Original
Article

Preoperative Estimated Glomerular Filtration Rate is an Independent Predictor of Late Cardiovascular Morbidity after Mitral Valve Surgery

Taro Nakazato, MD,¹ Teruya Nakamura, MD, PhD,¹ Naosumi Sekiya, MD, PhD,¹
and Yoshiaki Sawa, MD, PhD²

Purpose: Renal dysfunction affects outcomes of cardiac surgery, although its role in mitral valve operation has been limitedly documented.

Methods: Two hundred and ten patients who underwent mitral valve operation between 2004 and 2011 were divided into 3 groups according to preoperative estimated glomerular filtration ratio (eGFR): group A (eGFR ≥ 60 ml/min/1.73 m², n = 102), group B (eGFR, 59–30 ml/min/1.73 m², n = 92) and group C (eGFR < 30 ml/min/1.73 m², n = 16).

Results: Freedom from all-cause and cardiovascular death at 5 years was 77.2% and 93.0%, respectively. No significant differences existed between the 3 groups. In contrast, there was a significant difference in freedom from major adverse cardiovascular events (MACE) between groups (70.4%, 57.1%, and 42.8% in group A, B, and C, respectively; $p = 0.008$). By univariate and multivariate analysis, eGFR < 60 ml/min/1.73 m² (HR: 1.92, 95% CI: 1.02–3.68, $p = 0.044$) and left ventricular ejection fraction $< 40\%$ (HR: 2.69, 95% CI: 1.17–6.23, $p = 0.02$) were independent risk factors of MACE, although serum creatinine failed to represent an independent risk factor.

Conclusion: Patients who underwent mitral valve surgery had acceptable perioperative and long-term survival, irrespective of preoperative renal function. However, eGFR < 60 ml/min/1.73 m² was an independent predictor of late MACE.

Keywords: kidney, renal function, dialysis, mitral valve, mitral regurgitation

Introduction

Chronic kidney disease (CKD) is one of the largest worldwide public health problems. In the United States, more than 10% of individuals, over 20 million have CKD.¹⁾

¹Division of Cardiovascular Surgery, National Hospital Organization Kure Medical Center, Kure, Hiroshima, Japan

²Department of Surgery, Osaka University Graduate School of Medicine, Osaka, Osaka, Japan

Received: July 18, 2013; Accepted: September 4, 2013
Corresponding author: Teruya Nakamura, MD, PhD. Division of Cardiovascular Surgery, NHO Kure Medical Center, 3-1 Aoyama-Cho, Kure, Hiroshima 737-0023, Japan
Email: teruyan@kure-nh.go.jp
©2014 The Editorial Committee of *Annals of Thoracic and Cardiovascular Surgery*. All rights reserved.

CKD is an important risk factor for cardiovascular disease and is a strong predictor of late outcomes.^{1,2)} This disease has been well documented to negatively impact early and late outcome of patients undergoing cardiac surgery.³⁾ Although this impact has been more frequently described in coronary bypass surgery^{4,5)} or aortic valve replacement,⁶⁾ data with respect to mitral valve disease are relatively scant.

Traditionally, renal function has been evaluated by serum creatinine levels. On the other hand, glomerular filtration rate (GFR) is used to express kidney function more precisely, which can accurately be measured by time-consuming and labor-intensive methods. In recent clinical practice, serum creatinine-based formulae were used to calculate estimated GFR (eGFR), which offer a

good estimate of measured GFR.⁷⁾ The current guidelines of CKD classify chronic kidney disease by eGFR, one of which is calculated by the Modification of Diet in Renal Disease study (MDRD) formula.⁸⁾ Moreover, eGFR is a strong predictor of cardiovascular mortality.²⁾ Despite of these facts, it is undetermined whether eGFR predicts postoperative outcomes after cardiac surgery; it is also unknown whether eGFR is a better index than serum creatinine.

The purpose of this study was to analyze whether the eGFR classification based on the current guideline is associated with early and late outcomes of mitral valve surgery. Furthermore, this study examined whether eGFR is an independent predictor of early and long-term morbidity and mortality.

Patients and Methods

Between January 2004 and December 2011, 343 patients underwent mitral valve procedures for mitral regurgitation (MR) at our institute. Of these patients, redo operations and concomitant procedures on aortic valve or thoracic aorta were excluded; 210 patients were included in the study. All data were obtained retrospectively from the medical records. The Institutional Review Board approved this study, and patient consent was waived due to the retrospective nature of data collection. According to a recommendation from the National Kidney Foundation Kidney Disease Outcomes Quality Initiative (NKF KDOQI™) clinical practice guidelines, eGFR was calculated by the MDRD Study equation.⁸⁾ Based on eGFR, patients were separated into 3 subgroups: Group A (eGFR ≥ 60 ml/min/1.73 m²), Group B (eGFR, 59–30 ml/min/1.73 m²), and Group C (eGFR < 30 ml/min/1.73 m²). These subgroups correspond to CKD Stage 1–2, Stage 3 and Stage 4–5, respectively. Patients who were on preoperative hemodialysis received hemodialysis a day before surgery, which was resumed on postoperative day 1 or 2, depending on patients' arterial blood gas and fluid status. Renal replacement therapy (RRT) was applied either in continuous or intermittent manner for patients who were not on preoperative hemodialysis and presented postoperative acute renal failure despite optimal hemodynamic management. Our criteria for initiating RRT was as follows: Oliguria (< 0.5 ml/kg/hour) and fluid overload as evident by chest X-ray; decrease in eGFR < 15 ml/min/1.73 m²; symptoms or signs of uremia; and intractable hyperkalemia or metabolic acidosis.⁹⁾

All procedures were performed using standard cardiopulmonary bypass with bicaval and aortic cannulation under tepid temperature. A higher mean perfusion pressure (which was usually 80 mmHg) was maintained on bypass. For renoprotective purpose, human atrial natriuretic polypeptide (Carperitide) is administered continuously in most cases, irrespective of preoperative renal function.¹⁰⁾ If excessive hemodilution was observed, intraoperative modified ultrafiltration was liberally done.¹¹⁾ Choice of repair procedure or replacement was decided based on surgeon's preference. Generally, mitral ring annuloplasty was performed for Carpentier Type I or Type IIIb (functional) MR, and chordal replacement or quadrangular resection was performed for Type II MR. An annuloplasty ring or band was used in all repair cases.

Patients were followed-up by the clinic at our hospital, or using telephone interview. Follow-up in this patient series was 100%. The mean follow-up period was 3.36 ± 2.10 years.

Statistical analyses were performed using JMP® 10 (SAS Institute Inc., Cary, North Carolina, USA). Normally distributed continuous data were expressed as means $\pm$ SD. Univariate analyses were performed for all relevant categorical variables using Fisher's exact test, χ^2 analysis, and *t* tests or Mann-Whitney *U* test for continuous variables. Logistic regression was used to examine independent predictors of morbidity or mortality. Because of the strong interaction between eGFR and serum creatinine, these indices were excluded in the 2 separate analyses. Kaplan-Meier analysis was performed to depict all-cause or event-free survivals, using Log-rank tests for statistical analysis. The differences were considered statistically significant at $p < 0.05$.

Results

The clinical characteristics of patients are shown in **Table 1**. A total of 93 males (44%) and 117 females with a mean age of 69.6 ± 11.5 years (range: 25–90 years) were included in the study. Etiology was degenerative in 146 patients (70%), functional in 54 (25%), and rheumatic in 10 (5%). The mean serum creatinine of overall patients was 1.05 ± 0.80 mg/dl, and the mean eGFR was 56.6 ± 19.9 ml/min/1.73 m². Based on eGFR, patients were separated into three subgroups: Group A (eGFR ≥ 60 ml/min/1.73 m², $n = 102$), Group B (eGFR, 59–30 ml/min/1.73 m², $n = 92$), and Group C (eGFR < 30 ml/min/1.73 m², $n = 16$). Mean serum creatinine and eGFR of each group were as follows: Group A: 0.73 ± 0.13 mg/dl and

Table 1 Patient characteristics and operative parameters

Variables ^a	All patients (n = 210)	A (eGFR >60, n = 102)	B (eGFR 30–60, n = 92)	C (eGFR <30, n = 16)	p value
Age	69.6 ± 11.5	65.7 ± 12.5	73.4 ± 8.78	73.1 ± 11.6	<0.001
Male	93 (44)	49 (48)	38 (41)	6 (38)	0.555
Etiology					
Degenerative	146 (70)	77 (75)	60 (65)	9 (56)	0.135
Dilated cardiomyopathy	11 (5)	5 (5)	6 (7)	0 (0)	0.714
Ischemic	43 (20)	14 (14)	22 (24)	7 (44)	0.012
Rheumatic	10 (5)	6 (6)	4 (4)	0 (0)	0.572
BMI, kg/m ²	22.6 ± 4.15	22.9 ± 4.46	22.5 ± 3.80	21.3 ± 4.01	0.353
Serum creatinine, mg/dl	1.05 ± 0.80	0.73 ± 0.13	1.09 ± 0.23	2.92 ± 2.0	<0.001
eGFR, ml/min/1.73 m ²	56.6 ± 19.9	73.2 ± 11.2	44.8 ± 8.32	19.3 ± 7.91	<0.001
Hypertension	86 (41)	39 (38)	40 (43)	7 (44)	0.750
Hyperlipidemia	45 (21)	20 (20)	24 (26)	1 (6)	0.169
Diabetes	64 (30)	24 (24)	32 (35)	8 (50)	0.049
COPD	8 (4)	5 (5)	2 (2)	1 (6)	0.358
Stroke	29 (14)	15 (15)	13 (14)	1 (6)	0.862
Hemodialysis	3 (1)	0 (0)	0 (0)	3 (19)	<0.001
Pulmonary hypertension	44 (21)	18 (18)	20 (22)	6 (38)	0.198
Coronary disease	55 (26)	19 (19)	29 (32)	7 (44)	0.031
Atrial fibrillation	134 (64)	69 (68)	54 (59)	11 (69)	<0.001
LVEF, %	56.8 ± 14.1	57.4 ± 13.5	56.7 ± 14.7	53.3 ± 14.2	0.549
LVDD, mm	51.9 ± 7.84	51.3 ± 7.41	52.2 ± 8.34	54.1 ± 7.41	0.391
LVDS, mm	36.3 ± 8.47	35.5 ± 7.79	36.7 ± 9.15	38.9 ± 8.41	0.282
Valve repair	167 (80)	83 (81)	71 (77)	13 (81)	0.753
Replacement	43 (20)	19 (19)	21 (23)	3 (19)	0.753
Mechanical	6 (3)	4 (2)	2 (1)	0 (0)	0.805
Bioprosthetic	37 (17)	15 (7)	19 (9)	3 (1)	0.527
Concomitant procedures					
Tricuspid valve repair	150 (71)	70 (69)	68 (74)	12 (75)	0.731
Maze	137 (65)	69 (68)	57 (62)	11 (69)	0.699
CABG	35 (17)	13 (13)	17 (18)	5 (31)	0.151
Operation time, min	280 ± 80.1	278 ± 88.9	282 ± 73.1	287 ± 76.5	0.889
CPB time, min	144 ± 47.5	141 ± 42.1	150 ± 54.5	128 ± 30.6	0.175
ACC time, min	106 ± 31.2	105 ± 27.4	109 ± 35.9	91 ± 19.7	0.09
Postoperative stay, day	29.3 ± 51.9	25.6 ± 38	32.3 ± 66.3	35.3 ± 31.2	0.597
Mortality	4 (2)	2 (2)	1 (1)	1 (6)	0.363
Temporary renal replacement	13 (6)	2 (2)	4 (4)	7 (44)	<0.001
Respiratory failure	7 (3)	1 (1)	4 (4)	2 (13)	0.048
Transfusion	137 (65)	54 (53)	67 (73)	16 (100)	<0.001
Sternal re-exploration	3 (1)	1 (1)	2 (2)	0 (0)	0.689
Mediastinitis	1 (0.5)	1 (1)	0 (0)	0 (0)	1
ACEI/ARB use	185 (88)	96 (94)	80 (87)	9 (56)	<0.001

^aContinuous data presented as mean and standard deviation, and categorical data as number (%). BMI: body mass index; eGFR: estimated glomerular filtration rate; COPD: chronic obstructive pulmonary disease; ACEI: Angiotensin converting enzyme inhibitor; LVEF: left ventricular ejection fraction; LVDD: left ventricular diastolic dimension; LVSD: left ventricular systolic dimension; CABG: coronary artery bypass grafting; CPB: cardiopulmonary bypass; ACC: aortic cross-clamp

73.2 ± 11.2 ml/min/1.73 m²; Group B: 1.09 ± 0.13 mg/dl and 44.8 ± 8.32 ml/min/1.73 m²; and Group C: 2.92 ± 4.01 mg/dl and 19.3 ± 7.91 ml/min/1.73 m² (*p* < 0.001). As shown in **Table 1**, patients in Group A were younger, Group C patients had more comorbidities than Groups A and B, and prevalence of diabetes and coronary disease

significantly increased as eGFR declined. Three patients in Group C were on hemodialysis preoperatively. There was no difference in echocardiographic parameters between the groups.

The operative variables are detailed in **Table 1**. There was no difference in ratio of valve repair or replacement

and concomitant procedures between groups. Likewise, there was no difference in operative, cardiopulmonary bypass, or aortic clamp time between groups. There were four operative deaths; however, no differences between groups in this regard. Significant differences were found for the incidences of postoperative renal replacement therapy, respiratory failure, and transfusion. These incidences were significantly higher in Group C compared to the others. Postoperatively, patients in Group C were less likely to be on angiotensin-converting enzyme inhibitors (ACEI) or angiotensin receptor blockers (ARB) than those in other groups (**Table 1**).

A mean and median follow-up durations were 40.3 ± 25.2 months and 41 months, respectively. Kaplan-Meier analysis demonstrated that overall survival was 77.2% at 5 years: 80.1%, 76.9%, 62.6% for Groups A, B, and C, respectively. The survival of Group C was worse than that of the other groups, although the difference did not reach statistical significance (**Fig. 1A**). Likewise, there was no significant difference in cardiovascular death between groups (**Fig. 1B**). In contrast, overall freedom from major adverse cardiovascular events (MACE) was 62.2%, and 80.1%, 76.9%, and 62.6% in Groups A, B, and C, respectively. MACE-free survival significantly decreased as eGFR declined (**Fig. 2**, $p = 0.008$). To determine risk factors of MACE, univariate analysis was performed. Factors that reached statistical significance were as follows: coronary artery disease, left ventricular ejection fraction (LVEF) less than 40%, eGFR less than 60 ml/min/1.73 m², and serum creatinine greater than 0.9 mg/dl (**Table 2**). Multivariate analysis including eGFR revealed that LVEF <40% (HR: 2.69, 95% CI: 1.17–6.23, $p = 0.02$) and eGFR <60 ml/min/1.73 m² (HR: 1.92, 95% CI: 1.02–3.68, $p = 0.044$) were independent predictors of MACE (**Table 3**). In contrast, multivariate analysis including serum creatinine showed that only LVEF <40% (HR: 2.80, 95% CI: 1.22–6.47, $p = 0.016$) was statistically significant; coronary disease (HR: 1.63, 95% CI: 0.81–3.21, $p = 0.17$) and serum creatinine (HR: 1.77, 95% CI: 0.93–3.44, $p = 0.08$) were not significant. These findings suggest that eGFR has a stronger correlation with MACE than serum creatinine.

Discussion

It is widely known that renal dysfunction is an important factor for predicting early and long-term morbidity and mortality after cardiac surgery.^{3,12} This finding has been relatively well documented in coronary bypass^{4,5}

Number at risk									
A (eGFR >60)	102	85	67	53	43	23	11	9	2
B (eGFR 30–60)	92	85	69	56	38	21	12	5	2
C (eGFR <30)	16	11	11	9	5	4	4	3	2

Number at risk									
A (eGFR >60)	102	85	67	53	43	23	11	9	2
B (eGFR 30–60)	92	85	69	56	38	21	12	5	2
C (eGFR <30)	16	11	11	9	5	4	4	3	2

Fig. 1 Kaplan-Meier analysis for freedom from all cause (A) or cardiovascular death (B).

Number at risk									
A (eGFR >60)	102	76	55	44	34	17	8	6	2
B (eGFR 30–60)	92	75	56	43	27	14	4	1	
C (eGFR <30)	16	9	8	6	4	3	1		

Fig. 2 Kaplan-Meier analysis for freedom from major adverse cardiovascular event.

Table 2 Univariate analysis of variables associated with postoperative MACE

Variables ^a	MACE (–) (n = 150)	MACE (+) (n = 60)	HR (95% CI)	p value
Age ≥75	50 (33%)	28 (47%)	1.75 (0.95–3.23)	0.073
Male gender	68 (45%)	25 (42%)	0.86 (0.47–1.57)	0.628
Mitral stenosis	6 (4%)	4 (7%)	1.71 (0.42–6.23)	0.427
MVR	31 (21%)	12 (20%)	0.96 (0.44–1.98)	0.914
BMI >25 kg/m ²	36 (24%)	12 (20%)	0.79 (0.37–1.62)	0.529
Hypertension	57 (38%)	29 (48%)	1.53 (0.83–2.8)	0.171
Hyperlipidemia	33 (22%)	12 (20%)	0.89 (0.41–1.82)	0.748
Diabetes	41 (27%)	23 (38%)	1.65 (0.87–3.1)	0.122
COPD	6 (4%)	2 (3%)	0.83 (0.12–3.71)	0.817
Stroke	18 (12%)	11 (18%)	1.38 (0.58–3.12)	0.455
Hemodialysis	3 (2%)	0 (0%)	<0.001 (–2.23)	0.154
Pulmonary hypertension	30 (20%)	14 (23%)	1.22 (0.58–2.47)	0.595
Coronary disease	33 (22%)	22 (37%)	2.05 (1.06–3.94)	0.032
Atrial fibrillation	93 (62%)	41 (68%)	1.32 (0.71–2.54)	0.385
LVEF <40%	14 (9%)	15 (25%)	3.24 (1.45–7.3)	0.004
eGFR <60 ml/min/1.73m ²	69 (46%)	39 (65%)	2.18 (1.18–4.11)	0.012
Serum creatinine ≥0.9 mg/dl	79 (53%)	41 (68%)	1.94 (1.04–3.7)	0.036

^aContinuous data presented as mean and standard deviation, and categorical data as number (%). MACE: major adverse cardiovascular event; MVR: mitral valve replacement; BMI: body mass index; COPD: chronic obstructive pulmonary disease; LVEF: left ventricular ejection fraction; eGFR: estimated glomerular filtration rate; CI: confidential interval

Table 3 Multivariate analysis of variables associated with postoperative MACE

Variables ^a	HR	(95% CI)	p value
Coronary disease	1.59	0.79–3.15	0.19
LVEF <40%	2.69	1.17–6.23	0.02
eGFR <60 ml/min/1.73m ²	1.92	1.02–3.68	0.04

^aContinuous data presented as mean and standard deviation, and categorical data as number (%). MACE: major adverse cardiovascular event; LVEF: left ventricular ejection fraction; eGFR: estimated glomerular filtration rate; HR: hazard ratio; CI: confidential interval

or aortic valve surgery,⁶⁾ although fewer data are available for mitral valve surgery. Garriodo-Olivares and colleagues¹³⁾ demonstrated that preoperative non-dialysis dependent renal dysfunction impacts early mortality after mitral valve surgery significantly. Jokinen and colleagues¹⁴⁾ reported that preoperative renal dysfunction is associated with late mortality after mitral valve surgery. In the present study, we demonstrated that preoperative renal dysfunction, defined based on the classification of the CKD guidelines, is associated with late MACE after mitral valve surgery. It was also shown that eGFR and low LVEF are independent predictors of late MACE.

In most previous studies, renal dysfunction has mainly been defined by serum creatinine, and eGFR has

been underutilized despite recommendations of the CKD guidelines. Surprisingly, few data are available that demonstrate that eGFR as a predictor of early and late outcomes after cardiac surgery. Although serum creatinine is an authentic marker of renal function, eGFR is a more comprehensive index and is determined in combination with age, sex, weight, and race. Because age has a strong correlation with long-term morbidity and mortality, the use of eGFR may be superior to serum creatinine alone. Moreover, serum creatinine generation and filtration are affected by various factors, and begins increasing only after significant loss of functioning nephrons and decreases of glomerular filtration.^{1,8)} Therefore, it is very likely that eGFR is a more sensitive marker of preoperative renal function than is serum creatinine. In the present

study, we clearly showed that eGFR represents a useful marker to predict late morbidity after mitral valve surgery.

Other biomarkers that are used for perioperative renal function. Serum cystatin C is a relatively new marker that indicates the ability of glomerular filtration; a number of studies have demonstrated that serum cystatin C levels correlate well with serum creatinine in post cardiopulmonary bypass acute kidney injury.^{15,16} Spahillary and colleagues conducted a multi-center prospective cohort study and found that preoperative serum cystatin C better forecasted postoperative acute kidney injury than did creatinine.¹⁷ Conversely, the same group failed to demonstrate whether serum cystatin C changed more sensitively than did creatinine in postoperative acute kidney injury.¹⁸ Proteinuria or albuminuria is another marker that reflects structural damage to the glomeruli or kidney tubules.¹⁹ Coca and colleagues reported that preoperative albuminuria was an independent predictor of acute kidney injury and added a prognostic value to eGFR.²⁰ It is yet to be determined whether these markers are likely to replace creatinine-based eGFR in risk analysis for acute kidney injury and long-term outcomes of cardiac surgery.

Overall survival of our series was 77.2% at 5 years, which is comparable with other series.²¹ In contrast to previous reports, we did not find significant differences in early and late survival between three groups, albeit a trend toward the worse long-term survival of patients with eGFR <30 ml/min/1.73 m². This finding implies that our patients with renal dysfunction had acceptable early and late mortality. Interestingly, it has been shown that Japanese patients with renal failure have better clinical outcomes than do patients in western countries.²² This difference is possibly because of their health insurance system that allows easier access to hemodialysis and more frequent checkups.²² Therefore, it is possible that postoperative management may have improved outcomes of patients with mild to moderate renal insufficiency. For example, it is well known that blockade of the renin-angiotensin system is the main aim of therapy to slow progression of chronic kidney disease and improve survival.²³ Benedetto and colleagues reported that preoperative ACEI reduced postoperative acute kidney injury almost in half, which suggests a protective effect of ACEI on renal perfusion during cardiopulmonary bypass.²⁴ In the present study, about 90% of patients were on ACEI and/or ARB postoperatively. It is yet to be determined how medical management affected postoperative survival or MACE. Furthermore, only 3 patients

(1.4%) in group C were on preoperative hemodialysis in this series, which may be too small to affect survival.

Mild renal dysfunction is known to be a predictor of early and long-term worse outcomes after cardiac surgery.²⁵ In the present study, 2 patients in Group A and 4 in Group B had postoperative acute kidney injury and underwent temporary renal replacement therapy. These patients had prolonged bypass time (mean, 192 minutes), and 3 had a LVEF of less than 40%. Thus, it is likely that prolonged low cardiac output adversely affected renal function. To protect renal function, it is paramount to reduce cardiopulmonary bypass time as much as possible. Moreover, Carperitide is known to exert cardio and renoprotective effects even in patients with mild to moderate renal dysfunction.²⁶ It is intriguing to examine whether perioperative Carperitide improves postoperative outcomes in mitral valve surgery.

It has been well documented that preoperative left ventricular function is associated with worse late outcomes and is not limited to mitral valve cases. In the present study, LVEF was another strong predictor of late MACE, which is consistent with others.²¹ It is noteworthy that type of procedure (i.e., valve repair or replacement) and valve choice did not affect short and long-term outcomes. Recent data have supported that there is no difference in postoperative survival of patients with end-stage renal failure irrespective of valve choices.²⁷ Thus, our current strategy for mitral valve disease is to recommend an early operation before ventricular function declines and perform valve repair as much as possible. If valve replacement is needed, we usually opt to use a tissue valve unless the patient declines.

There are several limitations in this study. The retrospective nature is one of the major limitations. Additionally, the sample size was small, which may have lead to a Type II statistical error. The follow-up period was short for some patients. Propensity score matching was not possible because of the small numbers of each group. Patients with very poor renal function might not have been operated due to high EURO score, which may not exclude the possibility of selection bias. Finally baseline etiology of mitral valve disease and concomitant procedures were diverse, which might have affected the short and long-term results.

Conclusion

In conclusion, our series of mitral valve surgery had acceptable perioperative and long-term outcomes, even

in patients with renal dysfunction. eGFR is a good index to predict long-term outcome after mitral valve surgery, and should be included with serum creatinine in preoperative patient evaluation. Further studies are warranted to determine the role of preoperative eGFR in pre and post-operative patient management.

Acknowledgement

We thank Dr. Junko Tanaka (Hiroshima University) for assisting statistical analysis.

Disclosure Statement

The authors have no commercial association or sources of support that may pose a conflict of interest.

References

- Centers for Disease Control and Prevention. National Chronic Kidney Disease Fact Sheet: General Information and National Estimates on Chronic Kidney Disease in the United States, 2010. Atlanta: U.S. Department of Health and Human Services, CDC, 2010.
- Chronic Kidney Disease Prognosis Consortium, Matsushita K, van der Velde M, et al. Association of estimated glomerular filtration rate and albuminuria with all-cause and cardiovascular mortality in general population cohorts: a collaborative meta-analysis. *Lancet* 2010; **375**: 2073-81.
- Filsoufi F, Rahmanian PB, Castillo JG, et al. Early and late outcomes of cardiac surgery in patients with moderate to severe preoperative renal dysfunction without dialysis. *Interact Cardiovasc Thorac Surg* 2008; **7**: 90-5.
- Lin Y, Zheng Z, Li Y, et al. Impact of renal dysfunction on long-term survival after isolated coronary artery bypass surgery. *Ann Thorac Surg* 2009; **87**: 1079-84.
- Sajja LR, Mannam G, Chakravarthi RM, et al. Impact of preoperative renal dysfunction on outcomes of off-pump coronary artery bypass grafting. *Ann Thorac Surg* 2011; **92**: 2161-7.
- Thourani VH, Chowdhury R, Gunter RL, et al. The impact of specific preoperative organ dysfunction in patients undergoing aortic valve replacement. *Ann Thorac Surg* 2013; **95**: 838-45.
- Stevens LA, Levey AS. Measured GFR as a confirmatory test for estimated GFR. *J Am Soc Nephrol* 2009; **20**: 2305-13.
- National Kidney Foundation. K/DOQI clinical practice guidelines for chronic kidney disease: evaluation, classification, and stratification. *Am J Kidney Dis* 2002; **39**: S1-266.
- Dombros N, Dratwa M, Feriani M, et al. European best practice guidelines for peritoneal dialysis. 2 The initiation of dialysis. *Nephrol Dial Transplant* 2005; **20** Suppl 9: ix3-7.
- Sezai A, Hata M, Niino T, et al. Results of low-dose human atrial natriuretic peptide infusion in nondialysis patients with chronic kidney disease undergoing coronary artery bypass grafting: the NU-HIT (Nihon University working group study of low-dose HANP Infusion Therapy during cardiac surgery) trial for CKD. *J Am Coll Cardiol* 2011; **58**: 897-903.
- Kameyama T, Ando F, Okamoto F, et al. The effect of modified ultrafiltration in pediatric open heart surgery. *Ann Thorac Cardiovasc Surg* 2000; **6**: 19-26.
- Murakami M, Yamaguchi H, Suda Y, et al. Mitral valve repair for 52 patients with severe left ventricular dysfunction. *Ann Thorac Cardiovasc Surg* 2009; **15**: 160-4.
- Garrido-Olivares L, David TE, Maganti M, et al. Effect of preoperative non-dialysis-dependent renal dysfunction on isolated aortic and mitral valve surgery: a propensity score analysis. *J Thorac Cardiovasc Surg* 2011; **142**: 155-61.
- Jokinen JJ, Hippeläinen MJ, Pitkänen OA, et al. Mitral valve replacement versus repair: propensity-adjusted survival and quality-of-life analysis. *Ann Thorac Surg* 2007; **84**: 451-8.
- Jarvela K, Maaranen P, Harmoinen A, et al. Cystatin C in diabetics as a marker of mild renal insufficiency after CABG. *Ann Thorac Cardiovasc Surg* 2011; **17**: 277-82.
- Wyckoff T, Augoustides JG. Advances in acute kidney injury associated with cardiac surgery: the unfolding revolution in early detection. *J Cardiothorac Vasc Anesth* 2012; **26**: 340-5.
- Shlipak MG, Coca SG, Wang Z, et al. Presurgical serum cystatin C and risk of acute kidney injury after cardiac surgery. *Am J Kidney Dis* 2011; **58**: 366-73.
- Spahillari A, Parikh CR, Sint K, et al. Serum cystatin C- versus creatinine-based definitions of acute kidney injury following cardiac surgery: a prospective cohort study. *Am J Kidney Dis* 2012; **60**: 922-9.
- Wu VC, Huang TM, Wu PC, et al. Preoperative proteinuria is associated with long-term progression to chronic dialysis and mortality after coronary artery bypass grafting surgery. *PLoS ONE* 2012; **7**: e27687.
- Coca SG, Jammalamadaka D, Sint K, et al. Preoperative proteinuria predicts acute kidney injury in patients undergoing cardiac surgery. *J Thorac Cardiovasc Surg* 2012; **143**: 495-502.
- Maltais S, Schaff HV, Daly RC, et al. Mitral regurgitation surgery in patients with ischemic cardiomyopathy and ischemic mitral regurgitation: factors that influence survival. *J Thorac Cardiovasc Surg* 2011; **142**: 995-1001.
- Shinoda T, Koda Y. Clinical evaluation indices for hemodialysis/hemodiafiltration in Japan. *Contrib*

- Nephrol 2011; **168**: 173-8.
- 23) Sarafidis PA, Bakris GL. Renin-angiotensin blockade and kidney disease. *Lancet* 2008; **372**: 511-2.
- 24) Benedetto U, Sciarretta S, Roscitano A, et al. Preoperative Angiotensin-converting enzyme inhibitors and acute kidney injury after coronary artery bypass grafting. *Ann Thorac Surg* 2008; **86**: 1160-5.
- 25) Howell NJ, Keogh BE, Bonser RS, et al. Mild renal dysfunction predicts in-hospital mortality and post-discharge survival following cardiac surgery. *Eur J Cardiothorac Surg* 2008; **34**: 390-5; discussion 395.
- 26) Sezai A, Nakata KI, Iida M, et al. Early results of human atrial natriuretic peptide infusion in non-dialysis patients with chronic kidney disease undergoing isolated coronary artery bypass grafting: the NU-HIT trial for CKD-II. *Ann Thorac Cardiovasc Surg* 2013. (in press)
- 27) Thourani VH, Sarin EL, Keeling WB, et al. Long-term survival for patients with preoperative renal failure undergoing bioprosthetic or mechanical valve replacement. *Ann Thorac Surg* 2011; **91**: 1127-34.