, MA, USA) using centrifugation method. Plasma volume was calculated with the formula "weight×0.065×(1-Htc)," and fresh frozen plasma (FFP) was used as replacement fluid. A double-lumen hemodialysis catheter placed in the femoral or internal jugular vein provides vascular access. Citrate anticoagulation was performed as standard, and oral calcium supplementation was provided for all of the patients.

Table 2. Demographic, clinical, and procedure-related data of the patients

	Number	Gender (F/M)	Age (mean±SD)	Indication category*	Number of sessions (per patient mean±SD)	Replaced fluid volume (liter) (mean±SD)	Complication (number of patients)	Outcome (number of patients)
Rapidly progressive glomerulonephritis	17	5/12	51.12±21.3	I	7.8±2.3	3.26±0.38	Cramp (2) Allergic reaction (2) Hypotension (1) Thrombocytopenia(6)	Full recovery (3) Partial recovery (7) Unresponsive (5) Death (2)
Thrombotic microanjiyopathy	13	6/7	44.9±18.9	III-IV	5.4±2.2	3.57±0.48	Hematoma (1) Thrombocytopenia (3)	Full recovery (3) Unresponsive (8) Death (2)
Renal transplantation (rejection)	9	3/6	38.4±23.7	I	6.8±1.4	3.28±0.66	Cramp (1)	Full recovery(3) Partial recovery (5) Unresponsive (1)
Focal segmental glomerulosclerosis	4	1/3	49.7±13.6	I	3.1±2.2	3.46±0.34	Allergic reaction (1)	Unresponsive (2) Partial recovery (2)
Multiple myeloma	4	4/0	62.0±9.3	II	4.0±2.5	3.24±0.55	Cramp (1) Hypotension (2) Thrombocytopenia (4)	Recovery (1) Unresponsive (1) Death (2)

The indications and categories of plasmapheresis were determined according to the guidelines of the American Apheresis Society (ASFA) (Table 1) (8, 9).

In all patients, diagnosis of rapidly progressive glomerulonephritis was made by the histological crescent formation and capillary necrosis in renal biopsy.

Diagnosis of TMA was established with the presence of clinical and laboratory data of acute renal injury, microangiopathic hemolytic anemia, and thrombocytopenia. Thrombotic thrombocytopenic purpura was excluded with normal ADAMTS13 activity.

Focal segmental glomerulosclerosis (FSGS) was diagnosed by renal biopsy.

Myeloma cast nephropathy in patients with multiple myeloma was established by detecting increased free light chain levels in patients with acute kidney injury.

Response to treatment was staged as partial healing, complete recovery, and unresponsive. The reversal of the patient's clinical and laboratory data to pre-disease values was defined as complete recovery, lack of improvement in clinical and laboratory data after plasmapheresis sessions as unresponsive, and results between these groups as partial recovery (2).

Statistical Analysis

All numerical data were represented as mean±SD. Descriptive analysis was done by using Statistical Package for the Social Sciences (SPSS) for Windows, version 25.0. (IBM Corp., Armonk, N.Y., USA).

RESULTS

A total of 251 plasmapheresis procedures (mean number of sessions per person was 5.61±2.79) were applied to 47 (28 male, 19 female, mean age 48±14.68 years) nephrology patients in our apheresis unit for three years. Totally used FFP volume was calculated as 3.28±0.48 L.

The demographic data of the cases, the indications/categories of plasmapheresis, the complications of the procedure, and the in-hospital outcomes are shown in Table 2.

In our study, hemodialysis (mean creatinine levels 6.34±1.85 mg/dL) and plasmapheresis treatments were performed on consecutive days in 17 patients with RPGN. High-dose corticosteroids and cytotoxic immunosuppressive therapy were accompanied by plasmapheresis. One of these patients was diagnosed with systemic lupus erythematosus (SLE)-associated nephritis and one with crescentic IgA nephropathy. Complete recovery was achieved with immunosuppressive and plasmapheresis treatments in three patients (17.6%), partial recovery was achieved in seven patients (41.2%), and patients were followed up without dialysis (mean creatinine values 2.65±0.86 mg/dL). Despite

a combination of plasmapheresis and immunosuppressive therapy, 5 (29.4%) patients remained dialysis-dependent. One patient died because of massive alveolar hemorrhage, and one patient died because of catastrophic SLE.

Complete recovery (23.1%) was achieved in 3 of 13 patients with TMA. Two of these patients were considered to have infection-related TMA, and one to have persistent HELLP (hemolysis, elevated liver enzyme levels, low platelet level) syndrome after pregnancy. Out of seven patients who required hemodialysis (mean creatinine level 7.86±2.14 mg/dL), one was diagnosed as having TMA because of cancer, three were associated with chemotherapeutics, and one with scleroderma renal crisis. The cause was not found in two patients. The patients were discharged with hemodialysis treatment. Two patients who were followed up in the intensive care unit and were diagnosed with TMA died because of sepsis. One of the patients was diagnosed with complement-related TMA (complement factor H-related protein 5 mutation) and treated with eculizumab for being unresponsive to the plasmapheresis.

One patient had plasmapheresis treatment because of the recurrence of FSGS after kidney transplantation, and three patients had it because of FSGS resistance to the steroid and immunosuppressive therapies in the native kidney. In the patient with recurrence after renal transplantation, a decrease of more than 50% of the baseline in proteinuria is achieved by plasmapheresis. In the same case, Fabry disease was diagnosed, and recombinant alpha-galactosidase A enzyme treatment was given. In a patient diagnosed with FSGS in the native kidney, partial response was achieved with plasmapheresis treatment, but partial or complete resolution could not be obtained in other patients.

Because of acute humoral rejection, plasmapheresis was performed in patients with renal transplantation (four live, five cadaveric).

No procedure-related mortality was observed in any of the patients who had plasmapheresis. Thrombocytopenia (27.6%) developed in 13 patients as a technical complication because of the procedure, and no data record was found for hemolysis. In our study, a data record of hemolysis could not be found. The most common complication encountered in the procedures was muscle cramps (8.5%).

Six patients (12.7%) died because of the severity of their primary diseases or complications because of it. The cause of death was reported to be massive alveolar hemorrhage in 1 (2.1 %) patient, cerebrovascular accident because of severe hyperviscosity syndrome in 1 (2.1%) patient, catastrophic lupus syndrome in 1 (2.1%) patient, and sepsis in 3 (6.3%) patients.

DISCUSSION

In this study, the data of plasmapheresis procedure performed in renal diseases in the last three years in our clinic were retrospectively reviewed. Conventional plasma exchange therapy is the therapeutic apheresis technique primarily used for the removal of large molecular weight substances from plasma, especially in hematological diseases, at the beginning. Today, diseases treated with plasmapheresis are classified into five main categories: neurological, renal, hematological, immunological, and metabolic diseases (9). In updated guidelines, indications for disease treatable with plasmapheresis are increasing; and the use of plasmapheresis in vasculitis has been categorized in the latest ASFA guideline (Table 1) (8). The technical complexity of this method has proven effective in definite indications, and the inclusion of newly developed more expensive methods (such as immunoadsorption) into the field also necessitates a careful discussion of the cost-benefit relationship (5). In Germany, the cost of therapeutic plasma exchange is between 830€ and 1620€ and in Turkey, this amount varies between 790₺ and 1580₺ for five to ten sessions according to the current cost schedule of the Ministry of Health (5, 10).

Among the indications of plasmapheresis in our study, RPGN cases (17/47, 36.2%) were most common. In the study of Samancı et al. (2), antinuclear cytoplasmic antibody (ANCA)-related and RPGN cases with plasmapheresis were reported at a similar rate (35%). According to the ASFA 2016 guidelines, plasmapheresis is recommended as category I in the case of dialysis dependency or presence of DAH in ANCA-related RPGNs, as category III in the case of dialysis dependency in Goodpasture syndrome (5-9). Plasmapheresis treatment is recommended in RPGN associated with immune complex vasculitis as category III, in SLE nephritis as category IV (6, 8, 11, 12). The efficacy of plasmapheresis treatment in RPGN cases associated with idiopathic or other vasculitis other than ANCA-associated RPGN is controversial. The addition of plasmapheresis to the conventional treatment of lupus nephritis provides a rapid reduction of circulating antibodies, but it does not suppress the humoral immune response and does not positively contribute to the prognosis of the disease (1, 4). Immunoadsorption is a more effective option in patients with severe SLE resistant to conventional immunosuppressive therapy (4). In our case, immunoadsorption could not be applied because of technical insufficiency; and it did not responded to the plasmapheresis treatment together with conventional immunosuppressive treatment.

Microangiopathic hemolytic anemia and unexplained thrombocytopenia are adequate indications for plasmapheresis treatment. Early removal of the immune complex and toxins rapidly breaks the pathogenetic process, and it provides a more effective treatment than other therapeutic interventions (5, 6, 8). Although the literature data on the efficacy of plasmapheresis treatment in TMA cases in which with renal involvement is at the forefront is contradictory, it is seen as a logical option when the poor prognosis in adults is considered (5, 8). Although there is no indication of plasmapheresis in the HELLP syndrome, plasmapheresis treatment may be beneficial if platelet levels do not improve in the first week after pregnancy (13, 14). Our case also showed complete recovery.

The efficacy of plasmapheresis and consecutive intravenous immunoglobulin (IVIG) treatment has been proven in acute humoral rejection after renal transplantation (15-17). White et al. demonstrated that plasmapheresis and successive IVIG therapy provided graft survival in eight patients in their retrospective study with nine patients with AHR diagnosed by biopsy (15). In another study, one-year graft survival rate was reported as 70% in patients with AHR with plasmapheresis and IVIG treatment (16). In accordance with the literature, in our study, graft survival was achieved in eight of the nine patients (Table 2).

Focal segmental glomerulosclerosis is a histological description of glomerular injury. Despite the steroid and other immunosuppressive treatment, plasmapheresis is indicated for persistent proteinuria in the treatment of FSGS in native kidneys (2, 6). Data on the positive effects of plasmapheresis treatment in patients with recurrent FSGS after kidney transplantation are available, and it is recommended in the 2016 ASFA guideline with category I indication (6, 8, 18, 19). In a study, the effect of plasmapheresis was examined in ten patients with recurrent primary FSGS after renal transplantation; it was found at the end of a mean follow-up period of ten months, six patients had complete response (proteinuria <500 mg/day), three patients had a partial response, and one patient remained unresponsive (18). Because of the natural progress of FSGS, the role of plasmapheresis treatment on graft survival in the long term should be monitored. In our study, we found a decrease in proteinuria by plasmapheresis treatment in our relapsed FSGS case after transplantation, but no information could be reached on primary/secondary FSGS distinction in unresponsive native kidney cases.

Myeloma cast nephropathy is a condition caused by increased levels of free immunoglobulin light chain (kappa or lambda) in the serum of the patients with multiple myeloma. It can cause acute kidney damage. Although the results of the application of plasmapheresis therapy in patients with myeloma are quite contradictory, it is more likely to be effective in acute myeloma cast nephropathy (6, 8, 20-22). Two of our patients with multiple myeloma who developed acute kidney injury and had plasmapheresis treatment died because of the complications related to their primary diseases. One patient had recovery in renal function with plasmapheresis treatment, and one patient remained unresponsive.

Adverse effects associated with plasmapheresis treatment can be listed as technical complications (thrombocytopenia and hemolysis), bradycardia, hypotension, allergic/febrile reactions, nausea-vomiting, leukopenia, hypocalcemia/cramps, paresthesia, convulsions, bleeding, and catheter-related problems (2). Consistent with the literature, 23% (4.38% of all treatments) of our cases had mild complications that did not require termination of the procedure (2, 4, 23). Hypocalcemia and cramps because of the use of citrate anticoagulation are the most common encountered complications (2, 4). No mortality was observed because of the procedure itself.

CONCLUSION

The rapidly evolving therapeutic methods used in recent years to resolve the plasma and its components are safe and effective options. They can be applied with definite indications in some renal diseases that may have serious consequences. The increasing indications of therapeutic plasma exchange in the updated guidelines suggest that clinicians will experience this type of treatment more in practice. However, the cost-benefit relationship should be discussed in detail, especially in view of the financial burden imposed on health reimbursement by newly developed expensive technological methods.

Ethics Committee Approval: Authors declared that the research was conducted according to the principles of the World Medical Association Declaration of Helsinki "Ethical Principles for Medical Research Involving Human Subjects", (amended in October 2013).

Informed Consent: Informed consent is not necessary due to the retrospective nature of this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – S.E., F.L., C.C., A.A., S.D.S., H.Ç., H.A.; Design – S.E., F.L., C.C., A.A., S.D.S., H.Ç., H.A.; Supervision – S.E., F.L., C.C., A.A., S.D.S., H.Ç., H.A.; Data Collection and/or Processing – F.L., S.E., A.A., C.C., H.A.; Analysis and/or Interpretation – S.E., H.Ç., A.A., H.A.; Literature Search – S.E., A.A., C.C., S.D.S., H.Ç.; Writing – S.E., A.A., H.Ç., C.C., H.A.; Critical Reviews – S.E., F.L., S.D.S., A.A., H.Ç., C.C., H.A.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Sabath E, Denker B M: Plasmapheresis. In: Brenner and Rector's (eds), The Kidney. Philadelphia: Elsevier, 2016; 2148-64.
2. Sengul Samanci N, Ayer M, Gursu M, Ar MC, Yel K, Ergen A, et al. Patients treated with therapeutic plasma exchange: A single center experience. Transfus Apher Sci 2014; 51: 83-9. [CrossRef]
3. Nakanishi T, Suzuki N, Kuragano T, Nagasawa Y, Hasuike Y. Current topics in therapeutic plasmapheresis. Clin Exp Nephrol 2014; 18: 41-9. [CrossRef]
4. Visvardis G, Manou E, Griveas I, Meimaridou D, Mitsopoulos E, Kyriklidou P, et al. Therapeutic apheresis of immune diseases in nephrology department. Ren Fail 2004; 26: 569-74. [CrossRef]
5. Bambauer R, Latza R, Burgard D, Schiel R. Therapeutic Apheresis in Immunologic Renal and Neurological Diseases. Ther Apher Dial 2017; 21: 6-21. [CrossRef]
6. Sanchez AP, Ward DM. Therapeutic apheresis for renal disorders. Semin Dial 2012; 25: 119-31. [CrossRef]
7. Aydin Z, Gursu M, Karadag S, Uzun S, Tatli E, Sumnu A, et al. Role of plasmapheresis performed in hemodialysis units for the treatment of anti-neutrophilic cytoplasmic antibody-associated systemic vasculitides. Ther Apher Dial 2011; 15: 493-8. [CrossRef]
8. Schwartz J, Padmanabhan A, Aqui N, Balogun RA, Connelly-Smith L, Delaney M, et al. Guidelines on the Use of Therapeutic Apheresis in Clinical Practice-Evidence-Based Approach from the Writing

Committee of the American Society for Apheresis: The Seventh Special Issue. J Clin Apher 2016; 31: 149-62. [CrossRef]
9. Schwartz J, Winters JL, Padmanabhan A, Balogun RA, Delaney M, Linenberger ML, et al. Guidelines on the use of therapeutic apheresis in clinical practice-evidence-based approach from the Writing Committee of the American Society for Apheresis: the sixth special issue. J Clin Apher 2013; 28: 145-284. [CrossRef]
10. Public Health Services Price Schedule. http://tig.saglik.gov.tr/TR,26173/kamu-saglik-hizmetleri-fiyat-tarifesi-guncellenmistir.html
11. Pagnoux C. Plasma exchange for systemic lupus erythematosus. Transfus Apher Sci 2007; 36: 187-93. [CrossRef]
12. Shenoy M, Ognjanovic MV, Coulthard MG. Treating severe Henoch-Schönlein and IgA nephritis with plasmapheresis alone. Pediatr Nephrol 2007; 22: 1167-71. [CrossRef]
13. Katz VL, Watson WJ, Thorp JM Jr, Hansen W, Bowes WA Jr. Treatment of persistent postpartum HELLP syndrome with plasmapheresis. Am J Perinatol; 9: 120-2. [CrossRef]
14. Esplin MS, Branch DW. Diagnosis and management of thrombotic microangiopathies during pregnancy. Clin Obstet Gynecol 1999; 42: 360-7. [CrossRef]
15. White NB, Greenstein SM, Cantafio AW, Schechner R, Glicklich D, McDonough P, et al. Successful rescue therapy with plasmapheresis and intravenous immunoglobulin for acute humoral renal transplant rejection. Transplantation 2004; 78: 772-4. [CrossRef]
16. Ibernón M, Gil-Vernet S, Carrera M, Serón D, Moreso F, Bestard O, et al. Therapy with plasmapheresis and intravenous immunoglobulin for acute humoral rejection in kidney transplantation. Transplant Proc 2005; 37: 3743-5. [CrossRef]
17. Brown CM, Abraham KA, O'Kelly P, Conlon PJ, Walshe JJ. Long-term experience of plasmapheresis in antibody-mediated rejection in renal transplantation. Transplant Proc 2009; 41: 3690-2. [CrossRef]
18. Valdivia P, Gonzalez Roncero F, Gentil MA, Jiménez F, Algarra G, Pereira P, et al. Plasmapheresis for the prophylaxis and treatment of recurrent focal segmental glomerulosclerosis following renal transplant. Transplant Proc 2005; 37: 1473-4. [CrossRef]
19. Gungor O, Sen S, Kircelli F, Yilmaz M, Sarsik B, Ozkahya M, et al. Plasmapheresis therapy in renal transplant patients: five-year experience. Transplant Proc 2011; 43: 853-7. [CrossRef]
20. Clark WF, Stewart AK, Rock GA, Sternbach M, Sutton DM, Barrett BJ, Heidenheim AP, Garg AX, Churchill DN; Canadian Apheresis Group. Plasma exchange when myeloma presents as acute renal failure: a randomized, controlled trial. Ann Intern Med 2005; 143: 777-84. [CrossRef]
21. Leung N, Gertz MA, Zeldenrust SR, Rajkumar SV, Dispenzieri A, Fervenza FC, et al. Improvement of cast nephropathy with plasma exchange depends on the diagnosis and on reduction of serum free light chains. Kidney Int 2008; 73: 1282-8. [CrossRef]
22. Drew MJ. Plasmapheresis in the dysproteinemias. Ther Apher 2002; 6: 45-52. [CrossRef]
23. Schmidt JJ, Asper F, Einecke G, Eden G, Hafer C, Kielstein JT. Therapeutic plasma exchange in a tertiary care center: 185 patients undergoing 912 treatments - a one-year retrospective analysis BMC Nephrol 2018; 19: 12. [CrossRef]