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***Original Article** / Özgün Makale*

The effects of perioperative ultrafiltration on postoperative outcomes in dialysis-dependent patients undergoing open heart surgery

Perioperatif ultrafiltrasyonun açık kalp ameliyatı yapılan diyalize bağımlı hastalarda ameliyat sonrası sonuçları üzerine etkileri

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Background: This study aims to investigate the effects of perioperative ultrafiltration (UF) on postoperative outcome in hemodialysis-dependent patients undergoing open heart surgery.

Methods: Between March 2000 and May 2008, 46 hemodialysis-dependent patients who underwent open heart surgery were included. Patients were divided into two groups based on utilization of ultrafiltration: UF (+) and UF (-) group. All patients underwent hemodialysis one day before surgery and two days after surgery. Of 46 patients, 26 had UF during surgery (UF (+) group). The length of hospital stay including intensive care unit and morbidity and mortality rates were compared between the groups. Pre- and postoperative central venous pressure, blood urea nitrogen (BUN), creatinine, serum potassium, hemoglobin (Hgb) concentrations were analyzed.

Results: The length of intensive care unit stay (56±28 hours vs. 95±93 hours, respectively; p=0.04) and hospital stay (5.5±1.4 days vs. 8.1±3.4 days, respectively; p=0.002) were significantly different between the groups. There were significant differences in postoperative mean values of BUN (50.6±13.5 mg/dl vs. 59.8±13.7 mg/dl, respectively; p=0.02) and hemoglobin (9.9±1.0 g/dl vs. 8.8±0.9 g/dl, respectively; p=0.001) between the groups.

Conclusion: Utility of perioperative UF in dialysis-dependent patients during open heart surgery may shorten the length of hospital stay and improve biochemical and hemodynamic parameters.

Key words: Dialysis-dependent patient; open heart surgery; ultrafiltration.

Amaç: Bu çalışmada açık kalp cerrahisi yapılan hemodiyalize bağımlı hastalarda perioperatif ultrafiltrasyonun (UF) ameliyat sonrası sonuçları üzerine etkileri araştırıldı.

Çalışma planı: Mart 2000 - Mayıs 2008 tarihleri arasında açık kalp ameliyatı yapılan hemodiyalize bağımlı 46 hasta çalışmaya dahil edildi. Hastalar ultrafiltrasyon (UF) kullanımına göre iki gruba ayrıldı: UF (+) ve UF (-) grubu. Tüm hastalar ameliyattan bir gün önce ve ameliyattan iki gün sonra hemodiyalize alındı. Kırk altı hastanın 26'sına ameliyat sırasında UF yapıldı (UF (+) grubu). Her iki grubun yoğun bakımda kalış süresi dahil olmak üzere, hastanede kalış süreleri ve morbidite ve mortalite oranları karşılaştırıldı. Ameliyat öncesi ve sonrası santral venöz basınçları, kan üre nitrojen (BUN), kreatinin, serum potasyum ve hemoglobin (Hgb) konsantrasyonları incelendi.

Bulgular: Yoğun bakımda kalış süresi (sırasıyla 56±28 saat ve 95±93 saat; p=0.04) ve hastanede kalış süresi (sırasıyla 5.5±1.4 gün ve 8.1±3.4 gün; p=0.002) gruplar arasında anlamlı olarak farklı idi. Gruplar arasında ameliyat sonrası ortalama BUN (sırasıyla 50.6±13.5 mg/dl ve 59.8±13.7 mg/dl; p=0.02) ve hemoglobin düzeylerinde (sırasıyla 9.9±1.0 g/dl ve 8.8±0.9 g/dl; p=0.001) anlamlı farklılıklar vardı.

Sonuç: Diyalize bağımlı hastalarda açık kalp perioperatif UF uygulaması, hastanede kalış süresini kısaltabilir ve biyokimyasal ve hemodinamik parametrelerde iyileşme sağlayabilir.

Anahtar sözcükler: Diyalize bağımlı hasta; açık kalp cerrahisi; ultrafiltrasyon.

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The use of ultrafiltration (UF) during open heart surgery with regard to the operative and postoperative outcomes in dialysis-dependent patients is controversial.[1] In particular, the proper control of fluid balance, serum electrolytes, metabolic acidosis, and azotemia is considered to be the most crucial issue in the perioperative period. Bearing this in mind, various strategies, such as perioperative hemodialysis and hemofiltration, have been successful in producing favorable surgical outcomes.[2,3]

Ultrafiltration is a technique that removes plasma water and low-molecular-weight solutes by a connective process using hydrostatic forces across a semipermeable membrane. Conventional UF usually begins at the initiation of the surgery and lasts until the end of the cardiopulmonary bypass (CPB). The volume of filtrates that can be removed during UF is restricted by the volume of the venous reservoir. Therefore, conventional UF has only a limited ability to remove excess water and reverse hemodilution;[4] however, it is effective in preventing the accumulation of excess total body water.[5]

The purpose of our study was to investigate the efficacy of perioperative UF on the postoperative outcomes in terms of hospital stay, morbidity, and mortality.

PATIENTS AND METHODS

Patient selection

We retrospectively studied 46 consecutive dialysis-dependent patients who underwent either coronary artery bypass grafting (CABG) (n=39), CABG with a ventricular aneurysmectomy (n=2), or CABG with mitral valvuloplasty (MV) (n=5) between March 2000 and May 2008. Hemodialysis was performed on all patients one day before the surgery and on the second day after surgery in the intensive care unit (ICU). During the operation, 26 patients underwent UF [UF (+) group] while 20 patients did not [UF (–) group]. This decision was made at the discretion of each surgeon.

Surgical procedure

All surgical procedures were performed via a median sternotomy, and CPB was established through standard aortocaval cannulation, mild hypothermia (30-32 °C), and a pump flow of approximately 80 ml/min/kg while maintaining a perfusion pressure of greater than 70 mmHg. All patients received antegrade, intermittent, mild hypothermic blood cardioplegia via the aortic root for myocardial protection. The infused dosage and crystalloid composition, including potassium (K) concentration of cardioplegic solution, were identical in both groups (potassium concentrations of induction and maintenance solutions were 30 mEq/l and 20 mEq/l, respectively). No substitution solution was administered in the operating room.

Strategy for perioperative management

The same perioperative management procedure was conducted for all patients. They had their final dialysis the day before surgery, and during CPB, UF was performed, which was connected to the CPB circuit, after surgery, no UF was used on the day of surgery, but on the second postoperative day, hemodialysis was performed with unfractionated heparin as an anticoagulant agent. In addition, the patients' blood urea nitrogen (BUN), creatinine (Cre), serum K, and serum hemoglobin (Hgb) values were measured preoperatively, and these were compared to the postoperative values.

Hemodialysis and UF techniques

Preoperative hemodialysis was performed through the arteriovenous fistulas that were present. A triple-lumen Acute 12 Fr. ARROWgard Blue® catheter (Arrow International, Reading, PA, USA) was inserted into the jugular vein as the vascular access point for the postoperative hemodialysis.

The low flux dialyzer PolyPure® 13 (Allmed Medical GmbH, Pulsnitz, Germany), with a surface area of 1.3 m^2 and a maximum pressure of 500, was used for the intraoperative UF. The UF was initiated and terminated at the beginning and end of CPB and involved the filtration of the blood at a flow of 300 ml/min that was received from the PolyPure® 13 device which was connected to the arterial line of the oxygenator. The filtered blood was then returned to the venous reservoir, and the filtrate was removed from the system (Figure 1). The prime volume given to all study participants consisted of 1300 ml ringer lactate, 0.5 mg/kg mannitol, and 50 mg heparin. The UF time included the entire CBP period independent of the Hgb values and hemodynamic parameters.

The elapsed time of the postoperative intubation along with the amounts of hemorrhagic drainage and blood transfusion in both groups were compared. Additionally, the central venous pressure (CVP), systemic arterial pressure (SAP), use of inotropes, length of stay in the ICU and hospital, and 30-day hospital mortality and morbidity were also assessed.

All of the patients were transferred from the ICU to the cardiovascular surgery ward when clinical and hemodynamic stability was achieved. They were then discharged when they became mobile and were capable of doing daily activities.

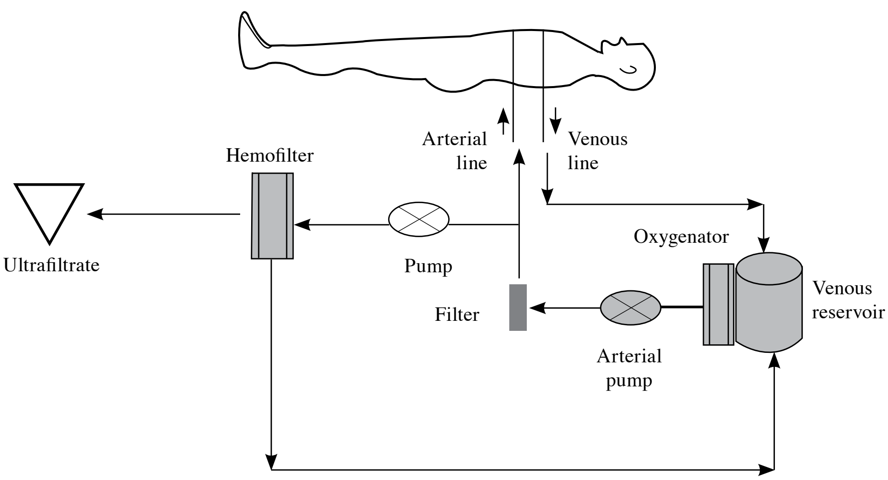

Figure 1. Ultrafiltration circuit during bypass.

Statistical analysis

Continuous data was expressed as mean value ± standard deviation, with category variables being expressed as a percentage. This data was then compared with repeated measures analysis of variance (ANOVA). Categorical data was analyzed using chi-square statistics. In addition, the Newman-Keuls test for multiple comparisons of sub-groups and an independent t-test for quantitative data were also utilized. The data was analyzed using the NCSS 2007 statistical software package (NCSS, LLC, Kaysville, Utah, USA). In all analyses, a *p* value of less than 0.05 was considered to be statistically significant.

RESULTS

The baseline clinical characteristics of the patients are summarized in Table 1. The differences between the groups regarding the mean age of the patients in the UF (+) group versus UF (–) group (57.6±7 vs. 58±1 years; p=0.91) and the male gender frequency in the same two groups [23 (88.5%) vs. 14 (70%); (p=0.11)] were statistically insignificant. Although there was not a marked difference in the left ventricular ejection fraction (LVEF) (43±12% vs. 46±10%, respectively; p=0.49), the patients in the UF (+) group had a higher New York Heart Association (NYHA) functional class (p=0.01). We also found no significant differences between the operative data and surgical procedures in the two groups (Table 1). In the UF (+) group, the mean volume of fluid that was removed during surgery was 3,392±1,295 ml (range, 1300-8000 ml). Furthermore, we discovered that the median perioperative total fluid balance was significantly different in the UF (+) and UF (–) groups [400 (–1400 and + 1300) ml vs. 1500 (1100-2200) ml, respectively; p<0.001)].

The mean values of the preoperative and postoperative BUN, Cre, K, and Hgb levels were also compared within the UF (+) and UF (–) groups (Table 2). Only the BUN (51.9±15.1 mg/dl vs. 59.8±13.7 mg/dl, respectively; p=0.001) and the Hgb (11±1.5 g/dl, 8.8±0.9 g/dl, respectively; p=0.0001) values were significantly different in the UF (–) group. In addition to changes in the BUN and Hgb, in the UF (+) group, the mean serum Cre levels decreased significantly after filtration (6.3±2.7 mg/dl) when compared with the UF (–) group (5.5±1.9 mg/dl), p=0.01).

In addition, the pre- and postoperative mean values of the BUN, Cre, Hgb, and K were compared between the two groups (Table 2), and a significant postoperative decrease in BUN (50.6±13.5 mg/dl vs. 59.8±13.7 mg/dl, respectively; p=0.02) and an increase in Hgb (9.9±1 g/dl vs. 8.8±0.9 g/dl, respectively; p=0.001) were observed.

There were no postoperative significant differences between the UF (+) and UF (–) groups in terms of duration of intubation, bleeding, blood transfusion, the use of positive inotropes, and complications. However, a significant difference in length of stay in the ICU (56±28 hours vs. 95±93 hours, respectively; p=0.04) and in- hospital length of stay (5.5±1.4 days vs. 8.1±3.4 days, respectively; p=0.002) was noted (Table 3). The postoperative mean values of the CVP at zero hour were found to be lower in the UF (+) group (6.3±2.9 mmH_2O) than in the UF (–) group (9.3±2.9 cm H_2O) (p=0.002) (Figure 2). However, there were no statistically significant differences between the groups at 6^{th}, 12^{th}, 24^{th}, and 48^{th} hours.

Table 1. Baseline characteristics of the study group

Variable	UF (–)				UF (+)				
	n	%	Mean±SD	Median (min.-max.)	n	%	Mean±SD	Median (min.-max.)	*p*
Gender			0.11						
Male	14	70			23	88.5			
Famale	6	30			3	11			
Age			58±11				57.6±7		0.91
NYHA classification			0.01						
Class I	10	50			2	7.7			
Class II	6	30			15	57.7			
Class III	3	15			8	30.8			
Class IV	1	5			1	3.8			
Left ventricular ejection fraction			46±10				43±12		0.49
Associated diseases									
Chronic obstructive lung disease	1	5			5	19.2			0.15
Hypertension	15	75			13	50			0.08
Diabetes mellitus	9	45			17	65.4			0.16
Hyperlipidemia	4	20			13	50			0.03
Peripheral vascular disease	1	5			5	19.2			0.15
Smoking	7	35			8	30.8			0.76
Myocardial infarction	7	35			16	64			0.05
Cerebrovascular disease	1	5			1	4			0.87
Surgery									
Elective	16	80			19	73.1			
Emergency	4	20			7	26.9			0.58
Procedure									
Coronary artery bypass grafting	16	80			23	88.5			0.42
CABG + LVA	1	5			1	3.8			0.84
CABG + MVP	3	15			2	7.6			0.40
Grafts in CABG			3.5±1.3				3.8±1.4		0.41
Cardiopulmonary bypass time (min)			94.4±44.7				96.8±36.3		0.85
Aortic cross-clamp time (min)			54.8±25.3				62.3±20.2		0.32
Total amount of fluid removal during intraoperative UF (ml)			–				3392±1295		
Amount of fluid balance during UF (ml)			–				1115±568		
Perioperative total fluid balance (ml)				1500 (1100-2200)				400 (-1400-1300)	<0.001

UF: Ultrafiltration; SD: Standard deviation; Min.: Minimum; Max.: Maximum; NYHA: New York Heart Association; CABG: Coronary artery bypass grafting; LVA: Left ventricular aneurysmectomy; MVP: Mitral valvuloplasty.

DISCUSSION

More aggressive approaches are now being applied to patients who are dependent on dialysis and need open heart surgery versus those with normal functioning kidneys.[6] Novel operative techniques and preoperative management are necessary for favorable surgical and

Table 2. Changes in blood urea nitrogen, creatinine, potassium, and hemoglobin

Variable	UF (–)		UF (+)		
	Mean±SD	*p*	Mean±SD	*p*	*p*
Preoperative blood urea nitrogen (mg/dl)	51.9±15.1	0.001	59.5±21	0.02	0.17
Postoperative blood urea nitrogen (mg/dl)	59.8±13.7		50.6±13.5		0.02
Preoperative creatinine (mg/dl)	5.9±3.3	0.88	6.3±2.7	0.01	0.64
Postoperative creatinine (mg/dl)	5.9±2.7		5.5±1.9		0.58
Preoperative potassium (mEq/dl)	4.8±0.7	0.34	4.7±1.1	0.15	0.95
Postoperative potassium (mEq/dl)	4.6±0.9		4.4±0.5		0.50
Preoperative hemoglobin (g/dl)	11±1.5	0.0001	11.7±1.6	0.0001	0.13
Postoperative hemoglobin (g/dl)	8.8±0.9		9.9±1		0.001

UF: Ultrafiltration; SD: Standard deviation.

Table 3. Postoperative variables

Variable	UF (–)			UF (+)			
	n	%	Mean±SD	n	%	Mean±SD	*p*
Duration of intubation (hours)			12.7±7			14±5	0.52
Drain output (ml), in the first 24 hours			675±350			611±400	0.57
Transfusions (units) in the first 24 hours							
Red cells			2.6±1.3			1.8±1.2	0.07
Fresh frozen plasma			2.2±1.2			2.4±1.5	0.67
Platelet	7			4			0,12
Number of inotropes used	13			13			0.54
Number of hours inotropes used			28.5±20			18.8±14.8	0.16
Postoperative complications							
Postoperative bleeding	4	20		3	11.5		0.42
Reoperation for hemorrhage	3	15		1	3.8		0.30
Wound infection	1	5		–	–		
Atrial fibrillation	1	5		1	3.8		
Congestive heart failure	–	–		1	3.8		
Cerebrovascular accident	1	5		–	–		
Intensive care unit stay (hours)			95±93			56±28	0.04
Postoperative hospital stay (days)			8.1±3.4			5.5±1.4	0.002
In hospital mortality	1	5		1	3.8		0.84

UF: Ultrafiltration; SD: Standard deviation.

long-term outcomes.[7,8] In order to obtain positive surgical results, special attention should be given to problems such as fluid and electrolyte imbalance, improper hemodynamics, and bleeding at each period of the operation. Several reports have described various strategies, including intraoperative UF and hemodialysis, for perioperative management.[8,9] However, there are only a few studies that have documented the effects of routine intraoperative UF in conjunction with pre- and postoperative hemodialysis in dialysis-dependent patients who underwent open heart surgery.[10,11] The amount of alteration that occurs in the serum electrolytes with hemofiltration depends on the volume of the ultrafiltrate and the composition and amount of fluid replacement. Hence, UF with hemofiltration during CPB may theoretically be more efficient in the management of intraoperative fluid overload, hyperkalemia, and uremia than hemofiltration alone.[3]

A one-year survival rate of between 83 and 95% has been reported for dialysis patients undergoing CABG alone.[12,13] However, when CABG was combined with valve replacement, the ratio declined to 70%,[14] and five-year survival rates have been chronicled as low as 20%.[6] Furthermore, the reported hospital mortality rates have ranged between 0 and 20%.[13,15] Durmaz et al.[16] showed that prophylactic dialysis might decrease postoperative morbidity and mortality, and they reported a 12.5% hospital mortality rate along with a 75% complication rate. Mortality can be attributed to infection as well as cardiac, adverse gastrointestinal, and cerebral events.[10] In fact, the mortality rate could be reduced to as low as 9.8% by hemofiltration during CPB and postoperative continuous venovenous hemodiafiltration in unstable patients.[10] However, the hospital stay duration could be prolonged with this procedure due to the length of the CPB, concomitant procedures, and emergency operations.[10] Overall 15% of the patients in our study suffered from bleeding, 8% need a reoperation because of hemorrhage, 2% had wound infections, 4% needed atrial fibrillation, 2% experienced cardiac events, and 2% had cerebral events. Moreover, there was 4% mortality as one

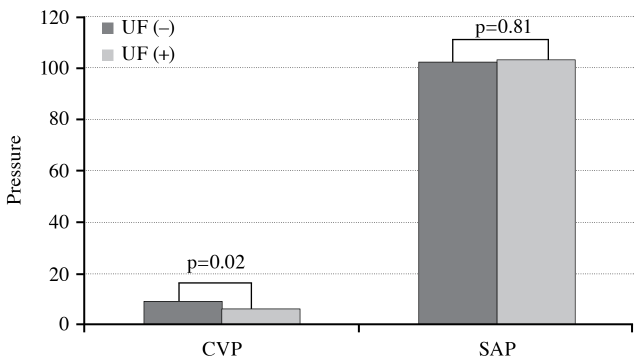

Figure 2. Comparison of postoperative levels of central venous pressures (CVP, cmH_2O) and systolic arterial pressures (SAP, mmHg).

patient died of cardiac failure and one from ischemic stroke. In contrast to previous reports, we compared two groups based on using UF during surgery and found shorter ICU and hospital stays in the UF (+) group.

Dialysis-dependent patients have a tendency to stay longer in the hospital after cardiac surgery[11] because intravascular volume overload, anemia, and hyperkalemia may complicate the perioperative management of this type of surgery in these patients. Furthermore, CPB leads to additional volume overload and anemia as a result of hemodilution. To avoid these obstacles, several reports have suggested the use of intraoperative hemofiltration during CPB.[2,17,18] Unfortunately, none of the aforementioned studies investigated hospital stay duration. Our results possibly indicate that dialysis-dependent patients may require shorter hospitalization stays, including their time in the ICU, and this could be attributed to, CVA, wound infection, duration of inotrope usage, and postoperative bleeding. Reoperation for hemorrhage might also play a role, but not a statistically significant one.

The CVP, an important parameter for hemodialysis-dependent patients, was lower after the surgery in patients who received UF. These patients had no postoperative volume overload, and their hemodynamics were better. However, further studies with a larger cohort are needed to determine how much these parameters contribute to shorter hospital stays.

In this study, we evaluated the efficacy of UF for dialysis-dependent patients who underwent open heart surgery in which preoperative hemodialysis, intraoperative UF, and postoperative hemodialysis were employed. We observed steady results in fluid balance, BUN, Cre, and serum K along with minimal ICU and hospital stays. These results, especially those concerning better hemodynamics and shorter hospital stays, may add to the growing body of evidence which indicates that intraoperative heart failure, at least in the early stages, can improve the outcome in patients with dialysis-dependent end stage renal disease who undergo cardiac surgery.

Certain limitations in our study must be addressed in the future. For example, it was conducted on a retrospective basis with a low number of patients. Additionally, systemic inflammatory reaction, which affects the postoperative results of open heart surgery, was not evaluated. Therefore, more studies are needed to verify our results.

In conclusion, adding perioperative UF to pre- and postoperative hemodialysis could serve to facilitate perioperative management, in particular the maintenance of fluid balance and electrolyte homeostasis. Furthermore, combining introperative UF with hemodialysis can be a therapeutic option for perioperative management in dialysis-dependent patients receiving open heart surgery since it prevents excessive increases in the levels of serum K and biochemical solute metabolites (BUN and Cre). These generally increase during CPB and allow for less of a decrease in Hgb concentration, thus possibly contributing to better postoperative hemodynamics. Patients also appear to undergo shorter ICU and hospital stays with this procedure.

Declaration of conflicting interests

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