

Acute Renal Failure after Coronary Artery Bypass Surgery with Extracorporeal Circulation – Incidence, Risk Factors, and Mortality

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Objective

To identify the incidence, risk factors, and mortality of acute renal failure (ARF) in patients undergoing myocardial coronary artery bypass surgery with extracorporeal circulation.

Methods

All patients undergoing myocardial coronary artery bypass surgery were prospectively studied, and their clinical and laboratory variables were assessed using uni- and multivariate analysis (logistic regression).

Results

Acute renal failure occurred in 16.1% of the 223 patients studied; 4.9% of patients required dialysis. Risk factors associated with ARF in the univariate analysis were: age > 63 years, OR 3.6 (95% CI=1.6 to 8.3); preoperative serum creatinine > 1.2 mg/dL, OR 5.9 (95% CI=2.4 to 14.6); duration of extracorporeal circulation > 90 min, OR 2.1 (95% CI=1.0 to 4.4); use of intraaortic balloon, OR 2.6 (95% CI=1.2 to 5.5); need for inotropic drugs, OR 4.4 (95% CI=1.9 to 10.2). In the multivariate analysis, independent factors associated with ARF were: age > 63 years, OR 3.0 (95% CI=1.3 to 7.2); preoperative serum creatinine > 1.2 mg/dL, OR 4.3 (95% CI=1.6 to 11.4); need for inotropic drugs, OR 3.2 (95% CI=1.3 to 8.0). Mortality in the patients with ARF was 25.0% compared with 1.1% in those without ARF and 63.6% in those who required dialysis.

Conclusion

Acute renal failure after myocardial coronary artery bypass surgery is a frequent complication associated with a high mortality rate. The independent risk factors are age, previous renal failure, and the need for inotropic drugs.

Key words

acute renal failure, coronary artery bypass surgery, cardiac surgery, extracorporeal circulation

Acute renal failure is a severe condition that occurs in 2.0% to 7.0% of patients during hospital stay¹⁻³. In 18.0% to 47.0% of cases, it is related to a surgical event, and acute tubular necrosis is the main type of lesion^{1,2,4}. The great variation in the incidence of acute renal failure among the studies presents a multifactor profile, including different diagnostic criteria, such as the study design, inclusion and exclusion criteria, profile of the patients and of the centers involved in the sample, hindering study comparisons⁵.

In cardiac surgery, its incidence ranges from 3.5% to 31.0%⁵⁻¹², and the need for dialysis occurs in 0.3% to 15.0% of cases⁵⁻¹⁸. The presence of acute renal failure in these patients increases the mortality rate from 0.4% to 4.4% to 1.3% to 22.3%, and when dialysis is required, these rates reach 25.0% to 88.9%⁵⁻¹⁸, making it an independent risk factor for mortality, according to Chertow et al¹⁶, and increasing 8-fold the death odds ratio among these patients.

The presence of conditions that determine hypoperfusion and renal ischemia are directly related to the development of ARF. Patients who present with reduced renal functional reserve, in whom a reduction occurs in the glomerular filtration rate without serum creatinine elevation above normal values, are more likely to have ARF even with minor renal lesions¹⁶. Preoperative and intraoperative factors, such as age, previous level of creatinine, diabetes mellitus, cardiac output, the duration of extracorporeal circulation, and the use of the intraaortic balloon, are influential in the development of ARF^{5-8,10-12,19}. The severity of ARF may increase with the occurrence of complications in the postoperative period, such as infections, hemorrhage, and the use of nephrotoxic substances²⁰.

In Brazil, few studies have reported the incidence of ARF after cardiac surgery, its risk factors, and its outcomes. The great impact of ARF in the outcomes of cardiac surgery demand its study in our population, encouraging to the elaboration of this study, which aims at identifying the incidence, risk factors, duration of ICU stay, and mortality due to ARF after myocardial coronary artery bypass surgery in a university hospital in Brazil.

Methods

From 10/1/2001 to 9/30/2002, 223 of 247 patients undergoing myocardial coronary artery bypass surgery were prospectively studied. Exclusion criteria were: surgery without extracorporeal circulation (12 patients), death within the first 24h after surgery

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(8 patients), preoperative serum creatinine > 3.0 mg/dL (2 patients), and incomplete examination results, making it impossible to define acute renal failure (2 patients).

The patients were followed-up after surgery until the 5th postoperative day, as long as they remained in the hospital. This follow-up would be carried out until death or until intensive care unit discharge to define the need for dialysis. In most patients, daily dosages of serum creatinine were maintained until the patients were discharged from the ICU.

Acute renal failure in the postoperative period was defined as the presence of serum creatinine \geq 1.8 mg/dL in patients with preoperative serum creatinine \leq 1.2 mg/dL, or with an increase > 0.5 mg/dL in the levels of creatinine in the postoperative period in patients with preoperative creatinine > 1.2 mg/dL and \leq 2.0 mg/dL, or 1.0 mg/dL increase in creatinine in the postoperative period in patients with preoperative creatinine > 2.0 mg/dL, or those patients who required dialysis in the first 5 postoperative days. Previous renal failure was defined as preoperative creatinine > 1.2 mg/dL.

Data collected regarding the preoperative period were age; gender; diabetes mellitus history; systemic blood hypertension; antihypertensive medication use; myocardial infarction or angina; stroke; history of peripheral vascular failure based on the presence of intermittent claudication or on Doppler diagnosis or on MMII arteriography compatible with vascular failure; heart failure according to the New York Heart Association (NYHA) classification defined by history of ICU stay, weight, height, creatinine, and number of coronary arteries with stenosis \geq 75%. Additionally, we have collected data concerning intraaortic balloon use, the need for inotropic medication until the second postoperative day, the number of arteries undergoing coronary artery bypass surgery, extracorporeal circulation duration, urinary flow, serum creatinine, ICU stay, and mortality during the study period.

The mean age of the 223 study patients was 62.5 ± 9.3 years, 151 (67.7%) were male, and 72 (32.3%) were female. Table I describes general and preoperative characteristics of the study population.

The method of dialysis used in patients requiring it was continuous hemodialyses or continuous hemofiltration.

The Student *t* test was used to compare continuous variables between the group that developed acute renal failure and those who did not develop it. Categorical variables were assessed using the chi-square test or Fisher's exact test. Some continuous variables were categorized using univariate analyses with a 2x2 table; a *P* value < 0.05 was defined as statistically significant. For the multivariate analysis of risk factors for acute renal failure, we used logistic regression analysis with a *P* value < 0.05 as statistically significant. SPSS software version 9.0 was used for all data analysis.

Results

Acute renal failure in the postoperative period occurred in 36 (16.1%) of the 223 study patients; of whom, 11 (30.6%), or 4.9% of all patients, required dialysis. Table II describes the comparative analysis of the patients regarding preoperative characteristics; and shows that average of age and previous serum creatinine were statistically significant when patients with or without acute renal failure were compared.

Risk factors associated with acute renal failure in the post-

Table I - Patients' general features	
Patients n=223	
Age (average in years)	62.5 SD \pm 9.3
Age > 63 years old	53.8%
Gender (male)	67.7%
Creatinine (average in mg/dL)	1.0 SD \pm 0.2
Previous renal failure	10.8%
Involved arteries	2.9 SD \pm 0.9
History of diabetes mellitus	35.0%
Systemic blood hypertension	74.0%
History of myocardial infarction or angina	80.3%
History of stroke	5.4%
History of myocardial coronary artery bypass surgery	4.9%
Peripheral vascular failure	4.0%
SD - standard deviation.	

operative period are presented in table III. Mean age was higher in the acute renal failure group, and, when it was categorized, based on the median value, it is the second factor most associated with its development. Mean duration of extracorporeal circulation in patients with acute renal failure (n=36) was 101.1 ± 25.6 min, higher than that of patients without it (n = 187), 87.4 ± 24.8 min (*P* < 0.001). This difference was significant when the median value of extracorporeal circulation duration was taken into account. Although the average of serum creatinine was higher in patients with acute renal failure, the presence of previous renal failure was significantly associated with the development of the syndrome. Other factors, such as diabetes history, systemic blood hypertension, previous angina or myocardial infarction, previous stroke, previous myocardial coronary artery bypass surgery, total number of arteries undergoing coronary artery bypass surgery, and peripheral vascular failure, described as significant in other studies did not have statistically significant differences in our study.

Logistic regression analysis was performed including, in the initial model, the risk factors included in the univariate analysis apart from peripheral vascular failure, because of its narrow correlation with the presence of diabetes. The need for inotropic drugs, as well as the use of an intraaortic balloon, reflects the presence of hemodynamic instability with a decrease in cardiac performance.

Table IV presents the results of the multivariate analysis. The duration of extracorporeal circulation was significant in the univariate analysis; however, it did not demonstrate statistical significance in the multivariate analysis, nor did diabetes mellitus, included in the analysis because of its significance demonstrated in other studies. Use of the intraaortic balloon wasn't significant in the statistical analysis, and the use of inotropic drugs remained an independent risk factor for acute renal failure, as well as renal failure in the perioperative period and age > 63 years.

Mean ICU stay was 4.2 ± 4.3 days. Among the patients with acute renal failure (n=36), it was 9.1 ± 7.8 days, and among the patients without it (n=187), it was 3.3 ± 2.2 days. This difference was statistically significant with *P* < 0.001.

The global mortality rate was 4.9% (11 out of 223). Among the patients that did not have acute renal failure, mortality was 1.1% (2 out of 187), lower than in those patients that had it, 25.0% (9 out of 36, *P* < 0.001). The relative risk of death was 23.4 (95% CI = 5.3 to 103.7) for the patients with the syndrome. Among the patients requiring dialysis, mortality was 63.6%

Preoperative variables	Patients with ARF n=36	Patients without ARF n=187	P value
Age (years)	68.14 (± 8.18)	61.45 (± 9.09)	0.001
Creatinine (mg/dL)	1.10 (± 0.28)	0.94 (± 0.20)	0.001
Involved arteries	3.03 (± 0.77)	2.91 (± 0.87)	0.448
Gender (male)	25 (69.4%)	126 (67.4%)	0.808
History of diabetes mellitus	14 (38.9%)	64 (34.2%)	0.591
Systemic blood hypertension	30 (83.3%)	135 (72.2%)	0.163
History of myocardial infarction or angina	29 (80.6%)	150 (80.2%)	0.962
History of stroke	1 (2.8%)	11 (5.9%)	0.422
History of myocardial coronary artery bypass surgery	2 (5.6%)	9 (4.8%)	0.693
Peripheral vascular failure	3 (8.3%)	6 (3.2%)	0.162

ARF - acute renal failure; SD - standard deviation.

Table III - Univariate analysis of risk factors for acute renal failure

Factors	Patients	OR	95% CI	P value
Age > 63 years	28/120 (23.3%)	3.61	1.57 a 8.34	0.002
Preoperative creatinine > 1.2 mg/dL	11/24 (45.8%)	5.89	2.38 a 14.57	< 0.001
Peripheral vascular failure	3/9 (33.3%)	2.74	0.65 a 11.51	0.152
Diabetes mellitus	14/78 (17.9%)	1.22	0.586 a 2.55	0.591
ECC duration > 90 min	21/95 (22.1%)	2.14	1.04 a 4.41	0.037
Intraaortic balloon use	14/51 (27.5%)	2.58	1.21 a 5.52	0.012
Need for inotropic drugs	12/31 (38.7%)	4.42	1.91 a 10.24	< 0.001

OR - odds ratio; CI - confidence interval; ECC - extracorporeal circulation. Need for inotropic drugs – need for dopamine or dobutamine, or both, from the immediate postoperative period until the second postoperative day.

Factors	OR	95% CI	P value
Age > 63 years	2.98	1.25 a 7.11	0.014
Preoperative creatinine > 1.2 mg/dL	4.98	1.93 a 12.83	0.001
Need for inotropic drugs	3.21	1.29 a 8.0	0.012

ARF - acute renal failure; OR - odds ratio; CI - confidence interval. Need for inotropic drugs – need for dopamine or dobutamine, or both, from the immediate postoperative period until the second postoperative day.

(7 out of 11), and among those patients not requiring it, it was 1.9% (4 out of 212, $P < 0.001$), the relative risk of death was 33.7 (95% CI=11.6 to 98.2). Among the 11 patients that died, 90.9% (10 out of 11) were > 63 years old.

Discussion

Acute renal failure, as a postoperative complication of heart surgery, is a severe event correlated with high mortality and morbidity rates^{21,22}. Mortality ranges from 3.5% to 31.0%^{5-12,16-19,23}, and this variation may be because of the criteria used for its diagnosis: the number and characteristics of hospitals involved in each study, the patients' features, and the size of the sample^{11,24}. These aspects hinder data comparison among the several studies performed.

In the present study, we considered serum creatinine variation as an index of renal function decrease; however, it is known that an increase in serum creatinine is a not very sensitive estimation of the decrease in renal function, because small increases may reflect substantial decreases in renal function, due to the exponential correlation curve between serum creatinine and renal function^{5,25}, just as the reduction in muscular mass, occurring with

aging, leads to a reduction in the production of creatinine and consequently in decreased serum levels of creatinine. The elderly, therefore, may have normal levels of serum creatinine, with creatinine clearance as low as 30 mL/min⁴.

Levey et al²⁵, using insulin clearance demonstrated that a reduction occurs in the glomerular filtration rate with age, around 10 mL/min at each decade. Thus, considering the aspect already mentioned, and that the mean age of patients undergoing myocardial coronary artery bypass surgery is around 65 years, we have defined as normal renal function, serum creatinine levels ≤ 1.2 mg/dL, and as previous renal failure, levels of serum creatinine > 1.2 mg/dL, the same parameter used by other authors³.

The incidence of acute renal failure described in this study was 16.1%, similar to that described by Andersson et al¹⁹ (16.4%) and Zanardo et al¹² (15.1%). However, it is two times the levels described by Mangano et al¹¹ (7.7%) and Conlon et al⁸ (8.0%), using less strict criteria for the diagnosis of acute renal failure.

When the incidence of acute renal failure in the postoperative period was assessed according to the parameters used by Mangano et al¹¹, it would be 11.2%, considering maximum creatinine in the postoperative period as > 2.0 mg/dL and the increase in serum levels of creatinine > 0.7 mg/dL above that value of the preoperative period. According to the parameters used by Conlon et al⁸, it would be 10.8%, and the increase in the levels of serum creatinine > 1.0 mg/dL above the preoperative period value. Both percentages remain higher than the rate described by Mangano et al¹¹ and Conlon et al⁸, however, with a smaller difference, reflecting the effect of the parameters used for the diagnosis of acute renal failure in the incidence of this event.

Acute renal failure requiring dialysis (acute renal failure-D) after cardiac surgery, occurs from 0.5% to 15.0%^{5-19,23,26}. Its occurrence in our study was 4.9% (11 cases), greater than that reported in other studies, apart from that of Suen et al¹⁵ and of

Corwin et al⁹ who reported 15.0%. The need for dialysis is a less heterogeneous parameter for the diagnosis of the syndrome; however, it may differ regarding the criteria for the start of dialytic therapy, which may increase the occurrence of acute renal failure-D if it started early. This is one of the aspects that may be related to the need for dialysis; however, this aspect was not quantified for analysis in this study.

In patients with acute renal failure-D, diabetes mellitus, systemic blood hypertension, and peripheral artery disease are significant risk factors¹⁶. Diabetes frequency and blood hypertension in the patients from this study were 35.0% and 74.0%, respectively, greater than those described in other studies; this factor may be related to the greater occurrence observed.

This study did not assess the most sensitive and specific parameters for the evaluation of cardiac performance after myocardial coronary artery bypass surgery; however, the need for an intraaortic balloon was observed in the postoperative period in 22.9% of patients and the need for inotropic medication until the second postoperative day was observed in 38.7% of patients. This suggests poor cardiac performance associated with hemodynamic instability, which may have exposed a greater number of patients to renal ischemia with an increase in the frequency of acute renal failure and greater disease severity leading to a more frequent need for dialysis.

The presence of preexisting renal failure is related to the development of acute renal failure as previously demonstrated in other studies^{5,6,8,9,11,12,16}. Age > 63 years was an independent risk factor for the syndrome according to other authors, possibly associated with loss in renal functional reserve by the progressive decrease in the glomerular filtration rate, which is evidenced by age, making these patients more susceptible to more severe renal lesion due to renal hypoperfusion^{5,8,12}. Duration of extracorporeal circulation > 90min, which was significant in the univariate analysis, was not significant in the multivariate analysis, just as described by other authors^{5,8,12}. These authors correlate the occurrence of acute renal failure especially with the postoperative is-

chemic event, since inotropic support was considered an independent risk factor for acute renal failure. The use of intraaortic balloon in the postoperative period was significant in the univariate analysis, but not in the multivariate analysis, since the need for inotropic medication seems to be a more sensitive parameter associated with a decrease in cardiac performance, presenting a more consistent association. Diabetes, gender, blood hypertension, and peripheral vascular failure were not statistically significant risk factors as demonstrated by other studies^{5-7,19}.

The presence of acute renal failure in this study, corroborating other studies, demonstrates an association between its development and the greater increase in the mortality rate when dialysis is required. It also determines prolonged ICU stay, as already described by other authors^{5,9,11,12}. Acute renal failure-D is a severe complication in myocardial coronary artery bypass surgery, as demonstrated in our study.

Mortality related to acute renal failure-D reported in the literature varies from 23.9% to 88.9%^{6-11,14-16,18,19}, and in the last 10 years, these values have varied from 23.9% to 63.7%^{8,11,15,16,18,19}. The mortality rate observed in patients without acute renal failure was 1.6%, compared with 25.0% for those with it. This rate was greater than that described in other studies, which remained between 1.3% and 22.3%^{5-8,11,12,19,21} in patients with acute renal failure, and this incidence was correlated with a greater percentage of patients with acute renal failure-D, which has a higher mortality rate. However, the criteria that determined myocardial coronary artery bypass surgery (emergency or elective) related to a worse prognosis were not assessed in this study^{15,17}.

In conclusion, acute renal failure after myocardial coronary artery bypass surgery is a frequent complication in our country, being associated with high mortality rates and prolonged ICU stays. Age > 63 years old, the presence of renal failure prior to surgery, and the need for inotropic medication in the postoperative period of myocardial coronary artery bypass surgery are independent risk factors for the development of acute renal failure.

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