Is preoperative serum creatinine a reliable indicator of outcome in patients undergoing coronary artery bypass surgery?

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Objective: Evaluating renal function by calculating creatinine clearance as an alternative measure to serum creatinine may give a better estimation of postoperative renal function in patients undergoing coronary artery bypass grafting.

Methods: Using our database, we conducted a retrospective review of the records of all 11,884 patients aged 21 years or older undergoing pure bypass grafting who required cardiopulmonary bypass. Preoperative renal function was categorized as normal renal function (serum creatinine ≤1.1 mg/dL and creatinine clearance > 60 mL/min), occult renal insufficiency (serum creatinine ≤ 1.1 mg/dL and creatinine clearance ≤ 60 mL/min), mild renal insufficiency (1.1 mg/dL < serum creatinine ≤ 1.5 mg/dL and creatinine clearance ≤ 60 mL/min) or moderate renal insufficiency (serum creatinine > 1.5 mg/dL and creatinine clearance ≤ 60 mL/min).

Results: Out of 11,884 patients in the sample, 7856 (66.1%) had normal renal function, and 706 (5.9%) had occult renal insufficiency. The rate of postoperative mortality, renal failure, atrial fibrillation, prolonged ventilation, intra-aortic balloon pump usage, and prolonged hospital stay (>7 days) was higher in patients with occult renal insufficiency than in the normal group in univariable analysis. Multivariable logistic regression analysis demonstrated that patients with occult renal insufficiency compared with the group with normal renal function were at higher risk for mortality (odds ratio = 2.59, 95% confidence interval 1.15–5.86; $P = .022$) and prolonged hospital stay (>7 d) (odds ratio = 1.30, 95% confidence interval 1.08–1.57; $P = .005$).

Conclusions: To identify higher-risk patients requiring special intensive care, and in whom new interventions can be performed to improve outcome, we recommend the preoperative calculation of creatinine clearance, especially in older women with a lower body mass index.

Preoperative renal dysfunction is a significant risk factor that influences the outcome of cardiac surgery.[1,2] With the rapid rise in the aged population, more patients with renal insufficiency (RI) are being referred for coronary artery bypass graft (CABG) operations.[3] Patients with impaired renal function undergoing CABG surgery present a higher operative risk, a higher incidence of morbidity and need for dialysis, and prolonged hospital length of stay after CABG.[4]

Elevated serum creatinine (Cr) level is not a reliable screening test for renal impairment because it has important limitations. Serum Cr level varies with factors aside from renal function, such as age, sex, muscle mass, hypertension, and metabolism; therefore, it can remain within the normal range even when renal function is significantly impaired.[5] Creatinine clearance (CrCl), as an alternative measure of preoperative renal reserve, is the most useful clinical estimate of glomerular filtration rate. Direct measurement of CrCl is more accurate, but cumbersome, and not a possible option in routine clinical practice or large clinical studies.[6] Using prediction formulas that estimate glomerular filtration rate with moderate precision and accuracy would be a practical solution. Among the formulas, the Cockcroft–Gault equation was chosen because it is calculated by readily available clinical data and is reasonably associated with measured CrCl in patients with cardiac disease.[7,8]

The aims of this study were (1) to define the preoperative demographics as well as intraoperative and postoperative characteristics of patients undergoing CABG who have occult RI (serum Cr ≤ 1.1 mg/dL and CrCl ≤ 60 mL/min) and (2) to examine the hypothesis whether CABG patients with occult RI incur greater morbidity and mortality than CABG patients with normal renal function (NRF) (serum Cr ≤ 1.1 mg/dL and CrCl > 60 mL/min).

METHODS

Demographic, intraoperative, and in-hospital outcome data were collected prospectively and entered into a computerized database on all patients undergoing cardiac surgery at our institution (Tehran Heart Center). After institutional ethics approval was obtained, the records of all 11,884 patients aged 21 years and older undergoing pure CABG between January 2002 and February 2007 were retrieved from this database for analysis. Other cardiac procedures such as cardiac valve surgery and surgery for congenital heart disease were excluded from the study.

Because of the retrospective nature of the study, requirement for written informed consent was waived by the ethics committee. All entries were based on definitions of the Society of Thoracic Surgeons. Patients' data

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Abbreviations and Acronyms

BMI = body mass index
BSA = body surface area
CABG = coronary artery bypass graft
Cr = creatinine
CrCl = creatinine clearance
NRF = normal renal function
RI = renal insufficiency

included the following variables: age, sex, body mass index (BMI), history of smoking, hypertension, peripheral vascular disease, chronic obstructive pulmonary disease, and cerebrovascular accident, as well as left ventricular ejection fraction, left main coronary artery involvement, and number of significant coronary arteries involved. The operation data, such as aortic crossclamp time and use of intra-aortic balloon pump, and the outcome of CABG, including in-hospital mortality and postoperative complications such as stroke, renal failure, prolonged ventilation, prolonged length of stay (>7 days), and atrial fibrillation, were also gathered.

Postoperative renal failure was defined as acute or worsening renal failure after CABG resulting in one or more of the following: increase of serum Cr more than 2 mg/dL (176.8 μmol/L) or a new requirement for dialysis. Prolonged ventilation was defined as pulmonary insufficiency requiring ventilator support including but not limited to causes such as adult respiratory disease syndrome, pulmonary edema, and/or any patient ventilated more than 24 hours postoperatively. Postoperative atrial fibrillation was defined as new-onset atrial fibrillation necessitating treatment for symptoms or hemodynamic compromise that did not include recurrence of atrial fibrillation that had been present preoperatively. Postoperative stroke was defined as any neurologic deficit of abrupt onset resulting from a disturbance in cerebral blood supply documented by the neurologist on the basis of the brain imaging pictures that did not resolve within 24 hours.

Renal function was assessed by serum Cr, and CrCl was estimated by the Cockcraft–Gault equation.[7,8] In all patients, serum Cr level in milligrams per deciliter was determined preoperatively.

The Cockroft–Gault equation was selected as the most consistently favored algorithm to calculate preoperative and postoperative CrCl.[9] The following equation was used for men:

$$\text{CrCl} = ([140 - \text{age}] \cdot \text{weight})/(\text{serum Cr} \cdot 72).$$

Units are weight (kg), age (years), and serum Cr (mg/dL).

The proportion of muscle mass on body weight is relatively lower in women than in men. Therefore, the calculated value of CrCl was multiplied by the factor of 0.85 in female patients.

The Cockroft–Gault equation was adjusted for body surface area (BSA) by multiplying by (1.73/BSA) mL $\cdot$ min^{-1} per 1.73 m^2, with BSA calculated by the following DuBois formula: BSA (m^2) = (weight [kg]) 0.425 $\cdot$ (height [cm]) 0.725 $\cdot$ 0.007184.[10,11]

Patients were divided into four categories on the basis of preoperative renal function as follows: NRF (serum Cr $\leq$ 1.1 mg/dL and CrCl > 60 mL/min), occult RI (serum Cr $\leq$ 1.1 mg/dL and CrCl $\leq$ 60 mL/min), mild RI (1.1 mg/dL < serum Cr $\leq$ 1.5 mg/dL and CrCl $\leq$ 60 mL/min), or moderate RI (serum Cr >1.5 mg/dL and CrCl $\leq$ 60 mL/min). Patients with severe preoperative RI, defined as serum Cr greater than 3.4 mg/dL, were excluded.

Statistical Analysis

Numerical variables were presented as mean $\pm$ SD, and categorized variables were summarized by absolute frequencies and percentages in parentheses. Continuous variables were compared by the Student's *t* test and categorized variables were compared by the χ^2 test (or Fisher's exact test as required) across two groups (with NRF and with occult RI).

Multivariable logistic regression models were established to compare outcome variables including postoperative renal failure, mortality, and prolonged hospital stay across four groups with the presence of confounders such as age, sex, and BMI. Variables entered into the multivariable model if the *P* value in the univariable analysis was found to be less than or equal to .15. For each analysis, patients with NRF served as the reference group against which all others were compared. All analyses were conducted with SPSS software (version 13.0; SPSS, Inc, Chicago, Ill) and version 9.1 of the SAS System for Windows (SAS Institute, Inc, Cary, NC). All *P* values were 2-tailed.

RESULTS

During the study period, 11,933 patients underwent isolated CABG. A total of 49 patients were excluded owing to severe preoperative RI (24 patients) or dialysis dependency (25 patients). Table 1 reveals demographics and operative characteristics of 11,884 patients included in the study, categorized by renal function.

The entire patient cohort consisted of 8860 (74.6%) men and 3024 (25.4%) women. The mean age for all patients was 58.7 $\pm$ 9.6 years. Occult RI was present in 706 (5.9%) of our patients, and almost 1 in 10 of the studied patients with a normal preoperative serum Cr (serum Cr $\leq$ 1.1mg/dL) was found to have CrCl of 60 mL/min or less. As shown in Table 1, patients with occult RI were more likely to be women, older, and had a lower BMI than patients with NRF (All *P* values < .001). Patients with occult RI had also more frequent preoperative comorbidities such as hypertension, peripheral vascular disease, and triple coronary vessel disease, whereas cigarette smoking was less common in the occult RI group than in the NRF group.

Operative data are also shown in Table 1. Rate of intra-aortic balloon pump use was significantly higher in the occult RI group than in the NRF group. Patients with NRF had a longer aortic crossclamp time than did the occult RI group (43.3 $\pm$ 13.4 vs 41.3 $\pm$ 14.0 minutes; *P* < .001).

Postoperative results are listed in Table 2. Patients with occult RI had more than threefold increased rate of in-hospital mortality and nearly threefold increased prevalence of postoperative RI as compared with patients with NRF (*P* < .001 and *P* = .020, respectively).

Risk-adjusted outcomes for various groups of patients based on renal function are reported in Table 3. The following variables were included in the multivariable analyzing model: patient categories based on renal function, age, left ventricular ejection fraction, BMI, sex, cigarette smoking, hypertension, preoperative cerebrovascular accident, peripheral vascular disease, triple coronary artery involvement, left main coronary artery involvement, intra-aortic balloon pump usage, aortic crossclamp time, as well as postoperative atrial fibrillation, prolonged ventilation, and stroke. In addition, outcomes such as prolonged hospital stay (>7 days), postoperative renal failure, and in-hospital mortality were

TABLE 1. Baseline and intraoperative characteristics of the study patients stratified by renal function

	Entire population (n = 11,884)	NRF (n = 7856)	Occult RI (n = 706)	Mild RI (n = 2353)	Moderate RI (n = 969)	*P* value for NRF vs occult RI
Characteristics						
Male gender	8860 (74.6)	6037 (76.8)	241 (34.1)	1789 (76.0)	793 (81.8)	<.001
Age (y)	58.7 ± 9.6	55.4 ± 8.7	68.6 ± 6.0	65.4 ± 7.0	61.9 ± 9.3	<.001
BMI (kg/m^2)	27.1 ± 4.0	27.7 ± 3.9	24.8 ± 3.6	26.04 ± 3.6	27.0 ± 3.9	<.001
Cr concentration (mg/dL)	1.16 ± 0.28	1.05 ± 0.18	1.05 ± 0.06	1.33 ± 0.10	1.81 ± 0.31	.655
CrCl (mL/min)	68.7 ± 19.4	78.8 ± 15.5	55.0 ± 4.4	51.3 ± 5.8	39.7 ± 7.5	<.001
Comorbid disease						
Diabetes mellitus	3731 (31.4)	2446 (31.1)	250 (35.4)	705 (30)	330 (34.1)	.190
Hypertension	6296 (53.0)	3969 (50.5)	436 (61.8)	1319 (56.1)	572 (59)	<.001
Cigarette smoker	4655 (39.2)	3344 (42.6)	129 (18.3)	804 (34.2)	378 (39)	<.001
History of COPD	290 (2.4)	176 (2.2)	23 (3.3)	64 (2.7)	27 (2.8)	.080
History of CVA	818 (6.9)	475 (6)	53 (7.5)	192 (8.2)	98 (10.1)	.122
PVD	183 (1.5)	90 (1.1)	14 (2.0)	42 (1.8)	37 (3.8)	.050
Left main coronary involvement	1175 (9.9)	704 (9)	75 (10.6)	281 (11.9)	115 (11.9)	.141
3VD involvement	8825 (74.3)	5732 (73)	542 (76.8)	1809 (76.9)	742 (76.6)	.029
LVEF (%)	49.3 ± 10.0	49.5 ± 9.8	51.0 ± 9.8	48.7 ± 10.3	47.3 ± 10.9	<.001
Surgical details						
IABP usage	316 (2.7)	171 (2.2)	30 (4.2)	76 (3.2)	39 (4.0)	<.001
Elective surgery	10334 (87.0)	6924 (88.1)	611 (86.5)	1984 (84.3)	815 (84.1)	.212
Aortic crossclamp time (min)	42.9 ± 13.3	43.3 ± 13.4	41.3 ± 14.0	42.0 ± 12.4	42.7 ± 13.1	<.001

NRF, Normal renal function; *RI,* renal insufficiency; *BMI,* body mass index; *Cr,* creatinine; *CrCl,* creatinine clearance; *COPD,* chronic obstructive pulmonary disease; *CVA,* cerebrovascular accident; *PVD,* peripheral vascular disease; *3VD,* triple coronary vessel disease; *LVEF,* left ventricular ejection fraction; *IABP,* intra-aortic balloon pump. All continuous variables are presented as mean ± standard deviation; all categorical variables are presented as number and percentages within parentheses.

assessed across four groups (on the basis of renal function) in a logistic regression analysis model.

Multivariable logistic regression analysis demonstrated that patients with occult RI were at higher risk for mortality than patients with NRF (odds ratio = 2.59, 95% confidence interval 1.15–5.86; $P = .02$). Prevalence of prolonged hospital stay was also significantly higher in the occult RI group as well as the mild RI group and individuals with moderate RI in comparison with the NRF group.

On the basis of conventional methods of postoperative RI definition by using serum Cr cutoff, only patients with moderate RI were at higher risk of postoperative renal failure compared with the group with NRF. However, patients with occult RI or mild RI did not show a significantly higher risk of postoperative renal failure as compared with patients with NRF.

DISCUSSION

The association between preoperative and postoperative renal failure on one hand and the adverse outcome in cardiac surgery on the other is well established.[2,12] Renal function is an important determinant of in-hospital mortality in cardiac surgery,[13] and when it is severe enough to require dialysis, morbidity and mortality are markedly increased despite dialysis and supportive intensive care.[14] However, there is modest information on the effects of lesser degrees of renal failure on operative outcome.[15,16] Moreover, renal function was mostly detected by checking the serum Cr levels as a diagnostic test.[16,17] However, use of serum Cr has been questioned in several reports as it can be normal even when renal function is impaired, and it may underestimate mild-to-moderate degrees of RI.[18,19]

TABLE 2. Postoperative characteristics of the study patients stratified by renal function

Outcomes	Entire population (n = 11,884)	NRF (n = 7856)	Occult RI (n = 706)	Mild RI (n = 2353)	Moderate RI (n = 969)	*P* value for NRF vs occult RI
In-hospital mortality, n (%)	106 (0.9)	42 (0.5)	13 (1.8)	32 (1.4)	19 (2)	<.001
Postoperative renal failure, n (%)	87 (0.7)	34 (0.4)	8 (1.1)	17 (0.7)	28 (2.9)	.020
Prolonged mechanical ventilation, n (%)	133 (1.1)	64 (0.8)	12 (1.7)	36 (1.5)	21 (2.2)	.010
Prolonged hospital stay (>7 d), n (%)	3780 (31.8)	2189 (27.9)	298 (42.2)	910 (38.7)	383 (39.5)	<.001
ICU stay (h), (mean ± SE)	40.6 ± 32.0	39.1 ± 0.3	44.4 ± 1.3	42.3 ± 0.7	45.4 ± 1.1	<.001
Atrial fibrillation, n (%)	711 (6.0)	356 (4.5)	69 (9.8)	199 (8.5)	87 (9)	<.001
Stroke, n (%)	36 (0.3)	17 (0.2)	4 (0.6)	9 (0.4)	6 (0.6)	.089

NRF, Normal renal function; *RI*, renal insufficiency; *ICU*, intensive care unit; *SE*, standard error.

TABLE 3. Multivariable analysis of adjusted risk of postoperative outcomes including prolonged hospital stay, renal failure, and in-hospital mortality

	Odds ratio	95% CI	*P* value
Prolonged hospital stay (>7 d)			
Normal renal function	1*	—	—
Occult RI	1.302	1.082–1.567	.0052
Mild RI	1.293	1.121–1.492	.0004
Moderate RI	1.517	1.163–1.978	.0021
Postoperative renal failure			
Normal renal function	1*	—	—
Occult RI	2.099	0.816–5.396	.1239
Mild RI	1.174	0.582–2.370	.6538
Moderate RI	5.492	3.036–9.934	<.0001
In-hospital mortality			
Normal renal function	1*	—	—
Occult RI	2.592	1.147–5.857	.0220
Mild RI	2.402	1.145–5.040	.0204
Moderate RI	5.651	1.499–21.309	.0106

CI, Confidence interval; *RI,* renal insufficiency. *Reference group.

Browner, Li, and Mangano[20] initially suggested impaired renal function as a significant predictor of postoperative mortality after noncardiac surgery. More recently, Mangano and associates[1] reported outcomes in more than 2200 patients undergoing CABG with or without valvular surgery, revealing that 14% of their study population had at least some degrees of impaired renal function before myocardial revascularization and that the pre-existing mild renal failure (preoperative serum Cr of 1.4–2.0 mg/dL equivalent to 123.8–176.8 μmol/L) was an independent predictor of developing acute renal failure after CABG surgery.

In contrast to our study, Wijeysundera and associates[5] reported that risk of acute renal failure necessitating renal replacement therapy is higher in the group with occult RI (serum Cr $\leq$ 100 μmol/L and CrCl $\leq$ 60 mL/min), and there was no significant difference between the occult and mild RI groups with regard to risk of renal replacement therapy. One reason for that could be the fact that their criteria for RI definition were stricter than ours.

Wijeysundera and associates[5] also showed that patients with occult RI were more likely to be elderly women with lower BMI, which was similar to our findings.

Data from our analyses confirm and extend most of these observations.

We suggested that the risk of postoperative mortality and prolonged hospital stay increases when CrCl falls below 60 mL/min, even if serum Cr is in the normal range. In addition, although in our study patients with occult RI experienced a higher rate of acute renal failure than did the NRF group, calculation of CrCl was only related to the outcomes in univariable analysis and not in the adjusted multivariable model. As stated before, it seems that our criteria for definition of post-CABG renal failure should be restricted and even CrCl estimation taken into account.

LIMITATIONS

First, our study was observational and retrospective in nature, possibly restricting us to identify and analyze all potential confounders. Second, although no formula is more widely used and accepted for predicting CrCl than that proposed by Cockcroft and Gault, it does not provide absolutely accurate results, particularly in elderly patients, as compared with values obtained from plasma and 24-hour urine collection samples.[21] Finally, out hospital complications and mortality could not be assessed owing to lack of follow-up data in the hospital records.

CONCLUSION

The current study suggests that the significantly greater mortality and morbidity in CABG patients with occult RI than CABG patients with NRF may remain unrecognized by physicians who rely on serum Cr abnormalities alone to identify RI. Therefore, we recommend preoperative calculation of CrCl as well as serum Cr to estimate renal function, especially in older women with lower BMI, to identify higher-risk patients requiring special intensive care and in whom new interventions can be performed to improve outcome. These interventions may include decisions on the best procedural method (off-pump vs on-pump), drug adjustment, particularly antibiotics on the basis of CrCl, hemodynamic care, especially blood pressure control during CPB, request for a renal consult, preoperative hemodialysis if required, and preparation for immediate postoperative hemodialysis or continuous renal replacement therapy on demand.

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References

1. Mangano CM, Diamondstone LS, Ramsay JG, Aggarwal A, Herskowitz A, Mangano DT. Renal dysfunction after myocardial revascularization: risk factors, adverse outcomes, and hospital resource utilization. The Multicenter Study of Perioperative Ischemia Research Group. *Ann Intern Med*. 1998;128:194-203.
2. Weerasinghe A, Hornick P, Smith P, Taylor K, Ratnatunga C. Coronary artery bypass grafting in non–dialysis-dependent mild-to-moderate renal dysfunction. *J Thorac Cardiovasc Surg*. 2001;121:1083-9.
3. Massad MG, Kpodonu J, Lee J, Espat J, Gandhi S, Tevar A, et al. Outcome of coronary artery bypass operations in patients with renal insufficiency with and without renal transplantation. *Chest*. 2005;128:855-62.
4. Zakeri R, Freemantle N, Barnett V, Lipkin GW, Bonser RS, Graham TR, et al. Relation between mild renal dysfunction and outcomes after coronary artery bypass grafting. *Circulation*. 2005;112(9 Suppl):I270-5.
5. Wijeysundera DN, Karkouti K, Beattie WS, Rao V, Ivanov J. Improving the identification of patients at risk of postoperative renal failure after cardiac surgery. *Anesthesiology*. 2006;104:65-72.
6. Cittanova ML, Zubicki A, Savu C, Montalvan C, Nefaa N, Zaier K, et al. The chronic inhibition of angiotensin-converting enzyme impairs postoperative renal function. *Anesth Analg*. 2001;93:1111-5.
7. Cockcroft DW, Gault MH. Prediction of creatinine clearance from serum creatinine. *Nephron*. 1976;16:31-41.
8. Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new

prediction equation. Modification of Diet in Renal Disease Study Group. *Ann Intern Med*. 1999;130:461-70.
9. Robertshaw M, Lai KN, Swaminathan R. Prediction of creatinine clearance from plasma creatinine: comparison of five formulae. *Br J Clin Pharmacol*. 1989;28: 275-80.
10. Lin J, Knight EL, Hogan ML, Singh AK. A comparison of prediction equations for estimating glomerular filtration rate in adults without kidney disease. *J Am Soc Nephrol*. 2003;14:2573-80.
11. Rossing P, Astrup AS, Smidt UM, Parving HH. Monitoring kidney function in diabetic nephropathy. *Diabetologia*. 1994;37:708-12.
12. Lok CE, Austin PC, Wang H, Tu JV. Impact of renal insufficiency on short- and long-term outcomes after cardiac surgery. *Am Heart J*. 2004;148:430-8.
13. Walter J, Mortasawi A, Arnrich B, Albert A, Frerichs I, Rosendahl U, et al. Creatinine clearance versus serum creatinine as a risk factor in cardiac surgery. *BMC Surg*. 2003;3:4.
14. Chertow GM, Lazarus JM, Christiansen CL, Cook EF, Hammermeister KE, Grover F, et al. Preoperative renal risk stratification. *Circulation*. 1997;95:878-84.
15. Anderson RJ, O'Brien M, MaWhinney S, VillaNueva CB, Moritz TE, Sethi GK, et al. Renal failure predisposes patients to adverse outcome after coronary artery bypass surgery. VA Cooperative Study #5. *Kidney Int*. 1999; 55:1057-62.
16. Wouters SC, Noyez L, Verheugt FW, Brouwer RM. Preoperative prediction of early mortality and morbidity in coronary bypass surgery. *Cardiovasc Surg*. 2002;10:500-5.
17. Nashef SA, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R. European system for cardiac operative risk evaluation (EuroSCORE). *Eur J Cardiothorac Surg*. 1999;16:9-13.
18. Duncan L, Heathcote J, Djurdjev O, Levin A. Screening for renal disease using serum creatinine: who are we missing? *Nephrol Dial Transplant*. 2001;16:1042-6.
19. Swedko PJ, Clark HD, Paramsothy K, Akbari A. Serum creatinine is an inadequate screening test for renal failure in elderly patients. *Arch Intern Med*. 2003; 163:356-60.
20. Browner WS, Li J, Mangano DT. In-hospital and long-term mortality in male veterans following noncardiac surgery. The Study of Perioperative Ischemia Research Group. *JAMA*. 1992;268:228-32.
21. Baracskay D, Jarjoura D, Cugino A, Blend D, Rutecki GW, Whittier FC. Geriatric renal function: estimating glomerular filtration in an ambulatory elderly population. *Clin Nephrol*. 1997;47:222-8.