Acute kidney injury based on KDIGO (Kidney Disease Improving Global Outcomes) criteria in patients with elevated baseline serum creatinine undergoing cardiac surgery

Lesão renal aguda baseada nos critérios KDIGO (Kidney Disease: Improving Global Outcomes) em pacientes com creatinina sérica elevada submetidos à cirurgia cardíaca

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Abstract

Introduction: Preoperatively elevated serum creatinine (SCr) is considered an independent risk factor for morbidity and mortality after cardiac surgery. The aim of this study was to apply the Kidney Disease Improving Global Outcomes classification for acute kidney injury in a population of patients with preoperatively elevated serum creatinine who underwent cardiac surgery (coronary artery bypass grafting or cardiac valve surgery) and to evaluate the acute worsening of renal function as a predictor of 30-day mortality.

Methods: This was a single-center retrospective study that included patients from the Postoperative Cardiac Surgery Intensive Care Unit of the Hospital de Base, São José do Rio Preto Medical School. Demographics, type of surgery, laboratory data and pre, peri and postoperative data were obtained from a prospectively collected database. From January 2003 to June 2013, 2,878 patients underwent cardiac surgery, either coronary artery bypass grafting or cardiac valve surgery, at the Hospital de Base de São José do Rio Preto Medical School. Out of those, 918 showed elevated preoperative serum creatinine, with SCr > 1.30 mg/dL for men and > 1.00 mg/dL for women. Five hundred and forty nine patients (60%) undergoing coronary artery bypass grafting or cardiac valve surgery, at the Hospital de Base of São José do Rio Preto Medical School. Out of those, 918 showed elevated preoperative serum creatinine, with SCr > 1.30 mg/dL for men and > 1.00 mg/dL for women. Five hundred and forty nine patients (60%) undergoing coronary artery bypass grafting or cardiac valve surgery, at the Hospital de Base of São José do Rio Preto Medical School. Out of those, 918 showed elevated preoperative serum creatinine, with SCr > 1.30 mg/dL for men and > 1.00 mg/dL for women. Five hundred and forty nine patients (60%) undergoing coronary artery bypass grafting or cardiac valve surgery, at the Hospital de Base of São José do Rio Preto Medical School.

Multivariate Cox Proportional Hazard Model (stepwise) was used to assess the relationship between AKI and mortality at 30 days.

Results: Out of the 918 patients studied, 391 (43%) had postoperative AKI: 318 (35%) had Kidney Disease Improving Global Outcomes stage 1, 27 (2.9%) had Kidney Disease Improving Global Outcomes stage 2, and 46 (5.0%) had Kidney Disease Improving Global Outcomes stage 3. Patients in every stage of acute kidney injury showed progressive increase in EuroSCORE values, 30-day mortality rates cardiopulmonary bypass duration, and intensive care length of stay. Among patients classified as Kidney Disease Improving Global Outcomes stage 3, 76% required dialysis with a 30-day mortality of 66%. The Cox proportional hazards model showed that the hazard ratio for 30-day mortality was 4.8 for Kidney Disease Improving Global Outcomes stage 1 patients, 13.5 for Kidney Disease Improving Global Outcomes stage 2 patients, and 20.8 for Kidney Disease Improving Global Outcomes stage 3 patients (P<0.001 for all). Subgroup analyses (coronary artery bypass grafting and cardiac valve surgery) had similar results.

Conclusion: In this population, acute kidney injury based on the Kidney Disease Improving Global Outcomes criteria was a powerful predictor of 30-day mortality in patients with elevated preoperative serum creatinine who underwent cardiac surgery (coronary artery bypass grafting or cardiac valve surgery).

Descriptors: Acute Kidney Injury. Creatinine. Cardiovascular Surgical Procedures. Hospital Mortality.

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INTRODUCTION

As the population ages, more patients with renal dysfunction are being referred for cardiac surgery[1]. Elevated serum creatinine (SCr) preoperatively is considered an independent risk factor for morbidity and mortality after cardiac surgery[2,3], with the overall risk of death for patients with creatinine ≥ 1.5 mg/dL ranging from 5% to 30%. Postoperatively, small changes in SCr, however small they may be, are also associated with a significant reduction in survival[4,5]. Elevated SCr may be associated with increased morbidity and mortality even when its change does not meet the criteria for acute kidney injury (AKI)[6].

Several consensus definitions have been developed to provide uniform criteria for AKI diagnosis. In 2004, the “Acute Dialysis Quality Initiative (ADQI)” group proposed consensus guidelines and evidence-based treatment and prevention of AKI, which were later called the RIFLE criteria (Risk, Injury, Failure, Loss and End-stage Kidney Disease)[7]. The modification of these criteria was subsequently proposed by the “Acute Kidney Injury Network” (AKIN, which included the ADQI group)[8-10]. More recently, the AKI study group “Kidney Disease: Improving Global Outcomes (KDIGO)” proposed a modified definition, combining the differences between the RIFLE and AKIN definitions[11] (Table 1).

The aim of this study was to apply the criteria for AKI based on the KDIGO classification in a population of patients with preoperative SCr above normal limits after cardiac surgery [coronary artery bypass grafting (CABG) or cardiac valve surgery (CVS)] and to evaluate acute worsening of renal function as a predictor of risk of 30-day mortality.

METHODS

Patient selection

This was a single-center study. We carried out a retrospective evaluation in patients from the Cardiac Surgery Intensive Care Unit at a Brazilian Medical School Center. Demographics, type of surgery, laboratory data and information of pre, peri and postoperative periods were obtained from a prospectively collected database of 2,878 patients who were older than 18

Lesão renal aguda pelos critérios Kidney Disease Improving Global Outcomes destaca-se como excelente preditor de óbito em 30 dias em indivíduos submetidos à revascularização miocárdica ou cirurgia valvar que apresentam creatinina sérica alterada no pré-operatório (CrS > 1.30 mg/dL para homens e > 1.00 mg/dL para mulheres), compreendendo 549 pacientes (60%) submetidos à revascularização miocárdica e 369 pacientes (40%) submetidos à cirurgia valvar. O modelo de riscos proporcionais de Cox foi utilizado para avaliar a relação entre lesão renal aguda e mortalidade em 30 dias.

Resultados: Nesta casuística, 391 pacientes (43%) apresentaram lesão renal aguda no pós-operatório, sendo 318 (35%) Kidney Disease Improving Global Outcomes estágio 1, 27 (2,9%) Kidney Disease Improving Global Outcomes estágio 2 e 46 (5,0%) Kidney Disease Improving Global Outcomes estágio 3. EuroSCORE, mortalidade em 30 dias, tempo de circulação extracorpórea e permanência em ambiente de terapia intensiva aumentaram progressivamente em todos os estágios. Dentre os pacientes classificados como Kidney Disease Improving Global Outcomes 3, 76% necessitaram diálise com mortalidade em 30 dias de 66%. A análise de Cox evidenciou razão de risco para óbito em 30 dias de 4,8 para pacientes Kidney Disease Improving Global Outcomes estágio 1, 13,5 para pacientes Kidney Disease Improving Global Outcomes estágio 2 e 20,8 para pacientes com Kidney Disease Improving Global Outcomes estágio 3 (P<0,001 para todos). Análise dos subgrupos (revascularização miocárdica e cirurgia valvar) obteve resultados semelhantes.

Conclusão: Lesão renal aguda pelos critérios Kidney Disease Improving Global Outcomes destaca-se como excelente preditor de óbito em 30 dias em indivíduos submetidos à revascularização miocárdica ou cirurgia valvar que apresentam creatinina sérica pré-operatória alterada.

Descritores: Lesão Renal Aguda. Creatinina. Procedimentos Cirúrgicos Cardiovasculares. Mortalidade Hospitalar.
years and had undergone isolated CABG (1,786) or CVS (1,092) from January 2003 to June 2013. We excluded 51 patients with incomplete data, 23 dialysis patients and 1,886 patients with preoperative SCr within normal limits (Men – SCr ≤ 1.30 mg/dL / Women – SCr ≤ 1.00 mg/dL). After applying the exclusion criteria, 918 patients were analyzed [549 (60%) underwent CABG and 369 (40%) underwent CVS] (Figure 1).

This study was approved by the local Research Ethics (CAAE: 5974/2008). Because of its observational nature, informed consent was waived. This research fully adheres to Resolution 466/2012 of the National Health Council (CNS).

Serum Creatinine Measurement
The Jaffe colorimetric method (ADVIATM 1650, Bayer, Germany) was used to measure SCr concentration. The reference value for adults is 0.6 to 1.3 mg/dL for men and 0.6 to 1.0 mg/dL for women.

Stages of AKI based on KDIGO Classification[11]
Stage 1: Increase in SCr ≥ 0.3 mg/dL (in 48 hours) or 1.5 to 1.9 multiplied by baseline SCr;
Stage 2: 2.0 to 2.9 multiplied by baseline SCr;
Stage 3: 3.0 or more multiplied by baseline; increase in SCr ≥ 4.0 mg/dL; or beginning of renal replacement therapy regardless of a previous KDIGO stage.

Data Analysis
The criteria for AKI were applied in 918 patients in the first seven postoperative days. Due to lack of data on urinary output, only SCr was used to determine the categories of AKI. According to the changes in SCr, the patients were classified as no AKI (KDIGO 0) and AKI stages 1, 2 or 3, based on the KDIGO criteria. Glomerular filtration rate (eGFR) was estimated by the Cockcroft-Gault[12] equation. The risk of postoperative death was assessed by EuroSCORE[13,14], in the absence of a specific tool for our population.

Statistical Analysis
Variables are presented as absolute numbers and percentages or median and interquartile ranges (25th and 75th percentile) when applicable. Continuous variables were compared using the nonparametric Mann-Whitney or Kruskal-Wallis tests, and the chi-square or Fisher’s exact test was used to compare categorical variables.

Table 1. Classification and staging for RIFLE, AKIN, and KDIGO criteria.

| Class          | RIFLE SCr or GFR | Stage | AKIN SCr | Stage | KDIGO SCr |
|----------------|------------------|-------|----------|-------|-----------|
| Risk           | Increased SCr x 1.5 or GFR decrease > 25% (within 7 days) | 1     | Increase in SCr ≥ 0.3 mg/dL or ≥ 150% to 200% (1.5- to 2-fold) from baseline (within 48 hours) | 1     | Increase in SCr by ≥ 0.3 mg/dL within 48 hours or increase in SCr 1.5 to 1.9 times baseline which is known or presumed to have occurred within the prior 7 days |
| Injury         | Increased SCr x 2.0 or GFR decrease > 50% | 2     | Increase in SCr to more than 200% to 300% (> 2- to 3-fold) from baseline | 2     | Increase in SCr to 2.0 to 2.9 times baseline |
| Failure        | Increased SCr x 3.0 or GFR decrease > 75% or SCr ≥ 4.0 mg/dL or acute increase ≥ 0.5 mg/dL | 3     | Increase in SCr to more than 300% (> 3-fold) from baseline or SCr ≥ 4.0 mg/dL with an acute increase of at least 0.5 mg/dL or initiation of renal replacement therapy | 3     | Increase in SCr to 3.0 times baseline or increase in SCr to ≥ 4.0 mg/dL or initiation of renal replacement therapy |
| Loss           | Persistent acute renal failure = complete loss of kidney function > 4 weeks |       |          |       |           |
| End Stage Kidney Disease | End stage of kidney disease (> 3 months) |       |          |       |           |

Modified from Bellomo et al.[7], Mehta et al.[8] and Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Work Group[11]
Univariate and multivariate Cox proportional hazards models (stepwise) were used to determine the association between AKI and 30-day mortality. The model was adjusted for age (years), gender (reference – female gender), type of surgery (reference – CVS), body mass index (kg/m²), diabetes mellitus (reference – non-diabetic), left ventricular function (reference – preserved left ventricular ejection fraction), cardiopulmonary bypass (CPB) times (min) and AKI (reference – KDIGO 0). The adjusted Hazard Ratio (HR) and 95% confidence intervals (95% CI) were calculated for the predictors. Cumulative survival graphics were built to demonstrate the AKI impact as a predictor of 30-day mortality. \( P \) values<0.05 were considered statistically significant (two-tailed). The data were analyzed using the IBM SPSS Statistical Package v.20 (IBM Corporation, Armonk, NY).

RESULTS

Baseline characteristics of the patients are shown in Table 2. Median age was 61 years and 52% of the patients were male. Twenty-seven percent of the patients had preoperative eGFR above 60 mL/min. SCr measured in the immediate postoperative period was slightly lower than the preoperative SCr suggesting hemodilution during surgery (Table 3).

Of the 918 patients studied, 391 (43%) developed AKI: 318 (35%) stage 1, 27 (2.9%) stage 2 and 46 (5.0%) stage 3 (Table 3). Fewer patients in stage 2 may be because the indication for dialysis automatically classifies the patient in stage 3. Any degree of AKI was associated with a significant increase in overall mortality at 30 days compared with patients with no AKI (Table 4). In univariate analysis, the hazard ratio for death at 30 days was 5.4 for patients with KDIGO stage 1, 16.8 for patients with KDIGO stage 2 and 27.2 for patients with KDIGO stage 3 (\( P^<0.001 \) for all).

Patients with AKI had higher EuroSCORE scores, but there was no difference in the percentage of patients at low, intermediate and high risk among the groups (Table 5). The 30-day mortality rate increased progressively in all KDIGO stages (Table 4). Time on CPB and intensive care length of stay also increased (Table 5). The proportion of patients who required mechanical ventilation for more than 24 hours after surgery increased from 6.3% for patients with KDIGO 0 to 67% among those with KDIGO 3 (Table 5). Of the patients with KDIGO 3, 76% required dialysis with a 30-day mortality rate of 66%. However, patients treated with dialysis were more severely ill, as demonstrated by the EuroSCORE calculated preoperatively [4 (2-6) vs. 8 (5-10)], \( P^<0.001 \).
Table 2. Baseline characteristics of patients who underwent cardiac surgery.

| Type of surgery                                      | All Patients (n = 918) |
|------------------------------------------------------|------------------------|
|                                                      | Median (Q1 – Q3) or N (%) |
| Coronary artery bypass grafting                      | 549 (60)               |
| Cardiac valve surgery                                | 369 (40)               |
| Multiple cardiac valve surgery                       | 156 (42)               |
| Cardiac valve surgery during active infective endocarditis | 38 (10)               |
| Age (years)                                          | 61 (52 - 68)           |
| Male gender                                          | 477 (52)               |
| Weight (kg)                                          | 70 (61 - 80)           |
| Height (m)                                           | 1.63 (1.56 – 1.70)     |
| Body mass index (kg/m²)                              | 26 (23 - 29)           |
| Diabetes Mellitus                                    | 248 (27)               |
| Left Ventricular Systolic Dysfunction (moderate/severe) | 203 (22)               |
| Intra-aortic balloon pump                            | 43 (7.8)               |
| Reoperation                                          | 134 (15)               |
| Additive EuroScore                                    | 4 (2 - 6)              |
| Low risk (< 3)                                       | 248 (27)               |
| Intermediate risk (3 to 5)                           | 402 (44)               |
| High risk (5)                                        | 268 (29)               |
| Cardiopulmonary bypass                              | 781 (85)               |
| Total cardiopulmonary bypass time (min)              | 94 (79 - 114)          |
| < 90 min                                             | 312 (40)               |
| 90 - 120 min                                         | 308 (40)               |
| > 120 min                                            | 161 (20)               |
| Total number of grafts                               | 3 (2 - 3)              |
| Total Intensive Care length of stay                  | 3 (2 - 6)              |

Q1= percentile 25; Q3= percentile 75; N= number of individuals

Table 3. Renal function of patients who underwent cardiac surgery.

| Preoperative SCr (mg/dL) | All Patients (n = 918) |
|--------------------------|------------------------|
| Median (Q1 – Q3) or N (%) |                       |
| 1.40 (1.20 – 1.60)       |                        |

Preoperative eGFR (mL/min)

| eGFR ≥ 90 mL/min | 49 (39 - 60) |
| eGFR 60 – 89 mL/min | 17 (20)   |
| eGFR 30 – 59 mL/min | 231 (25)  |
| eGFR ≤ 29 mL/min  | 603 (66)   |

Serum creatinine (mg/dL)

| Immediate postoperative day | 1.30 (1.10 - 1.60) |
| 1st Postoperative day       | 1.50 (1.20 - 1.90) |
| 2nd Postoperative day*      | 1.30 (1.0 - 1.80)  |

AKI in the first 7 days postoperatively

| KDIGO Stage 0 | 391 (43) |
| KDIGO Stage 1 | 527 (57) |
| KDIGO Stage 2 | 318 (35) |
| KDIGO Stage 3 | 27 (2.9) |
| KDIGO Stage 3 | 46 (5.0) |

RRT in the first 7 days postoperatively

| 35 (3.8) |

Q1 - percentile 25; Q3 - percentile 75; SCr - serum creatinine; eGFR - estimated glomerular filtration rate; RRT - renal replacement therapy.

*There was no determination of SCr on 2nd postoperative day for 34 patients
Table 4. Postoperative complications of patients who underwent cardiac surgery.

| Complication                                           | All Patients (n = 918) |
|--------------------------------------------------------|------------------------|
| Readmission to the intensive care unit from the ward   | 73 (8.0)               |
| Prolonged intensive care length of stay (> 14 days)    | 97 (11)                |
| Bleeding requiring surgical reintervention              | 27 (2.9)               |
| New atrial fibrillation                                 | 86 (9.4)               |
| Postoperative reintubation (within the first 7 days)    | 79 (8.6)               |
| Mechanical ventilation > 24 hours                       | 135 (17)               |
| Mediastinitis                                           | 30 (3.3)               |
| Type I neurological injury                              | 42 (4.6)               |
| 30-day mortality                                        | 96 (10)                |

Q1 - percentile 25; Q3 - percentile 75; N - number of individuals

Table 5. Demographic data of patients who underwent cardiac surgery based on the KDIGO criteria.

| KDIGO | Median (Q1 – Q3) or N (%) | P-value |
|-------|---------------------------|---------|
| 0     | 319 (61) | 190 (60) | 16 (59) | 24 (52) | 0.745 |
| 1     | 208 (39) | 128 (40) | 11 (41) | 22 (48) | 0.533 |
| 2     | 81 (15)  | 60 (19)  | 5 (19)  | 10 (22) | 0.006 |
| 3     | 21 (4.0) | 9 (2.8)  | 1 (3.7) | 7 (15)  | <0.001 |

For Age (years), Male gender, Weight (kg), Height (m), Body mass index (kg/m²), Diabetes Mellitus, LVSD (moderate/severe), Intra-aortic balloon pump, Preoperative SCr (mg/dL), Preoperative eGFR (mL/min), Reoperation, Additive EuroSCORE, Low risk (< 3), Intermediate risk (3 to 5), High risk (5), CPB, Total CPB time (min), Total ICU length of stay, and Mechanical ventilation > 24 hours.

KDIGO 0: N = 527; KDIGO 1: N = 318; KDIGO 2: N = 27; KDIGO 3: N = 46

CVS - cardiac valve surgery; IE - infective endocarditis; LVSD - left ventricular systolic dysfunction; SCr - serum creatinine; eGFR - estimated glomerular filtration rate; CPB - cardiopulmonary bypass; ICU - intensive care unit
**Cox regression analysis**

In a multivariate analysis, age (years), CPB time (minutes) and AKI (KDIGO 1-3) were independent predictors of 30-day mortality, with KDIGO stage 3 being the strongest predictor. Male gender had a reduced risk of death at 30 days (Table 6, Figure 2). Subgroup analysis (CABG and CVS) demonstrated similar results, except for reduced risk of death among male patients who underwent CABG (data not shown).

![Fig. 2 - Overall survival curves of patients who underwent cardiac surgery, according to the KDIGO criteria.](image)

**DISCUSSION**

In our study, AKI after CABG or CVS was found to be common and associated with high rates of prolonged intensive care length of stay, morbidity and mortality. This study also demonstrated the importance of KDIGO AKI criteria as a powerful predictor of 30-day mortality in patients with preoperative SCr above normal limits. We found a higher risk of death in those with poor renal function as well as those who required dialysis; however, even slight increases in SCr postoperatively (KDIGO stage 1) were associated with a significant increase in mortality.

The reasons why small changes in SCr correlated with increased hospital mortality are not entirely clear. Possible explanations include the adverse effects of decreased renal function, such as volume overload, anemia, uremia, acidosis, electrolyte disturbances, and increased risk of infections\[11,15\]. Visual analysis of the survival curves graph of our study showed a continuous decrease of survival in patients who developed AKI, with a higher risk of death within the first week postoperatively (Figure 2).

Preoperative renal dysfunction is known as a postoperative risk predictor; however, in tools such as EuroSCORE\[13,14\], InsCor\[16\], and Parsonnet\[17\], preoperative renal dysfunction is considered a risk factor only in cases of advanced kidney disease (SCr>2.00 or 2.26 mg/dL) or in patients on dialysis. In its update published in 2012, called EuroSCORE II\[3\], assessment of renal function was included by calculating the eGFR, with values below 85 mL/min being a risk factor.

Estimates of preoperative renal function based on eGFR show that over 75% of patients undergoing CABG have an eGFR below 90 mL/min\[18\], highlighting the importance and high prevalence of renal dysfunction in patients undergoing heart surgery. Furthermore, these patients are older and have more comorbidities, such as cerebrovascular disease, peripheral artery disease, chronic obstructive pulmonary disease and diabetes mellitus\[18\].

Several studies have shown that slight changes in renal function have a significant impact on short and long term outcomes in patients undergoing cardiac surgery\[15,19-23\]. Other studies suggest that intraoperative factors such as CPB times are important contributors to postoperative renal dysfunction\[24-26\], as observed in our study (OR 1.01 - 95% CI 1.01 to 1.02, \( P \) value<0.001 - data not shown), but others have not demonstrated this direct relationship\[27,28\]. The use of off-pump CABG was also tested in preoperative renal dysfunction with contradictory results\[18,29,30\].

Many publications have reported preoperative renal dysfunction as a risk predictor for morbidity and postoperative mortality. Kumar et al.\[31\] identified class III obesity (BMI > 40 kg/m\(^2\)) as an independent predictor of AKI after on-pump CABG, and Brown et al.\[32\] found high rates of readmission within 30 days after cardiac surgery in patients who developed

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**Table 6. Cox proportional hazard model considering all patients who underwent cardiac surgery for predictors of 30-day mortality.**

| Predictor                              | HR (CI 95%)   | P-value |
|----------------------------------------|--------------|---------|
| Age (years)                            | 1.03 (1.01 - 1.05) | 0.007   |
| Male gender                            | 0.63 (0.42 – 0.95) | 0.028   |
| Total cardiopulmonary bypass time (min)| 1.01 (1.01 – 1.02) | < 0.001 |
| KDIGO Stage 0                          | Reference     |         |
| KDIGO Stage 1                          | 4.76 (2.55 – 8.88) | < 0.001 |
| KDIGO Stage 2                          | 13.54 (5.77 – 31.78) | < 0.001 |
| KDIGO Stage 3                          | 20.81 (10.14 – 42.69) | < 0.001 |

**HR - Hazard Ratio; CI - confidence interval**

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AKI. Zakeri et al. evaluated patients with mild to moderate impaired renal function (SCr < 2.26 mg/dL) who underwent CABG. Operative mortality was higher in this group of patients as well as the need for dialysis and occurrence of stroke post-operatively. Both the measurement of SCr as well as eGFR (< 60 mL/min) were independent predictors of hospital mortality and in a 3-year follow-up. Cooper et al. evaluated more than 483,000 patients using the American Society of Thoracic Surgeons database. Seventy-eight percent of patients had some degree of preoperative (CrCl < 90 mL/min) renal dysfunction. Mortality was inversely proportional to the renal function. In an adjusted model, the eGFR was one of the strongest predictors of morbidity and hospital mortality.

**Study limitations**

Our study has several limitations. First, these data originated from a single center. Although data were collected prospectively, the analysis was performed retrospectively. There was no determination of cause of death, which did not allow us to differentiate between cardiovascular death and death from all causes. Several known and unknown confounding variables could theoretically have influenced the observed mortality rates. Despite the use of multivariate models for control and adjustment of some of these variables, the possibility of the presence of other unknown confounders cannot be ruled out.

**CONCLUSION**

The development of AKI, based on KDIGO criteria, correlated with increased morbidity and was a robust predictor of 30-day mortality in patients with preoperative baseline SCr above normal limits undergoing coronary artery bypass grafting or cardiac valve surgery.

### Authors’ roles & responsibilities

| Role | Responsibilities |
|------|------------------|
| MNM  | Design of the project; data collection; statistical analysis; discussion of results; manuscript writing |
| MAN  | Discussion of results; manuscript writing, article review |
| LNM  | Discussion of results; manuscript writing, article review |

**REFERENCES**

1. 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(2):855-62.
2. Miceli A, Bruno VD, Capoun R, Romeo F, Angelini GD, Caputo M. Occult renal dysfunction: a mortality and morbidity risk factor in coronary artery bypass grafting surgery. J Thorac Cardiovasc Surg. 2011;141(3):771-6.
3. Nashef SA, Roques F, Sharples LD, Nilsson J, Smith C, Goldstone AR, et al. EuroSCORE II. Eur J Cardiothorac Surg. 2012;41(4):734-44.
4. Lassnigg A, Schmidlin D, Mouhieddine M, Bachmann LM, Druml W, Bauer P, et al. Minimal changes of serum creatinine predict prognosis in patients after cardiothoracic surgery: a prospective cohort study. J Am Soc Nephrol. 2004;15(6):1597-605.
5. Lassnigg A, Schmid ER, Hiesmayr M, Falk C, Druml W, Bauer P, et al. Impact of minimal increases in serum creatinine on outcome in patients after cardiothoracic surgery: do we have to revise current definitions of acute renal failure? Crit Care Med. 2008;36(4):1129-37.
6. Tolpin DA, Collard CD, Lee VV, Virani SS, Allison PM, Elayda MA, et al. Subclinical changes in serum creatinine and mortality after coronary artery bypass grafting. J Thorac Cardiovasc Surg. 2012;143(3):682-688.
7. Bellomo R, Ronco C, Kellum JA, Mehta RL, Palevsky P; Acute Dialysis Quality Initiative workgroup. Acute renal failure - definition, outcome measures, animal models, fluid therapy and information technology needs: the Second International Consensus Conference of the Acute Dialysis Quality Initiative (ADQI) Group. Crit Care. 2004;8(4):R204-12.
8. Mehta RL, Kellum JA, Shah SV, Molitoris BA, Ronco C, Warnock DG, et al; Acute Kidney Injury Network. Acute Kidney Injury Network: report of an initiative to improve outcomes in acute kidney injury. Crit Care 2007;11(2):R31.
9. Levin A, Warnock DG, Mehta RL, Kellum JA, Shah SV, Molitoris BA, et al; Acute Kidney Injury Network Working Group. Improving outcomes from acute kidney injury: report of an initiative. Am J Kidney Dis. 2007;50(1):1-4.
10. Molitoris BA, Levin A, Warnock DG, Joannidis M, Mehta RL, Kellum JA, et al; Acute Kidney Injury Network. Improving outcomes from acute kidney injury. J Am Soc Nephrol. 2007;18(7):1992-4.
11. Kidney Disease: Improving Global Outcomes (KDIGO) Acute Kidney Injury Work Group. KDIGO Clinical Practice Guideline for Acute Kidney Injury. Kidney Int Suppl. 2012;2:1-138.
12. Cockcroft DW, Gault MH. Prediction of creatinine clearance from serum creatinine. Nephron. 1976;16(1):31-41.
13. Nashef SA, Roques F, Michel P, Gauducheau E, Lemeshev S, Salamon R. European system for cardiac operative risk evaluation (EuroSCORE). Eur J Cardiothorac Surg. 1999;16(1):9-13.
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14. Roques F, Nashef SA, Michel P, Gauducheau E, de Vincentiis C, Baudet E, et al. Risk factors and outcome in European cardiac surgery: analysis of the EuroSCORE multinational database of 19030 patients. Eur J Cardiothorac Surg. 1999;15(6):816-22.

15. Hoste EA, Kellum JA. Acute renal failure in the critically ill: impact on morbidity and mortality. Contrib Nephrol. 2004;144:1-11.

16. Mejía OA, Lisboa LA, Puig LB, Moreira LF, Dallan LA, Pomerantz E, et al. InsCor: a simple and accurate method for risk assessment in heart surgery. Arq Bras Cardiol. 2013;100(3):246-54.

17. Parsonnet V, Dean D, Bernstein AD. A method of uniform stratification of risk for evaluating the results of surgery in acquired adult heart disease. Circulation. 1989;79(6 Pt 2):13-12.

18. Boulton BJ, Kilgo P, Guyton RA, Puskas JD, Lattouf OM, Chen EP, et al. Impact of preoperative renal dysfunction in patients undergoing off-pump versus on-pump coronary artery bypass. Ann Thorac Surg. 2011;92(2):595-601.

19. Devbhandari MP, Duncan AJ, Grayson AD, Fabri BM, Keenan DJ, Bridgewater B, et al. Effect of risk-adjusted, non-dialysis-dependent renal dysfunction on mortality and morbidity following coronary artery bypass surgery: a multi-centre study. Eur J Cardiothorac Surg. 2006;29(6):964-70.

20. Hirose H, Amano T, Takahashi A, Nagano N. Coronary artery bypass grafting for patients with non-dialysis-dependent renal dysfunction (serum creatinine \(\geq 2.0\) mg/dl). Eur J Cardiothorac Surg. 2001;20(3):565-72.

21. Simon C, Luciani R, Capuano F, Miceli A, Roscitano A, Tonelli E, et al. Mild and moderate renal dysfunction: impact on short-term outcome. Eur J Cardiothorac Surg. 2007;32(2):286-90.

22. 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):1270-5.

23. Filsoufi F, Rahmanian PB, Castillo JG, Chikwe J, Carpenter A, Adams DH. Early and late outcomes of cardiac surgery in patients with moderate to severe preoperative renal dysfunction without dialysis. Interact Cardiovasc Thorac Surg. 2008;7(1):90-5.

24. 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(3):194-203.

25. D’Onofrio A, Cruz D, Bolgan I, Aurieri S, Cresce GD, Fabbri A, et al. RIFLE criteria for cardiac surgery-associated acute kidney injury: risk factors and outcomes. Congest Heart Fail. 2010;16 Suppl 1:S32-6.

26. Rodrigues AJ, Evora PR, Bassetto S, Alves Júnior L, Scorzoni Filho A, Araújo WF, et al. Risk factors for acute renal failure after heart surgery. Rev Bras Cir Cardiovasc. 2009;24(4):441-6.

27. Jyrala A, Weiss RE, Jeffries RA, Kay GL. Effect of mild renal dysfunction (s-crea 1.2-2.2 mg/dl) on presentation characteristics and short- and long-term outcomes of on-pump cardiac surgery patients. Interact Cardiovasc Thorac Surg. 2010;10(5):777-82.

28. Pontes JC, Silva GV, Benfatti RA, Machado NP, Pontelli R, Pontes ER. Risk factors for the development of acute renal failure following on-pump coronary artery bypass grafting. Rev Bras Cir Cardiovasc. 2007;22(4):484-90.

29. Sajja LR, Mannam G, Chakravarthi RM, Sompalli S, Naidu SK, Somaraju B, et al. Coronary artery bypass grafting with or without cardiopulmonary bypass in patients with preoperative non-dialysis dependent renal insufficiency: a randomized study. J Thorac Cardiovasc Surg. 2007;133(2):378-88.

30. Tabata M, Takanashi S, Fukui T, Horai T, Uchimuro T, Kitabayashi K, et al. Off-pump coronary artery bypass grafting in patients with renal dysfunction. Ann Thorac Surg. 2004;78(6):2044-9.

31. Kumar AB, Bridget Zimmerman M, Suneja M. Obesity and post-cardiopulmonary bypass-associated acute kidney injury: a single-center retrospective analysis. J Cardiothorac Vasc Anesth. 2014;28(3):551-6.

32. Brown JR, Parikh CR, Ross CS, Kramer RS, Magnus PC, Chaisson K, et al. Northern New England Cardiovascular Disease Study Group. Impact of perioperative acute kidney injury as a severity index for thirty-day readmission after cardiac surgery. Ann Thorac Surg. 2014;97(1):111-7.

33. Cooper WA, O’Brien SM, Thouruni VH, Guyton RA, Bridges CR, Szczep LA, et al. Impact of renal dysfunction on outcomes of coronary artery bypass surgery: results from the Society of Thoracic Surgeons National Adult Cardiac Database. Circulation. 2006;113(8):1063-70.