

## Our ultrafiltration experience in open heart surgery patients with chronic renal failure

Ultrafiltration in open heart surgery with chronic renal failure

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### Abstract

**Aim:** Open-heart surgery is common in patients with chronic renal failure due to coronary artery and valve diseases. Ultrafiltration can be performed intraoperatively to reduce excess volume and level of inflammatory cytokines. In this study, we aimed to investigate the results of our ultrafiltration applications in patients over 18 years of age, who were diagnosed with chronic renal failure and underwent open-heart surgery and compare the results with the literature.

**Materials and Methods:** Sixty-two chronic renal failure patients over 18 years of age who underwent ultrafiltration during open-heart surgery in Bursa Yüksek İhtisas Hospital between April 2015 and September 2018 were evaluated. Demographic data, comorbidities, cardiopulmonary bypass, aortic cross-clamp and operation times, laboratory values, extubation times, intensive care unit and hospital stay and developing complications were investigated retrospectively.

**Results:** It was determined that 24 of the patients who underwent ultrafiltration during cardiopulmonary bypass were female and 38 were male. Thirty-five patients underwent open-heart surgery due to coronary artery disease and 27 patients due to valve pathologies. The mean age of our patients was  $53.17 \pm 16.1$  years. The most common comorbidities were hypertension (56.45%) and diabetes mellitus (37.1%). Arterial blood gas findings after ultrafiltration revealed a significant increase in hemoglobin and hematocrit values compared to that before ultrafiltration ( $p < 0.05$ ). Postoperative complications included 3 (4.83%) pneumonia, 4 (6.45%) bleeding revisions, 4 (6.45%) arrhythmias, and 3 (4.83%) neurological complications. The number of cases resulting in mortality was 5 (8.1%).

**Discussion:** Ultrafiltration is routinely performed in open-heart surgery in patients diagnosed with advanced stage chronic kidney failure. It has positive effects on reducing mortality and morbidity. Our results are compatible with the values in the literature.

### Keywords

Ultrafiltration; Kidney failure; Heart surgery

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## Introduction

One of the important comorbid factors in heart disease is chronic renal failure (CRF). The technological advances and increase in hemodialysis centers have prolonged life expectancy in these patients. It is stated in the literature that the frequency of coronary artery disease is approximately 15 times higher in patients with chronic renal failure compared to the normal population [1]. Also, the patients who have renal function deterioration, after cardiac surgery had stated increased in-hospital morbidity and mortality [2]. Coronary artery disease, as well as valvular calcification, conduction disorders, and infective endocarditis are among the reasons for the referral of CRF patients to cardiovascular surgery clinics. All these causes increase the incidence of open-heart surgery in CRF patients [3].

Cardiopulmonary bypass (CPB) is used to temporarily support the heart and respiratory functions in the surgical treatment of acquired heart diseases. In open-heart surgery accompanied by CPB, inflammatory mediators are secreted into circulation due to the contact of blood with a non-epithelial foreign surface. These mediators and the increase in the total amount of fluid are undesirable effects of CPB. This excess fluid leaks from the intravascular area through the tissues and prevents the organ and tissues from performing their normal functions. The volume load increased by open-heart surgery causes mortality and morbidity in patients with CRF to increase even more than the normal population [4]. Ultrafiltration is performed to decrease the excessive volume load during cardiopulmonary bypass.

It was used by Magilligan et al. for the first time for intraoperative dialysis purposes in the 1970s on renal failure patients who were unresponsive to diuretics and had to undergo open-heart surgery [5]. In the following years, ultrafiltration has been shown to help remove not only excess fluid in the body, but also circulating inflammatory cytokines [6]. Ultrafiltration technique was changed in 1991 by Naik, Knight and Elliot by changing the filtration time, not during CPB, but in the 10-15-minute period at the end of bypass, in contrast to the traditional technique. It was named the "Modified Ultrafiltration technique" [6]. Today, both techniques are used in centers where open-heart surgery is performed.

In our study, we investigated patients diagnosed with chronic renal failure who underwent open-heart surgery with cardiopulmonary bypass during which we performed ultrafiltration. We aimed to contribute to the literature by sharing our results.

## Material and Methods

### Study Design and Patient Selection

This study was conducted retrospectively in accordance with the guidelines of the Helsinki Declaration after obtaining the Ethics Committee approval. Among 126 CRF patients who underwent open-heart surgery between April 2015 and September 2018, sixty-two patients over the age of 18 years on whom intraoperative ultrafiltration was performed were included in this study. Exclusion criteria were being under 18 years of age, CRF patients who did not receive ultrafiltration and emergency operations.

The demographic data, comorbidities, CPB, aortic cross-clamp

and operation times, laboratory values, extubation times, intensive care unit and hospital stay, and complications were investigated retrospectively from patient files and hospital registry.

### Routine bypass surgery procedure in our clinic

In our clinic, preoperative preparations of the patients were completed, and patients' consents were obtained prior to the operation. Hemodialysis was performed 1 day before surgery in patients with advanced-stage CRF.

In the operation room, patients were monitored with electrocardiography in D2 and V5 leads, SpO<sub>2</sub> was monitored by pulse oximeter and systemic arterial pressure, by non-dominant radial artery cannulation. They were intubated following anesthesia induction with 3 mg/kg propofol (propofol Fresenius vial, Germany), 5 mcg/kg fentanyl (Talinat, Vem Pharmaceuticals, Turkey), and 0.5 mg/kg atracurium (Dematrac, Actavis Pharmaceuticals, Iceland). Anesthesia device (Dräger Primus, Germany) ventilation settings were adjusted as follows: Fresh gas inlet: 2 lt / min, tidal volume: 8-10 ml / kg, FiO<sub>2</sub>: 0.5, frequency: 10-12 / min, PEEP: 5. Central catheters were placed in the internal jugular vein with the Seldinger technique, and central venous pressure (CVP), as well as urine output, were monitored. Temperature monitoring was achieved with a heat probe. For the maintenance of anesthesia, 0.5 mg/kg/h atracurium, sevoflurane (Sevorane, Abbott, Turkey) inhalation (minimal alveolar concentration between 0.5 and 2) and fentanyl in analgesic doses were administered according to hemodynamic status. Before entering cardiopulmonary bypass, anticoagulation was achieved with 300 Units/kg dose of unfractionated heparin (koparin vial, Koçak Pharma, Turkey). Activated clotting time (ACT) was measured for anticoagulation assessment, along with simultaneous arterial blood gas evaluation. When ACT reaches over 450 seconds, cardiopulmonary bypass was started. Mean arterial pressures were kept at 50-70 mmHg during the cardiopulmonary bypass period, during which ultrafiltration was performed.

After cardiopulmonary bypass was terminated, heparin neutralization was applied with Protamine at a dose of 3.5 mg/kg (Promin, Vem Pharmaceuticals, Turkey). Simultaneous arterial blood gases were also examined during ACT control after protamine. At the end of the operation, patients were monitored and transferred to the intensive care unit, and were intubated. Patients who were monitored in the intensive care unit were extubated by gradually decreasing FiO<sub>2</sub> under appropriate weaning conditions with blood gas monitoring.

### Statistical methods

SPSS 21.0 (Statistic Inc. version Chicago, IL, U.S.A.) software program was used for statistical analysis of the data. Descriptive statistics were shown as mean ± standard deviation for continuous variables, and number of patients (%) for nominal variables. The results were considered statistically significant when  $p < 0.05$  at a 95% confidence interval.

## Results

Using patient files and the hospital registry, it was determined that 116 patients who underwent open-heart surgery were diagnosed with CRF, among which 62 patients who were also on hemodialysis program underwent ultrafiltration during

cardiopulmonary bypass. There were 24 females and 38 males. A total of 35 patients had coronary artery disease and 27 had valvular disease (Table 1). The demographic data and preoperative features of our patients are summarized in Table 1.

Patients' preoperative values following hemodialysis are presented in Table 2.

**Table 1.** Demographic data and preoperative characteristics of patients

	n	%
Female	24	38,7
Male	38	61,3
Coronary Artery Disease	35	56,4
Valvular Disease	27	43,6
ASA 3	26	41,9
ASA 4	36	58,1
Hypertension	35	56,45
Diabetes Mellitus	23	37,1
COPD	14	22,58
CVD	7	11,29
PAD	16	25,8
Age (Years) mean± SD	53,17± 16,1	
Body Mass Index mean± SD	27,94±5,27	
Ejection Fraction mean± SD	50,51±11,71	

n: Number of patients, ASA: American Society of Anesthesiologists, SD: Standard Deviation, COPD: Chronic Obstructive Pulmonary Disease, CVD: Cerebrovascular Disease, PAD: Peripheral Arterial Disease

**Table 2.** Preoperative Laboratory Values of Patients

	Mean	Standard Deviation
Potassium (mmol/ L)	4,36	0,29
Calcium (mg/dl)	8,09	0,52
BUN (mg/dl)	48,93	8,69
Creatinine (mg/dl)	2,43	0,41
Hemoglobin (gr/dl)	9,34	0,60
Hematocrit (%)	30,24	1,91
Thrombocyte (x103/mL)	207,05	12,15
Prothrombin Time (sec)	14,1	1,22
INR	1,32	0,1

BUN: Blood Urea Nitrogen, INR: International Normalized Ratio

The mean operation, CPB, and aortic cross-clamp times were 207,097 ± 12,82 minutes, 97,403±8,58 minutes and 76,31±9,16 minutes, respectively. Evaluation of intraoperative hemodynamic findings revealed that mean pulse before induction, after induction and after CPB were 79,65 ± 12,78 beats/min, 61,16 ± 9,29 beats/min and 98,85 ± 13,63 beats/min, respectively (Table 3), which were significantly different according to variance analysis (p<0.05). Mean arterial pressures before induction, after induction, and after CPB were 96,31 ± 13,41 mmHg, 77,71 ± 11,92 mmHg, and 65,91 ± 10,95 mmHg, respectively (Table 3).

**Table 3.** Intraoperative hemodynamic findings

	Mean	Standard Deviation
Pulse before induction (beats/minute)	79,65	12,74
Pulse after induction (beats/minute)	61,16	9,29
Pulse after CPB (beats/minute)	98,85	13,63
p	<0,05	
MAP before induction (mmHg)	96,31	13,41
MAP after induction (mmHg)	77,71	11,92
MAP after CPB (mmHg)	65,91	10,95
p	<0,05	

p<0,05: Significant, MAP: Mean Arterial Pressure

Variance analysis of repetitive measurements to determine the difference between mean arterial pressure times revealed that they were significantly different (p<0.05).

The patients were compared before and after ultrafiltration according to the values in arterial blood gas. A significant increase in hemoglobin and hematocrit values was detected in the comparison of the findings in arterial blood gas before and after ultrafiltration (hemoglobin values: 6,68±0,46 gr/dl vs. 8,59±0,35 gr/dl, p <0.05 and hematocrit values: 19,57±2,51 % vs. 25,74 ± 0,99 %, p <0.05, respectively). A significant decrease in potassium values was detected in the comparison of the findings in arterial blood gas before and after ultrafiltration (potassium values: 5,39±0,32 mmol/L vs. 4,47±0,24 mmol/L, p <0.05, respectively). There were also an insignificant decrease in lactate values and partial arterial pressure carbondioxide values (lactate values: 2,25±1,35 mmol/L vs. 2,16±1,12 mmol/L, p> 0.05 and partial arterial pressure carbondioxide values: 42,92±3,71 mmHg vs. 41,87±3,07 mmHg, p> 0.05, respectively). There was an insignificant increase in partial arterial pressure oxygen values (partial arterial pressure oxygen values: 165,87±12,41 mmHg vs. 166,90±12,51 mmHg, p>0.05, respectively).

Intraoperatively, 11 (17.74%) patients received inotropic support, and 2 (3.22%) patients received intra-aortic balloon support. EF (Ejection Fraction) values of these patients were 40% and below. Mean blood products transfused during the intraoperative period included 2,48 ± 1,21 units, 3,45 ± 1,57 units, and 1,29 ± 0,61 of erythrocyte suspension, fresh frozen plasma, and pooled platelet suspension, respectively.

During the postoperative period, the extubation time of the patients was 8.58 ± 2.25 hours, intensive care unit stay was 54.84 ± 12.11 hours, and hospital stay was 7.89 ± 1.04 days. Postoperative complications included 3 (4.83%) pneumonias, 4 (6.45%) bleeding revisions, 4(6.45%) arrhythmias, and 3 (4.83%) neurological complications. The number of cases resulting in mortality was 5 (8.1%).

## Discussion

CRF is one of the important risk factors for cardiac surgery. Associated risk factors and electrolyte imbalances caused by CRF render these patients exceptional for open-heart surgery. Results of studies on patients with CRF who have undergone open-heart surgery have been reported in the literature [7-9]. Between 1992 and 1997, Dacey LJ et al. examined 15574

coronary bypass surgery patients, 1.8% constituted by dialysis patients, among which the mortality outcome was 12.1% [9]. In another study, it was suggested that coronary bypass surgeries to be performed in chronic dialysis patients should be performed in the beating heart [10].

Gibbs et al. evaluated 57 adult patients with serum creatinine levels of 2 mg/ dl who did not receive dialysis and who underwent open-heart surgery. They concluded that in patients with moderate chronic renal failure, major cardiac procedures are safe and postoperative renal functions remain stable following the surgery [8]. Today, although the risk of mortality and morbidity is higher in operations to be performed in patients with chronic renal failure, it is possible to obtain better results with the surgical risk reduction strategies [11,12]. This also applies to open-heart surgery.

Other comorbidities that may be associated with chronic renal failure determine the intraoperative and postoperative risks and management strategies in open-heart surgery, as in all surgeries. Victor Hugo et al. found that the prevalence of hypertension, diabetes mellitus, and cardiovascular diseases were higher in chronic renal disease [12]. Based on the results they obtained, the prevalence of diabetes mellitus and hypertension according to stages in renal failure patients were as follows: Stage 1: DM: 19.8%, HT: 35.7%; stage 2: DM: 2.8%, HT: 52.2; stage 3: DM: 19.1%, HT: 64.1%; Stages 4 and 5: DM: 36.9%, HT: 82.2% [12]. In our cases, the frequency of hypertension and diabetes mellitus was 56.45% and 37.1%, respectively (Table 1). Considering that our patients are at an advanced stage, our DM rates are compatible with advanced stage CRF patients in Victor Hugo et al.'s study and HT rates are lower.

Conditions that should be considered during the preoperative preparation of CRF patients that may require certain precautions include hyperpotassemia, risk of coagulopathy and anemia [11]. The incidence of preoperative hyperkalemia in end-stage CRF patients is 19-38% [11]. One of the treatments of hyperpotassemia is preoperative dialysis. Uremia may increase the risk of hemorrhage by causing platelet dysfunction in end-stage CRF patients. When using antiplatelet agents in patients with cardiac disease, bleeding time parameters should be carefully monitored. In addition, in patients with renal failure, intense dialysis, and keeping the hematocrit levels above 30% are recommended for prolonged bleeding time. Low hematocrit levels are also associated with increased intraoperative complications [11]. In our patient series, patients were evaluated with anamnesis, physical examination, and laboratory results. Dialysis was performed within 24 hours before the operation to reduce the risks of excess volume, hyperkalemia, and bleeding. Hemodialysis that we performed in our patients led us to preoperative values that reduced the operation risk (Table 2).

It is recommended that premedication is kept to a minimum in patients with CRF. As a short-acting anxiolytic, midazolam can be administered at low doses [13]. It is mentioned in the literature that atracurium should be used for neuromuscular blockade in patients with CRF [13]. Ketamine, which is an intravenous anesthetic agent, can be used safely in chronic renal failure and propofol is also one of the recommended agents [13]. In these

patients, we use low-dose midazolam as premedication, and atracurium for neuromuscular blockade in anesthesia induction, along with propofol and ketamine as intravenous anesthetic agents. Despite the statistically significant decrease in mean arterial pressure and pulse after anesthesia induction, these values did not cause any hemodynamic problems in our patients (Table 3).

In the intraoperative period, it is suggested that central venous pressure monitoring in terms of fluid levels and potassium levels in terms of cardiac dysrhythmia should be monitored. Along with urine output monitoring, intraoperative dialysis is a recommended treatment for patients with CRF [13]. Ken Miyahara et al. investigated the effects of intraoperative hemodialysis in chronic dialysis patients and demonstrated that intraoperative hemodialysis is beneficial in decreasing morbidity and mortality by keeping hemodynamics and potassium levels stable in patients who will be administered blood products and fluid during long operations [14]. Excess fluid in circulation that may cause hemodilution during the CPB process will likely cause organ dysoxia and decreased perfusion due to low peripheral oxygen delivery, which will increase the lactate level. In a study by Raper et al., lactic acidosis has been reported following prolonged bypass [15]. Ranucci et al. also stated that hyperlactatemia is more likely after long CPB operations [16]. Hemoconcentration provided by ultrafiltration will increase oxygen delivery to tissues and have a positive effect on decreasing lactic acidosis [6]. The study by Naik and Elliott has shown that ultrafiltration reduces blood loss and blood product use [6].

In our patient series, potassium levels significantly decreased, hematocrit levels significantly increased and lactate levels non-significantly decreased following ultrafiltration. The non-significant change in lactate levels as opposed to the significant change in hematocrit is most likely due to the fact that cardiopulmonary bypass duration, which is the most hemodiluted period in the operation, was not very long. In addition, we think that ultrafiltration provides an effective solution for hyperpotassemia and anemia in CRF patients.

After cardiopulmonary bypass, fluid extravasates to the interstitial space as a result of increased vascular permeability due to systemic inflammatory response. Extravasation increases with prolonged bypass time. Accordingly, edema develops in the heart and the contractility of myofibrils decreases. A high level of inotropes may be required to ensure the adequacy of the cardiac output, which increases cardiac-related mortality and morbidity and worsens operation outcomes [17]. In the literature, it is reported that the heart size decreases, systolic blood pressure increases without an increase in systemic vascular resistance and the need for inotropic support decreases following ultrafiltration [5, 18].

In our study, the rate of inotropic agent use after cardiopulmonary bypass was 17.74%, and the fact that the EF (Ejection Fraction) values of these patients were 40% and below suggested that the presence of heart failure was effective in the use of inotropic agents. We think that ultrafiltration contributes to the contraction of myofibrils in our patient series, as stated in the literature, and reduces the need for inotropy.

Another organ affected by tissue edema is the lungs. In his study,

Bando et al. found that partial oxygen pressure values increased and partial carbon dioxide pressures decreased in patients who underwent ultrafiltration in the early postoperative period. They also stated that with effective gas exchange, the duration of the patient's ventilator dependence decreased [19]. Prolonged mechanical ventilation periods increase intensive care stay and cause an increase in mortality and morbidity [5]. In their study on chronic dialysis patients who underwent open-heart surgery, Ken Miyahara et al. investigated the effects of intraoperative hemodialysis in 2004 and found that the mean postoperative mechanical ventilation duration and intensive care unit stays were  $21 \pm 12$  hours and  $5.3 \pm 2.2$  days, respectively [14]. Ali Vefa et al. shared the results of intraoperative ultrafiltration performed on chronic renal failure patients during open-heart surgery in 2008 and stated that median extubation period, intensive care unit stay and hospitalization durations were 12 (8.0;18.0) hours, 4 (2.0; 5.0) days, and 12.0 (10.0; 18.0) days, respectively [3].

In our study, the extubation time of our patients was determined as  $8.58 \pm 2.25$  hours, intensive care unit stay as  $54.84 \pm 12.11$  hours, and duration of hospitalization as  $7.89 \pm 1.04$  days. These durations are shorter than those specified in the literature. We believe that technological advancement and increasing experience are effective in this result.

Eight hundred thirty-four patients who underwent heart valve operation were evaluated by Anderson et al. and among those with high serum creatinine levels, postoperative bleeding, respiratory complication, and cardiac complication rates were 16%, 29%, and 18%, respectively [20]. These rates were higher than the patients with normal kidney functions. In our study, the rates of postoperative bleeding were 6.45%, respiratory complications, 4.83%, and arrhythmia, 6.45%, which were lower than that reported by Anderson et al.

In most studies on chronic renal failure patients who underwent open-heart surgery, the mortality rate was reportedly high. Mortality rates vary between 3 and 25% but are reported as 9% on average [3, 21-23]. Our mortality rate is 8.1%, which is compatible with the literature.

This study, in which we present our experience in our clinic, has various limitations, including the scarce number of patients and its retrospective nature. We believe that prospective studies with more cases are required in this regard.

### Conclusion

The presence of CRF increases morbidity and mortality in open-heart surgery operations. Intraoperative ultrafiltration affects the results positively. In our cases, mortality, and morbidity rates, extubation time, intensive care and hospital stay are at standard rates. We believe that in these patients, the preoperative preparation is as important as intraoperative ultrafiltration.

### Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

### Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical

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### Conflict of interest

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### References

- Foley RN, Parfrey PS, Sarnak MJ. Cardiovascular disease in chronic renal disease. *Clinical epidemiology of cardiovascular disease in chronic renal disease. Am J Kidney Dis.* 1998; 32: 112-19.
- Mangano CM, Diamondstone LS, Ramsay JG, Aggerwal A, Herskowitz A, Mangona DT. Renal dysfunction after myocardial revascularization: Risk factors, adverse outcomes, and hospital resource utilization. *Ann Intern Med.* 1998; 128: 194-203.
- Özcan AV, Gökşin İ, Ocak E, Pazarcıkçı S, Adalı F. Açık Kalp Cerrahisi Sırasında Kronik Böbrek Yetmezlikli Hastalara Ultrafiltrasyon Uygulanması (Ultrafiltration Application to Patients with Chronic Renal Failure During Open Heart Surgery). *Firat Tıp Dergisi/ Frat Medical Journal.* 2008; 13(3):176-8.
- Boodhwani M, Hamilton A, Varennes B, Mesana T, Wells GA, Nathan H, et al. A multicenter randomized controlled trial to assess the feasibility of testing modified ultrafiltration as a blood conservation technology in cardiac surgery. *J Thorac Cardiovasc Surg.* 2010; 139(3): 701-6.
- Magilligan DJ, Oyama C. Ultrafiltration during cardiopulmonary bypass: Laboratory evaluation and initial clinical experience. *Ann Thorac Surg.* 1984; 27:33-9.
- Naik SK, Elliott MJ. Ultrafiltration and pediatric cardiopulmonary bypass. *Perfusion.* 1993; 8:101-12.
- Owen CH, Cummings RG, Sell TL, Schwab SJ, Jones RH, Glower DD. Coronary artery bypass grafting in patients with dialysis-dependent renal failure. *Ann Thorac Surg.* 1994; 58: 1729-33.
- Gibbs ER, Christian KG, Drinkwater DC, Pierson RN, Bender HW, Merrill WH. *Cardiac Surgery in Patients with Moderate Renal Impairment.* South Med J. 2002; 95, (3): 321-3.
- Dacey LJ, Liu JY, Braxton JH, Weintraub RM, DeSimone J, Charlesworth DC, et al. Long-term survival of dialysis patients after coronary bypass grafting. *Ann Thorac Surg.* 2002; 74:458-63.
- Ariyoshi T, Eishi K, Yamachika S, Hazama S, Takai H, Odate T, et al. Perioperative and midterm results of coronary bypass surgery in patients undergoing chronic dialysis. *Ann Thorac Cardiovasc Surg.* 2006; 12(4): 257-64.
- Krishnan M. Preoperative care of patients with kidney disease. *Am Fam Physician.* 2002; 66(8): 1471-6.
- Cárdenas VH, Vargas JG, Echeverri JE, Díaz SM, Méndez YM. Pre-anesthesia evaluation in patients with chronic renal disease (emphasis on cardiovascular risk). *Revista Colombiana de Anestesiología.* 2013; 41(2):139-45.
- Sefer S, Juranko V, Kes P, Degoricija V. Perioperative management of patients with chronic renal failure. *Acta Clin Croat.* 2004; 43: 397-415.
- Miyahara K, Maeda M, Sakurai H, Nakayama H, Murayama H, Hasegawa H. Cardiovascular surgery in patients on chronic dialysis: effect of intraoperative hemodialysis. *Interact Cardiovasc Thorac Surg.* 2004; 3:148-52.
- Raper RF, Cameron G, Walker D, Bowey CJ. Type B lactic acidosis following cardiopulmonary bypass. *Crit Care Med.* 1997; 25(1):46-51.
- Ranucci M, De Toffol B, Isgro G, Romitti F, Conti D, Vicentini M. Hyperlactatemia during cardiopulmonary bypass: Determinants and impact on postoperative outcome. *Crit Care.* 2006; 10(6):R167.
- Paç M, Akçevin A, Aka SA, Büket S, Sarıoğlu T. Kalp ve Damar Cerrahisi (Cardiovascular surgery). 1st ed. Ankara: Özyurt matbaacılık; 2004. p.1265- 75.
- Davies MJ, Nguyen K, Gaynor JW, Elliott MJ. Modified ultrafiltration improves left ventricular systolic function in infants after cardiopulmonary bypass. *J Thorac Cardiovasc Surg.* 1998; 115:36-39.
- Bando K, Turrentine MW, Vijay P, Sharp TG, Sekine Y, Lalone BJ, et al. Effect of modified ultrafiltration in high-risk patients undergoing operations for congenital heart disease. *Ann Thorac Surg.* 1998; 66:821-7.
- Anderson RJ, O'Brien M, MaWhinney S, VillaNueva CB, Moritz TE, Sethi GK, et al. Mild renal failure is associated with adverse outcome after cardiac valve surgery. *Am Journal Kidney Dis.* 2000; 35 (6): 1127-34.
- Kaul TK, Fields BL, Reddy MA, Kahn DR. Cardiac operations in patients with end-stage renal disease. *Ann Thorac Surg.* 1994; 57: 691-6.
- Luciani GB, Menon T, Vecchi B, Auriemma S, Mazzucco A. Modified ultrafiltration reduces morbidity after adult cardiac operations: a prospective, randomized clinical trial. *Circulation.* 2001; 104: 1253-9.
- Kamohara K, Yoshikai M, Yunoki J, Fumoto H, Murayama J, Hamada M, et al. Safety of perioperative hemodialysis and continuous hemodiafiltration for dialysis patients with cardiac surgery. *Gen Thorac Cardiovasc Surg.* 2007; 55: 43- 9.

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