

Is off-pump coronary bypass a good choice in patients with chronic renal failure?

Off-pump koroner bypass kronik renal yetmezliği olan hastalar için iyi bir seçenek midir?

Vedat Erentuğ, Hasan Basri Erdoğan, Nihan Kayalar, Adil Polat, Başar Sareyyüboğlu,
Kaan Kırallı, Esat Akıncı, Cevat Yakut

Department of Cardiovascular Surgery, Kartal Koşuyolu Heart and Research Hospital, İstanbul

Background: Patients with chronic renal disease who underwent coronary artery bypass grafting were studied and perioperative and postoperative results were analyzed.

Methods: Thirty one patients (23 males, 8 females; mean age 62.45 ± 9.34 years; range 41-75) with known chronic renal disease were operated for coronary artery disease in our clinics. Eleven patients were dialysis-dependent preoperatively. Mean preoperative creatinine value was 5.88 ± 2.84 mg/dl in dialysis-dependent patients and 2.4 ± 1.4 mg/dl in non-dialysis dependent patients. We performed on-pump coronary artery bypass surgery in 18 patients whereas 13 patients underwent coronary artery bypass grafting with off-pump technique. Mean number of grafts was 2.8 ± 0.9 in patients operated on with cardiopulmonary bypass and 1.6 ± 0.7 in patients operated on with off-pump technique. Complete revascularisation was accomplished in 77.7% of the former group whereas in 76.9% in the latter group. We analyzed both groups in regards to postoperative complications, mortality/morbidity and duration of intensive care unit and hospital stay.

Results: Early mortality rate was 9.6% (3 patients). Myocardial infarction developed in 2 patients during perioperative period and intraaortic balloon pump counterpulsation was performed. Postoperative complications such as sternal dehiscence, infection and neurological complications during early postoperative period were observed more frequently in patients undergoing cardiopulmonary bypass ($p=0.02$). There was no significant difference between the two groups with respect to mortality, arrhythmia, perioperative myocardial infarction and drainage amount. Mean duration of intubation, hospital stay and intensive care unit stay were shorter in the off-pump group, although not statistically significant.

Conclusion: Patients with dialysis-dependent chronic renal failure who present with coronary artery disease should be thoroughly evaluated preoperatively for risk factors and coexistent severe diseases. We believe that in patients with chronic renal failure, off-pump coronary revascularization is a good alternative.

Key words: Cardiac surgical procedures/adverse effects; intraoperative complications; kidney failure, chronic/complications; postoperative complications.

Amaç: Bu çalışmada, kronik renal yetmezliği olan hastalarda uygulanan koroner bypass cerrahisinin ameliyat anındaki ve ameliyat sonrasında sonuçları incelendi.

Çalışma planı: Bilinen kronik böbrek yetmezliği olan 31 hasta (23 erkek, 8 kadın; ort. yaş 62.45 ± 9.34 ; dağılım 41-75), koroner arter hastalığı nedeniyle ameliyat edildi. On bir hasta ameliyat öncesi dönemde diyalize bağımlıydı. Ameliyat öncesi ortalama kreatinin değerleri, diyalize bağımlı olan ve olmayan hastalarda sırasıyla 5.88 ± 2.84 mg/dl ve 2.4 ± 1.4 mg/dl idi. On sekiz hastaya on-pump koroner arter bypass cerrahisi, 13 hastaya off-pump tekniğe koroner arter bypass greft uygulandı. On-pump ve off-pump bypass yapılan hastalarda kullanılan ortalama greft sayıları sırasıyla 2.8 ± 0.9 ve 1.6 ± 0.7 idi. On-pump grupta komplet revaskülarizasyon hastaların %77.7'sinde sağlanabilirken off-pump grubunda %76.9 hastada sağlandı. Her iki grup için ameliyat komplikasyonları, mortalite/morbidite ile yoğun bakım ve hastane kalış süreleri incelendi.

Bulgular: Erken mortalite oranı üç hasta ile %9.6 oldu. İki hastada ameliyatta miyokardiyal infarktüs gelişti, hastaların ikisinde intraaortik balon kontrpulsasyonu ile destek gerekti. Sternal dehisens, enfeksiyon ve nörolojik komplikasyonlar gibi ameliyat sonrası sorunlara on-pump grubunda daha sık rastlandı ($p=0.02$). İki grup karşılaştırıldığında mortalite, aritmi, ameliyat sırasında miyokardiyal infarktüs ve drenaj miktarları açısından gruplar arasında anlamlı bir fark saptanmadı. İstatistiksel olarak anlamlı olmasa da ortalama entübasyon süresi, hastane ve yoğun bakımda kalış süreleri off-pump grupta biraz daha düşüktü.

Sonuç: Diyalize bağımlı kronik böbrek yetmezliği olan ve koroner arter hastalığı için ameliyat planlanan hastalar risk faktörleri ve eşlik eden hastalıklar açısından iyice araştırılmalıdır. Kronik renal yetmezliği olan hastalarda off-pump koroner revaskülarizasyonun iyi bir tercih olduğu düşüncesindeyiz.

Anahtar sözcükler: Kardiyak cerrahi prosedürler/yan etki; ameliyat komplikasyonları; kronik böbrek yetmezliği/komplikasyon; ameliyat sonrası komplikasyonlar.

Received: March 18, 2005 Accepted: June 27, 2005

Correspondence: Dr. Hasan Basri Erdoğan, Kartal Koşuyolu Yüksek İhtisas Eğitim ve Araştırma Hastanesi, Kalp ve Damar Cerrahisi Kliniği, 34846 Cevizli, İstanbul. Tel: 0216 - 459 40 41 e-mail: gulayhasan@superonline.com

Cardiac pathologies are among the most important factors of mortality in patients with chronic renal failure.^[1] Cardiac diseases have been reported to be responsible for 44% of deaths in patients on long term dialysis treatment.^[2] Risk of acute myocardial infarction, angina pectoris, pulmonary edema due to left ventricular dysfunction, sudden death, congestive heart failure and complex ventricular arrhythmias are more frequent in these patients. Dilated cardiomyopathy, hypertrophic hyperkinetic disease and development of calcifications involving cardiac valves and other cardiac structures are important complications related to renal failure in these patients.^[1] Moreover, morbidity related to cardiac disease causes more problems in those patients who are on hemodialysis therapy. Dialysis sessions may have to be ended prematurely due to hypotensive or anginal attacks.

Patients with decreased renal function but who are not on dialysis therapy (serum creatinine ≥ 2.0 mg/dl) present with an increased operative risk. Even if revascularization is provided, long-term freedom from cardiac events is less in patients with renal dysfunction than that in patients with normal renal function.^[3] Dialysis-dependent renal failure patients also have increased risk for coronary artery bypass graft operations. It is well known that renal failure is an important risk factor in cardiac operations, performed under cardiopulmonary bypass (CPB).^[1]

About two thirds of chronic renal failure cases are caused by primary hypertension, diabetes mellitus, or both. These diseases also cause serious cardiovascular pathologies and this coexistence makes the treatment highly complex. Moreover, an aggressive atherosclerotic process involving all coronary arteries is observed in patients with renal disease just as in diabetes. Presence of hypertension, hyperlipidemia and abnormal carbohydrate metabolism all contribute to this accelerated atherosclerosis.^[4] The optimal management of these patients, the pre- and postoperative measures, and the choice of operative strategies very important implications. Potential problems associated with CPB, such as fluid-electrolyte balance, hemoglobin concentration, and hemostasis, all make optimal perioperative management indispensable.

PATIENTS AND METHODS

Patient characteristics. Thirty one patients (23 males, 8 females; mean age 62.45 ± 9.34 years, range 41 to 75 years) with known chronic renal disease who were operated for coronary artery disease in our clinics were included in the study. Eleven patients were dialysis-dependent preoperatively, all being on hemodialysis. Demographic data and preoperative cardiac pathologies of patients are summarized in Table 1. Etiology of renal failure was

hypertensive nephropathy in 9, diabetes mellitus in 8 and lupus nephropathy in 1 patient. In 2 patients, renal parenchymal disease was detected ultrasonographically whereas etiology of renal dysfunction was not clear in the remaining patients. Two patients were included in dialysis programme one week before the operation. Mean duration of dialysis in the remaining patients, who were on dialysis programme at preoperative period, was 3.65 ± 2.87 (range; 0.6-8) years. Mean EF was $50.00 \pm 7.99\%$ (range; 35-64%). Mean preoperative serumcreatinine value was 5.88 ± 2.84 mg/dl in dialysis-dependent patients and 2.4 ± 1.4 mg/dl in nondialysis-dependent patients. One of the patients who had renal artery stenosis had underwent PTCA and stent implantation before the operation. This patient had impairment of renal function but was not on dialysis. Due to established renal failure, no corrective procedure for stenotic renal artery was performed before coronary revascularization. The female patient with lupus erythematosus was not in an acute flare-up stage at the time of revascularization.

Operation and postoperative follow up. All patients underwent a hemodialysis procedure 24 hours before the operation in order to attain optimal fluid-electrolyte and urea-creatinine values. All coronary artery bypass grafting (CABG) operations were performed through median sternotomies with or without CPB. In both groups left internal mammarian artery was used unless there was a contraindication. Right internal mammarian artery was used only in 1 patient who underwent a second operation due to restenosis of left anterior descending artery distal to the first anastomosis.

In patients operated with CPB, activated clotting time (ACT) was kept over 500" and to prevent volume overload hemofiltration was used during perfusion when necessary. Potassium-rich solutions were not used and hemoglobin levels were kept above 10 g/dL. To optimize preload, fresh-frozen-plasma was used for fluid replacement and packed red blood cells to increase the hematocrit levels when needed.

Patients spent postoperative first 2 days in the intensive care unit (ICU). If potassium levels and urea-creatinine values were stable and if volume status was normal, hemodialysis was not started until the 2nd postoperative day and none of the patients required dialysis earlier. Balanced glucose-insulin solutions were administered to the patients with high potassium levels, to reduce serum potassium levels to normal. The frequency of the dialysis was determined on an individual basis by closely monitoring laboratory results and the status of the patients.

Statistical analysis. Statistical analyses were performed by SPSS 11.0 software for windows (SPSS Inc., Chicago, USA III). All data are presented as

Table 1. Preoperative demographic data

Characteristic	On-pump	Off-pump
Sex		
Male/female	15/3	8/5
Age	62.16±8.06	62.84±11.22
Coronary artery disease + ischemic mitral regurgitation	1	2
Previous myocardial infarction	7	9
Left main coronary artery disease	2	0
Diabetes mellitus	8	2
Insulin dependent	2	1
Hypertension	15	8
Smoking	11	7
Canada class I-II	6	2
Canada class III-IV	12	11
New York Heart Association class I-II	17	11
New York Heart Association class III-IV	1	2
Hyperlipidemia	15	8
Obesity	3	2
Peripheral vascular disease	3	1
History of cerebrovascular accident	2	1
Renal artery stenosis	1	1
Chronic obstructive pulmonary disease	3	1
Ejection fraction <40%	3	7
Preoperative dialysis	5	6

mean±standard deviation for continuous variables, as numbers with percentage for categorical variables. Differences between categorical variables were tested using the χ^2 -test and Fisher's exact test; differences between continuous variables were tested using Paired t-test. $p \leq 0.05$ was considered to be significant.

RESULTS

Mean arterial pressure during perfusion was 87 ± 3.1 mmHg in patients undergoing CPB whereas mean systolic arterial pressure was 113.2 ± 13.1 mmHg in those operated with the off-pump technique (Table 2). Although mean number of grafts per patient was higher in the on-pump group (2.8 ± 0.9 vs. 1.6 ± 0.7) complete revascularization ratio was similar in both groups (77.77% vs. 76.9%).

Early mortality was 9.67% (3 patients). Two of these were operated on-pump whereas 1 was operated off-pump. One of the on-pump patients died of sepsis secondary to sternal infection on postoperative 22nd day and other two patients died of low cardiac output on postoperative 8th and 10th days. All three patients had nondialysis-dependent renal failure preoperatively but required hemodiafiltration in the ICU due to further deterioration of renal functions.

Anterior myocardial infarction developed in two patients during perioperative period and both required high dose inotropic and intraaortic balloon pump support because of low cardiac output syndrome. One of these patients underwent CPB and the other was operated with the off-pump technique. Additional two patients required high dose inotropic support and both

Table 2. Operations

Variable	On-pump	Off-pump
Mean systolic arterial pressure	87.07±3.17	113.22±13.14
Duration of total perfusion	103.22±34.76	
Duration of cross-clamp	65.5±23.99	
Graft number/patient	2.83±0.92	1.69±0.75
Complete revascularization	14 (77.7%)	10 (76.9%)
Use of left internal mammarian artery	16 (88.88%)	12 (92.30%)
Use of right mammarian artery	1 (5.55%)	0
Concomitant procedure	Mitral ring annuloplasty	0

were lost due to low cardiac output. Again, one of these patients was in on-pump group and other was in off-pump group. Supraventricular and ventricular arrhythmia were observed at similar frequencies in each group (Table 3).

Eight patients who were not dialysis-dependent preoperatively required hemodiafiltration in ICU due to increased urea-creatinine levels and volume overload secondary to cessation of urinary output and 1 patient due to high potassium levels. Three of these patients required chronic dialysis therapy thereafter.

In 1 patient operated with the on-pump technique, generalized tonic-clonic convulsion developed during early postoperative period and was treated with anti-convulsant therapy. In the off-pump group, no neurologic or sternal complications observed whereas in the on-pump group 3 patients required reintervention for sternal dehiscence one of which was secondary to sternal infection.

The frequency of dialysis was determined on an individual basis by closely monitoring laboratory results and the status of the patients in patients with dialysis-dependent renal failure. The frequency of postoperative hemodialysis was similar to that of preoperative hemodialysis. Cessation of dialysis due to hypotension or hemodynamic instability was not necessary in any patients. In patients who were not dialysis-depen-

dent preoperatively, indication of dialysis was determined by laboratory results, potassium levels and findings of volume overload.

DISCUSSION

The underlying cause of death in 40-50% of hemodialysis patients is coronary artery disease. It is not well known whether the progression of the coronary artery disease has a more accelerated course in hemodialysis patients, but many studies report that cardiac disorders have dismal outcome in the presence of coexisting diseases, including established renal failure.^[5] Calcification of the heart valves, coronary arteries, and the conduction system, and the probability of septic events such as endocarditis, are typical complications of long-term hemodialysis.^[6] In spite of the fact that reports on the outcomes of cardiac procedures and their effects on the long-term prognosis of patients with renal disease are scarce, recent findings indicate acceptable medium and long-term results.^[7,8]

CPB, hemodynamic factors and toxic effects on kidneys have been proposed to be responsible for the development of acute renal failure during postoperative period. When this renal impairment becomes severe enough to necessitate dialysis mortality increases markedly and was reported to be 60% to 100%.^[9,10] Also, for nondialysis -dependent patients, Rao et al.^[11] report higher blood transfusion requirements and a

Table 3. Mortality and morbidity

Variable	On-pump	Off-pump
Mortality	2	1
Myocardial infarction	1	1
Inotrop use	2	2
Intraaortic balloon pump use	1	1
Arrhythmia		
Supraventricular tachycardia	2	2
VPB/VT/VF	1/0/0	2/0/2
Dialysis requirement	5	4
Chronic dialysis	2	1
Sternal		
Infection	1	0
Dehiscence	3	0
Neurologic complication	1	0
Revision for bleeding	1	0
Postoperative blood loss	527.77±177.58	388.46±354.23
Transfusion requirement unit		
Packed red blood cells	2.25	1.75
Fresh frozen plasma	1.25	1
Whole blood	1.15	0.75
Duration of intubation	17.94±20.24	12.5±5.72
Duration of intensive care unit stay	9.5±17.33	6.23±5.23
Duration of hospital stay	18.44±14.14	14.38±9.82

VPB: Ventricular premature beat; VT: Ventricular tachycardia; VF: Ventricular fibrillation.

higher incidence of low cardiac output syndrome resulting in longer ICU and hospital stays.

Complications after coronary artery bypass surgery are seen more often in dialysis-dependent renal failure patients than in other patients.^[6,7] Accelerated atherosclerosis and diffuse cholesterol embolization produce cerebrovascular or visceral vascular complications. The high percentage of preoperative myocardial infarctions in these patients and the presence of triple-vessel disease and calcific arterial lesions all point to an accelerated progression of atherosclerotic disease. Postoperatively, the more frequent need of inotropic medications also indicates a higher risk of major cardiac events in these patients. In various studies, advanced age has been the most important predictive factor in survival in these patients, but cerebrovascular disease, an ejection fraction of less than 0.35, and the need for hemodialysis are other strong predictive factors.^[12] Due to the presence of calcified coronary artery lesions, surgeons usually have had to perform incomplete revascularizations in dialysis-dependent patients.^[13] Although mean number of grafts per patient was higher in the on-pump group (2.8 ± 0.9 vs. 1.6 ± 0.7) complete revascularization ratio was similar in both groups (77.77% vs. 76.9%). The reason is that at the beginning patients with low number of diseased vessels was selected for off-pump coronary revascularization. With the development of new surgical techniques for off-pump coronary surgery, patients with stenosis of distal circumflex branches have become suitable for off-pump coronary revascularization.

Many of the complications associated with CABG in patients with renal failure may be related to the use of CPB. Disorders like platelet dysfunction and susceptibility to infection increase the operative morbidity and mortality. The susceptibility to infections is related to decrease in leukocyte chemotaxis and leucopenia related to CPB. Absence of any infectious complications in the off-pump group supports this view. During CPB, there is difficulty in maintaining the fluid-electrolyte balance in dialysis-dependent patients; and in dialysis patients operated on-pump, there is greater risk of bleeding complications.^[14] With off-pump CABG it is possible to avoid adverse effects of CPB on immunological system and bleeding diathesis and to minimize these problems. In our series, only 1 on-pump patient required reoperation for bleeding whereas in the off-pump group bleeding problem was observed in 1 patient which did not require surgical intervention. The decreased number of bleeding problems lessens transfusion requirements and thereby transfusion-related complications. In patients operated off-pump, postoperative drainage and transfusion requirements were less

than on-pump group but this was not statistically significant due to low number of patients.

It is widely known that cerebrovascular accidents are more frequent in patients operated with the on-pump technique. Obviating the need to cross-clamp the aorta in diffusely atherosclerotic renal failure patients has the further advantage of diminishing the risk of thromboembolic events. None of our patients experienced a cerebrovascular event but in generalized tonic-clonic convulsion was observed in 1 patient in the on-pump group. No organic pathology was detected in this patient and was discharged from the hospital without neurologic sequelae.

Ischemic electrocardiographic changes were observed in 2 patients during perioperative period and both required high dose inotropic and intraaortic balloon pump (IABP) support because of low cardiac output syndrome. One of these patients was operated with CPB and other with the off-pump technique. Diffuse atherosclerotic disease was present and anterior myocardial infarction developed in both patients. These patients were in nondialysis-dependent group and did not require dialysis during postoperative period. This shows that atherosclerotic process is also accelerated in nondialysis-dependent patients and risk of major cardiac complications is also increased. Both of these patients were discharged from the hospital.

The maintenance of a good fluid-electrolyte balance, the avoidance of potassium-rich solutions in volume replacement, the decreased need for blood transfusions, the avoidance of potassium-rich banked bloods, and the early use of balanced glucose-insulin solutions all helped to delay the need for hemodialysis until the 2nd day of the postoperative period. In this way, it may be possible to delay and thereby lessen the detrimental effects of hemodialysis on hemodynamic parameters and on the bleeding diathesis in the very early postoperative period. The frequency of postoperative hemodialysis was determined in accordance to laboratory results and patient's clinical status and was unchanged from that of preoperative hemodialysis. Of 9 patients who were nondialysis-dependent preoperatively but required dialysis during postoperative period, 4 were in the off-pump group and five in the on-pump group. There was no difference between groups.

Duration of stay in hospital was longer in patients with renal failure because these patients had a worse general condition. Moreover, in order to schedule postoperative dialysis programme we followed these patients longer in the hospital. We observed that durations of intubation, ICU stay and hospital stay were longer in patients operated on under CPB (Table 3) but

this was not statistically significant. In the study of Ascione et al, the need for postoperative inotropic and intraaortic ballon pump support, prolonged intubation and the need for transfusions were observed more frequently in patients with nondialysis-dependent renal failure, and CPB was found to be an independent risk factor for worsening of renal failure.^[15]

Although coronary artery disease is seen more frequently in patients with dialysis-dependent and non dialysis-dependent renal failure, it is well known that cardiac surgical procedures carry a high risk in this patient subgroup. Concomitant serious diseases as well as a diffuse coronary arterial pathology make these patients more complex. An important part of complications in patients with coronary artery disease and dialysis-dependent renal failure are related to CPB (bleeding, volume overload, cerebrovascular accident). Since we observed less morbidity, fewer bleeding problems and shorter durations of stay in ICU in patients operated on with off-pump technique than in patients operated on under CPB, we propose to perform off-pump coronary revascularization whenever it is possible.^[16] Although the need for inotropic support was similar in both groups in our study, cardiac functions of patients in off-pump group were worse and off-pump technique was preferred also in order to avoid adverse effects of CPB on cardiac functions.

Off-pump coronary revascularization is a technique that could be preferred in patients with a risk of postoperative organ dysfunction, in the presence of diseases could be accelerated by CPB, (HIV, immune deficiency, malignant disease) or in patients with pathologies which requires avoidance from CPB such as coagulopathy. General condition of patients with renal failure, presence of complex concomitant diseases, tendency for infection and coagulopathy makes off-pump coronary surgery a suitable technique for these patients. Off-pump operations decrease the mortality and morbidity and shorten the durations of ICU and hospital stay.

REFERENCES

1. Horst M, Mehlhorn U, Hoerstrup SP, Suedkamp M, de Vivie ER. Cardiac surgery in patients with end-stage renal disease: 10-year experience. *Ann Thorac Surg* 2000;69:96-101.
2. Excerpts from the United States Renal Data System 1998 Annual Data Report. *Am J Kidney Dis* 1998;32(2 Suppl 1):S1-162.
3. Hirose H, Amano A, Takahashi A, Nagano N. Coronary artery bypass grafting for patients with non-dialysis-dependent renal dysfunction (serum creatinine > or =2.0 mg/dl). *Eur J Cardiothorac Surg* 2001;20:565-72.
4. Bagdade JD. Uremic lipemia. An unrecognized abnormality in triglyceride production and removal. *Arch Intern Med* 1970;126:875-81.
5. Hellerstedt WL, Johnson WJ, Ascher N, Kjellstrand CM, Knutson R, Shapiro FL, et al. Survival rates of 2,728 patients with end-stage renal disease. *Mayo Clin Proc* 1984;59:776-83.
6. Marshall WG Jr, Rossi NP, Meng RL, Wedige-Stecher T. Coronary artery bypass grafting in dialysis patients. *Ann Thorac Surg* 1986;42(6 Suppl):S12-5.
7. Suehiro S, Shibata T, Sasaki Y, Murakami T, Hosono M, Fujii H, et al. Cardiac surgery in patients with dialysis-dependent renal disease. *Ann Thorac Cardiovasc Surg* 1999;5:376-81.
8. Hosoda Y, Yamamoto T, Takazawa K, Yamasaki M, Yamamoto S, Hayashi I, et al. Coronary artery bypass grafting in patients on chronic hemodialysis: surgical outcome in diabetic nephropathy versus nondiabetic nephropathy patients. *Ann Thorac Surg* 2001;71:543-8.
9. Hilberman M, Derby GC, Spencer RJ, Stinson EB. Sequential pathophysiological changes characterizing the progression from renal dysfunction to acute renal failure following cardiac operation. *J Thorac Cardiovasc Surg* 1980;79:838-44.
10. Gailiunas P Jr, Chawla R, Lazarus JM, Cohn L, Sanders J, Merrill JP. Acute renal failure following cardiac operations. *J Thorac Cardiovasc Surg* 1980;79:241-3.
11. Rao V, Weisel RD, Buth KJ, Cohen G, Borger MA, Shiono N, et al. Coronary artery bypass grafting in patients with non-dialysis-dependent renal insufficiency. *Circulation* 1997;96(9 Suppl):II-38-43.
12. Prifti E, Bonacchi M, Leacche M, Frati G, Giunti G, Proietti P, et al. Myocardial revascularisation in chronic renal failure: 10-year experience. *Asian Cardiovasc Thorac Ann* 2001;9:176-81.
13. Koyanagi T, Nishida H, Kitamura M, Endo M, Koyanagi H, Kawaguchi M, et al. Comparison of clinical outcomes of coronary artery bypass grafting and percutaneous transluminal coronary angioplasty in renal dialysis patients. *Ann Thorac Surg* 1996;61:1793-6.
14. Franga DL, Kratz JM, Crumbley AJ, Zellner JL, Stroud MR, Crawford FA. Early and long-term results of coronary artery bypass grafting in dialysis patients. *Ann Thorac Surg* 2000;70:813-8.
15. Ascione R, Nason G, Al-Ruzzeh S, Ko C, Ciulli F, Angelini GD. Coronary revascularization with or without cardiopulmonary bypass in patients with preoperative nondialysis-dependent renal insufficiency. *Ann Thorac Surg* 2001;72:2020-5.
16. Erentuğ V, Akinci E, Kirali K, Kayalar N, Kaynak E, Ogus H, et al. Complete off-pump coronary revascularization in patients with dialysis-dependent renal disease. *Tex Heart Inst J* 2004;31:153-6.