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Renal dysfunction after myocardial revascularization☆

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Abstract

Objectives: In this study, we evaluate the incidence of and analyse the pre and intraoperative risk factors for the development of postoperative renal dysfunction (PRD), and the impact of such an event on perioperative mortality and on hospital length of stay. In addition, we sought to investigate the influence of a mildly increased serum creatinine (1.3–2.0 mg/dl) on perioperative mortality and morbidity. **Methods**: The study included 2445 consecutive patients who had no pre-existing renal disease (creatinine ≤2.0 mg/dl, without dialysis) and who underwent isolated coronary surgery under cardiopulmonary bypass between July 1996 and December 2001. The main outcome measure was PRD, defined as a postoperative serum creatinine level ≥2.1 mg/dl with a preoperative-to-postoperative increase ≥0.9 mg/dl. Univariate and multivariate analyses were performed where appropriate. **Results**: Global 30-day mortality was 0.7%. The incidence of PRD was 5.6% (136 patients). Mortality for patients who experienced PRD was 8.8 vs. 0.1% for patients who did not ($P < 0.001$). PRD increased the length of hospital stay by 3.4 days (7.6 vs. 11.0 days; $P < 0.001$), and patients who needed haemodialysis (11%) had a perioperative mortality of 33.3% and a mean hospital length of stay of 16 days. Multivariable logistic regression identified the following variables as independent predictors of PRD: age ($P = 0.017$; odds ratio (OR) 1.3 per 10 years), angina class III/IV ($P = 0.003$; OR 1.7); cardiopulmonary bypass time ($P = 0.007$; OR 1.01 per minute); preoperative serum creatinine levels: group 1 (1.3–1.6 mg/dl ($P < 0.001$; OR 5.5)) and group 2 (1.7–2.0 mg/dl ($P < 0.001$; OR 14.2)). Finally, a mild elevation of the preoperative creatinine level (1.3–2.0 mg/dl) increased significantly the probability of perioperative mortality, low cardiac output, haemodialysis and prolonged hospital stay. **Conclusions**: Although the likelihood of PRD in patients without pre-existing renal dysfunction is relatively low, it dramatically increases mortality, morbidity and length of stay after CABG. Mildly elevated (>1.2 mg/dl) preoperative serum creatinine level significantly increases the perioperative mortality and morbidity.

Keywords: Coronary artery bypass grafting; Renal failure; Risk factors

1. Introduction

Acute changes in renal function after coronary bypass surgery are not well understood and incompletely characterised, and represent a challenging clinical problem. Many reports have described the results of coronary surgery in patients with end-stage renal disease [1–5], but, there have been a limited number of studies reporting the outcome of patients with mild or moderate renal dysfunction not on dialysis [6–9]. Yet, the proportion of patients with this clinical status is much higher than that of patients with dialysis-dependent renal failure, hence it is important to identify and characterise the risk in this subgroup of patients.

The first objective of this study was to evaluate the incidence of postoperative renal dysfunction (PRD) and analyse the pre and intraoperative risk factors for the development of this complication, and its impact on perioperative mortality and on hospital length of stay. The second objective was to evaluate the influence of a mildly increased creatinine serum level (1.3–2.0 mg/dl) on perioperative mortality and morbidity.

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2. Patients and methods

2.1. Patient selection

A total of 2445 patients who had no significant pre-existing renal disease (creatinine ≤ 2.0 mg/dl and without dialysis) and who underwent isolated coronary surgery under cardiopulmonary bypass between July 1996 and December 2001 were recruited to the study. The data of these patients were prospectively collected in a dedicated data-base.

The highest serum creatinine level within the 2 days preceding the operation was taken as the preoperative creatinine level, which was not normally distributed, with a median of 1.0 mg/dl and an interquartile range of 0.8–1.1 mg/dl. The postoperative creatinine level was the highest in-hospital postoperative value and it was measured in all patients for a minimum of 2 days after peak values were reached to confirm that levels were decreasing.

The main outcome measure in this study was PRD, defined as a postoperative creatinine serum level ≥ 2.1 mg/dl plus an increase in the serum creatinine level ≥ 0.9 mg/dl from preoperative to maximum postoperative values (values rounded off to 0.1 mg/dl). The criteria for choosing these values were derived from the distribution of serum creatinine levels in an uncomplicated subset of patients. This subset excluded patients with a complicated perioperative course (in-hospital death, intra-aortic balloon pump or other mechanical assist device, use of inotropic drugs, reoperation for haemorrhage or sternal complications, respiratory failure, myocardial infarction, and prolonged hospital postoperative stay). Of the 2122 patients meeting these criteria only 5% had a maximum postoperative creatinine level ≥ 2.1 mg/dl and a maximum preoperative-to-postoperative change in creatinine level of 0.9 mg/dl or greater (Table 1).

2.2. Clinical variables

The demographic variables studied as potential risk factors for PRD and considered for inclusion in all the multivariable analyses performed were: age, sex, height, weight, body mass index (weight divided by height square), and body surface area. The clinical and laboratory variables evaluated were cardiomegaly, cerebral vascular disease, peripheral vascular disease, chronic obstructive pulmonary disease, anemia, recent tobacco use, diabetes mellitus, history of hypertension, dislipidemia, unstable angina, angina class (Canadian Cardiovascular Society), prior heart surgery, recent myocardial infarction, serum creatinine level (mg/dl) and surgical priority (elective, urgent, emergent). Defenitions for variables are listed in Appendix A.

For risk analysis of PRD, the preoperative creatinine serum was dived into two groups: Group 1—values above the upper limit of our institution's normal range of 1.2 mg/dl but equal to or less than 1.6 mg/dl, defined as mild elevation; Group 2—elevation to 1.7 mg/dl or above, and defined as moderate elevation. Accordingly, 228 patients (9.3%) had a creatinine level of 1.3–1.6 mg/dl, and 43 (1.8%) had a creatinine level of 1.7–2.0 mg/dl. The remaining 2174 patients (89.0%) had preoperative serum creatinine levels of less than 1.3 mg/dl.

Operative mortality was defined as death within 30 days of the operation or during the same hospitalisation. An in-hospital stay above the 90th percentile was defined as prolonged, equalling a postoperative stay of 10 days or greater. Low cardiac output syndrome (LCOS) was defined as the need for postoperative intra-aortic balloon pump and/or inotropic support, for any length of time, in the intensive care unit. Creatinine clearance was estimated from serum creatinine, age, weight and gender by the of Cockcroft and Gault's formula.

Table 1
Serum creatinine values in an uncomplicated subset of patients ($N = 2.122$)

	Serum creatinine (mg/dl)	
	Maximum postoperative	Preoperative to maximum postoperative change
Mean	1.36	+0.38
Median	1.3	+0.3
95-percentile	2.1	+0.9

2.3. Surgical technique for CABG

Cardiopulmonary bypass was conducted with non-pulsatile flow and mild hypothermia (32 °C), and the systemic perfusion pressure was electively maintained at 55–65 mmHg. A left ventricular vent was always introduced through the right superior pulmonary vein and left atrium. All operations were performed under ventricular fibrillation without cardioplegia, a technique described in detail in previous reports [10,11]. The mean number of grafts per patient was 2.8 ± 0.8, and the mean cardiopulmonary bypass time was 61.3 ± 20.1 min. A bloodless prime was used in more than 95% of the cases, whenever the preoperative haematocrit was greater than 35%, and blood was not administered unless it fell bellow 20–22% during cardiopulmonary bypass. Collected mediastinal blood shed during the first 6 postoperative hours was reinfused manually.

2.4. Statistical analysis

Distributions and univariate measures of preoperative, postoperative, and preoperative-to-postoperative changes in serum creatinine values were examined. Models were analysed in a piece-wise fashion (separate models were developed for each preoperative and operative period from

the significant unadjusted factors in each period). A final model with adjusted estimates was derived with factors that remained significant in the two-time-period models [12]. Operative variables were entered into the model in a forward stepwise fashion after adjustment for preoperative variables. The best-fitting models were selected from evaluation of the Hosmer–Lemeshow goodness-of-fit and Omnibus test statistic. The predictive ability of the models were also evaluated by the area under the curve of the receiving operating characteristic (ROC).

3. Results

3.1. Postoperative renal dysfunction

3.1.1. Incidence and risk analysis

PRD, as defined above, occurred in 136 (5.6%) of the 2445 patients in our study, 15 of whom (11.0, 0.6% of all study patients) required haemodialysis.

The distribution of serum creatinine values in the 2122 patients with an uncomplicated postoperative course shows that there was an increase in the median of 0.3 mg/dl between the preoperative (1.0 mg/dl) and the maximum postoperative (1.3 mg/dl) values with a range of 11.4 mg/dl (−0.7 to 10.4 mg/dl). Using the Cockcroft and Gault formula, this corresponds to a median reduction of 20 ml/min on the estimated creatinine clearance between preoperative (82 ml/min) and postoperative (62 ml/min) values.

Table 2 shows the final model of risk factors for PRD. Patients with a preoperative creatinine level of 1.3–1.6 mg/dl were 5.5 times as likely ($P < 0.001$) to develop PRD as patients with a preoperative creatinine level of less than 1.3 mg/dl, and patients with a preoperative creatinine level of 1.7 mg/dl or greater were 14 times as likely to have such a result ($P < 0.001$). The other preoperative variables identified by multivariable logistic regression to be independent predictors of PRD were increasing age ($P = 0.015$; OR 1.3 per 10 years), and angina class III/IV ($P = 0.003$; OR 1.7). Cardiopulmonary bypass time was the only operative variable identified-for each extra 10 min, the likelihood of PRD increased by a factor of 1.14 ($P = 0.007$). The model utilised demonstrated a good calibration and discriminatory power (Hosmer–Lemeshow test: $\chi^2 = 11.58$, df = 8, $P = 0.171$; mean ROC area of 0.75 (95% confidence interval = 0.70–0.79)).

3.1.2. Mortality and postoperative hospital stay

Global 30-day mortality was 0.7, 8.8% for patients who experienced PRD vs. 0.1% for patients who did not ($P < 0.001$). The mortality rate was 5.8% (7 of 114 patients) in patients with renal dysfunction who did not require dialysis and 33.3% (5 of 15 patients) among those who required dialysis.

Occurrence of PRD increased the length of hospital stay by 3.4 days (7.6 vs. 11.0 days; $P < 0.001$) and patients who needed haemodialysis (11%) had a mean hospital stay of 16.0 ± 12.8 days.

3.2. Influence of a mildly (1.3–2.0 mg/dl) increased preoperative serum creatinine levels on mortality and morbidity

The influence of the preoperative creatinine serum values on mortality and morbidity (need for new renal function support-haemodialysis-, LCOS, cerebrovascular accident, delirium, reoperation for haemorrhage or for sternal complications, myocardial infarction, and prolonged hospital stay) was also analysed.

Of the 2445 patients in the study, 271 (11.1%) had a preoperative serum creatinine level equal to or greater than 1.3 mg/dl. A comparative univariate analysis of the preoperative and operative data of this patient group with that of the group of patients with a normal preoperative creatinine level ($n = 2.174$), is shown in Table 3.

By multivariable analysis, the mortality was 3.3 times ($P = 0.031$) higher if the preoperative creatinine level rose to 1.3 mg/dl or greater (because the number of events was low, it was not possible to subdivide into small groups). Other factors contributing to increased mortality were the presence of cerebrovascular disease (OR 4.4; $P = 0.025$) and cardiomegaly (OR 3.5; $P = 0.023$) (Table 4).

Of the 2445 patients in the study, 15 (0.6%) required postoperative haemodialysis. Comparing with patients with a normal preoperative creatinine level, those with a level of

Table 2
Final model of risk factors for PRD

Covariate	Variable estimate	SE	*P*-value	Odds ratio	$IC_{95\%}$ (OR)	
Age	0.028	0.012	0.015	1.03	1.01	1.05
Angina class III/IV	0.541	0.187	0.004	1.72	1.19	2.48
Preoperative creatinine level (mg/dl)						
Group 1 (1.3–1.6)	1.704	0.214	<0.001	5.49	3.62	8.36
Group 2 (≥1.7)	2.630	0.341	<0.001	13.87	7.10	27.07
CPB time	0.013	0.005	0.007	1.01	1.00	1.02
Constant	−6.127	0.851	<0.001			

CPB, Cardiopulmonary bypass.

Table 3
Univariate analysis of preoperative and operative significant risk factors of patients with normal (<1.3 mg/dl) and elevated (1.3–2.0 mg/dl) preoperative creatinine serum level

Risk factors[a]	<1.3 mg/dl ($N = 271$)	1.3–2.0 mg/dl ($N = 2.174$)	*P*-value
Age (years)	65.5 ± 8.3	60.4 ± 9.0	<0.001
Body surface area (cm^2)	179.2 ± 13.1	176.9 ± 14.4	0.011
Female sex	7.0	14.1	0.001
Hypertension	67.2	57.7	0.002
Dislipidemia	52.4	59.6	0.024
Peripheral vascular disease	13.3	8.0	0.004
Cerebrovascular disease	8.5	4.1	0.001
Anaemia	5.9	3.3	0.027
Cardiomegaly	16.6	10.5	0.003
Unstable angina	14.0	6.8	<0.001
Angina CCS class III or IV	44.7	36.6	<0.010
LV dysfunction (EF < 0.4)	20.7	11.4	<0.001
No. of grafts (mean/pt)	2.9 ± 0.7	2.8 ± 0.8	0.012

[a] Unless otherwise specified, values are in percentage.

1.3 mg/dl or greater had an increased risk of 4.5 times for necessitating postoperative haemodialysis. The other independent risk factors identified were anaemia ($P < 0.001$) and angina class III/IV ($P = 0.035$) (Table 5).

LCOS occurred in 171 patients (7.0%). Multivariate analysis showed that the group of patients with a higher preoperative creatinine level had a significantly increased risk of developing LCOS. The other factors that increased the likelihood of developing this syndrome are shown in Table 6.

A postoperative stay of 10 days or longer was required in 194 patients (7.9%). By multivariable analysis, patients with a preoperative creatinine level of 1.3 mg/dl or greater had a nearly 2-fold likelihood of a prolonged postoperative hospital stay (OR 1.7; $P = 0.017$). Other factors contributing to a prolonged hospital stay were increasing age (OR 1.035 per year; $P = 0.002$), peripheral vascular disease (OR 1.7; $P = 0.020$), angina class III/IV (OR 1.6; $P = 0.003$), and use of double internal thoracic artery (OR 2.5; $P < 0.001$) (Table 7).

The preoperative serum creatinine level was not found to be a significant predictor of cerebrovascular accident, delirium, reoperation for haemorrhage or for sternal complications, and myocardial infarction.

4. Discussion

4.1. Postoperative renal dysfunction: incidence, risk analysis and outcomes

The causes of renal dysfunction after coronary surgery are multifactorial and usually attributed to the use of cardiopulmonary bypass, cardiovascular compromise, or toxic insults to the kidneys. Non-pulsatile flow, renal hypoperfusion, hypothermia, and duration of CPB are also thought to have adverse effects on renal function. Hence, it is to be expected that during and/or after surgery, even if uncomplicated, one might find some deterioration of the renal function. In this study, which included 2122 patients with a preoperative creatinine serum level ≤2.0 mg/dl and uncomplicated postoperative course, there was a mean increase of 0.3 mg/dl between preoperative (1.0 mg/dl) and maximum postoperative serum creatinine levels (1.3 mg/dl), and a reduction of 20 ml/min in the estimated creatinine clearance from pre (82 ml/min) to postoperative (62 ml/min) values. Similar results were reported by Ascione and Swaminathan and their associates [13,14] who have shown a 20% reduction in creatinine clearance after coronary surgery with CPB.

The precise level at which preoperative subclinical renal dysfunction begins to adversely affect outcome is unknown.

Table 4
Factors contributing significantly toward increased perioperative mortality

Covariate	Variable estimate	SE	*P*-value	Odds ratio	$IC_{95\%}$ (OR)	
Preoperative creatinine ≥1.3 mg/dl	1.025	0.559	0.031	3.34	1.11	9.99
Cardiomegaly	1.265	0.557	0.023	3.54	1.19	10.55
Cerebrovascular disease	1.482	0.662	0.025	4.40	1.20	16.14
Constant	−5.751	0.375	<0.001			

Table 5
Factors contributing significantly toward the need for postoperative haemodialysis

Covariate	Variable estimate	SE	*P*-value	Odds ratio	$IC_{95\%}$ (OR)	
Preoperative creatinine ≥1.3 mg/dl	1.508	0.565	0.008	4.52	1.49	13.68
Anaemia	2.295	0.655	<0.001	9.92	2.75	35.79
Angina class III/IV	1.304	0.618	0.035	3.68	1.10	12.37
Constant	−8.915	1.348	<0.001			

Table 6
Factors contributing significantly to the development of LOCS

Covariate	Variable estimate	SE	*P*-value	Odds ratio	$IC_{95\%}$ (OR)	
Preoperative creatinine ≥1.3 mg/dl	0.509	0.234	0.030	1.66	1.05	2.63
LV dysfunction (FE < 40%)	1.089	0.191	<0.001	2.97	2.04	4.32
Non-elective surgery	0.982	0.282	<0.001	2.67	1.54	4.64
ECC time	0.015	0.005	0.002	1.02	1.01	1.02
Constant	−2.443	1.375	<0.001			

Table 7
Factors contributing significantly toward prolonged postoperative hospital stay

Covariate	Variable estimate	SE	*P*-value	Odds ratio	$IC_{95\%}$ (OR)	
Preoperative creatinine ≥1.3 mg/dl	0.512	0.206	0.013	1.67	1.12	2.50
Age	0.035	0.011	0.001	1.04	1.01	1.06
Peripheral vascular disease	0.582	0.223	0.009	1.79	1.16	2.77
Angina class III/IV	0.494	0.154	0.001	1.64	1.21	2.22
Double IMA	0.841	0.209	<0.001	2.32	1.54	3.49
Constant	−5.151	0.691	<0.001			

IMA, internal mammary artery.

Some studies [6–9] attempting to address this issue looked at the effect of elevations of preoperative serum creatinine levels varying from 1.5 to 2.5 mg/dl, and found a significant negative influence of these values on perioperative mortality and morbidity. However, the effect of a more borderline elevation of preoperative serum creatinine levels (1.3–2.0 mg/dl), as we address in this study, has not been investigated in a large cohort multivariable model.

The reported incidence of renal dysfunction after cardiac surgery is significantly influenced by the definition used in a given study. Most studies previously published used only absolute creatinine values, while others used widely differing change criteria; this yielded incidences of dysfunction ranging from 0.9 to 29% [15–18,23]. As in the study by Mangano and associates [19], we sought to overcome this limitation by deriving the criteria for dysfunction from the distribution of serum creatinine values in an uncomplicated subset of patients and by defining PRD on the basis of an absolute creatinine value (≥2.1 mg/dl) coupled with a relative change in creatinine level (≥0.9 mg/dl) between the preoperative and the postoperative periods.

By multivariate analysis of the putative risk factors for the development of PRD in association with coronary surgery, we have identified higher preoperative serum creatinine levels as the strongest factor. When compared to preoperative creatinine levels of less than 1.3 mg/dl, levels of 1.3–1.6 mg/dl and of 1.7 mg/dl or greater increased the likelihood of developing PRD by 5.5 and 14 times, respectively. These results are in accordance with those previously reported by others [6–8,20–24] and confirm a significant influence of even minor elevations of preoperative creatinine serum levels on postoperative renal function. Because they probably have a greater proportion of functionally borderline glomeruli, patients with higher preoperative serum creatinine levels, are potentially more susceptible to deterioration of their renal function when exposed to a perioperative insult. The probability of developing PRD was also seen to be significantly greater in older patients, those with more advanced angina class and with increased cardiopulmonary bypass times. These risk variables have also been identified by other groups [19,22,23,25].

In the present study, the mortality rate of patients with PRD was significantly higher than in patients without PRD (8.8 vs. 0.1%). Additionally, we report a markedly increased mortality rate among patients with PRD who required dialysis (33.3 vs. 5.8%). These results are in accordance with others previously reported which also confirm the negative impact of PRD, especially among those who required dialysis, on perioperative mortality [1–5,18,19,26]. In addition, as it was also reported by others [9,19,21], this study showed that PRD increased significantly the length of hospital stay (7.6 vs. 11.0 days), even more prolonged in patients who needed haemodialysis (16.0 days).

4.2. Influence of a mildly increased (1.3–2.0 mg/dl) preoperative serum creatinine levels on mortality and morbidity

The current study highlighted a pronounced impact of the preoperative creatinine values on mortality, by showing that the effect is significant even at mild elevations of the preoperative serum creatinine values. The perioperative mortality was significantly increased (3.3 times) in the group of patients with a mildly increased (1.3–2.0 mg/dl) preoperative creatinine serum level. Further differences

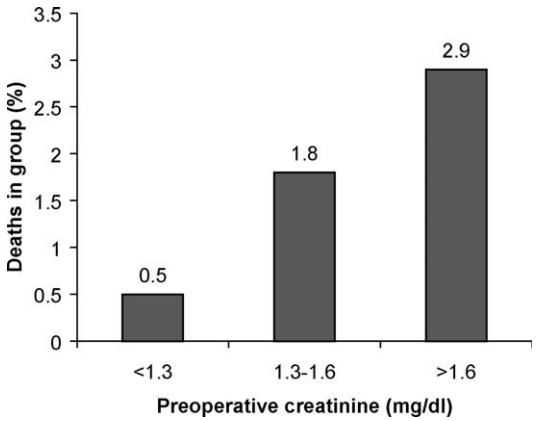

Fig. 1. Mortality by preoperative creatinine level (percentage of the total number of patients within each group).

could be demonstrated for different levels within this range. Patients with creatinine levels of 1.3–1.6 mg/dl and >1.6 mg/dl had a perioperative mortality of 1.8 and 2.9%, respectively (Fig. 1).

The VA Cooperative Study database demonstrated that patients with a preoperative serum creatinine level of 1.5–3 mg/dl had increased 30-day mortality after coronary surgery [26]. In a recent study, Weerasinghe et al. [8] also found a significant increase in the in-hospital mortality in patients with creatinine values ≥1.5 mg/dl.

We have also uncovered that a mild preoperative creatinine elevation was an independent risk factor for some morbidity events. Comparing with patients with a normal preoperative creatinine level, those with a level of 1.3 mg/dl or greater had a 4.5-fold increased risk of necessitating postoperative haemodialysis, had an almost 2-fold increased risk of developing LCOS, and a 2-fold increased likelihood of a prolonged hospital stay.

4.3. Study limitations

We have studied an unselected cohort of CABG patients that enabled the documentation of 136 cases of PRD and allowed the creation of a statistically powerful regression model to identify pre and intraoperative predictors of PRD in patients subjected to isolated coronary surgery. However, the present study has limitations that include those inherent to any retrospective analysis, even when data were colleted prospectively, as was the case. Another weakness of this study is related to the method used for detection of renal dysfunction. Serum creatinine was chosen because of the simplicity of measurement. Ideally, creatinine clearance, a well-established indicator of glomerular filtration rate, should be measured to assess renal function, since serum creatinine levels are influenced by body surface area and body water mass. But creatinine clearance is not routinely measured in our patients subjected to elective CABG.

5. Conclusion

PRD, which occurred in 5.6% of the 2445 patients subjected to isolated CABG, proved to be an important complication, carrying a significant morbidity and a mortality of 8.8%. Four preoperative and operative risk factors for PRD were identified: age, angina class III/IV, creatinine serum level and cardiopulmonary bypass time. Among these, elevations in preoperative serum creatinine levels were the stronger risk factors for PRD. Identification of the risk factors for PRD may constitute valuable information for preoperative risk stratification and to facilitate patient selection and/or optimisation. This study also confirms that the morbidity and mortality are increased in coronary surgery patients with a slightly elevation of the preoperative serum creatinine level.

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Appendix A

Clinical variables	Definitions
Diabetes mellitus	History of diabetes treated with oral agents or insulin
Hypertension	Blood pressure exceeding 140/90 mmHg, or a history of high blood pressure, or the need of antihypertensive medications
Dislipidemia	History of hypercholesterolemia and/or hypertrigliceridemia
Recent smoking	Within 4 weeks of surgery
Peripheral vascular disease	Manifested by one or more of: exertional claudication and/or rest pain, prior revascularisation procedure to the lower limbs, absent or diminished pulses in the legs, angiographic evidence of non-iatrogenic peripheral arterial obstruction of 50% of luminal diameter
Cerebrovascular disease	Previous stroke and/or transient ischemic attack
Anaemia	Haematocrit $\leq 34\%$
COPD	Resulting in one or more of: functional disability, hospitalisation, requirement of chronic bronchodilator therapy, $FEV_1 < 75\%$ of predicted
Cardiomegaly	A cardiothoracic ratio >0.50 demonstrated on a preoperative chest film
Recent AMI	Evidence of AMI in the last 30 days before surgery
Unstable angina	Use of intravenous nitrates within 48 h of surgery
LV dysfunction	Left ventricular ejection fraction $<40\%$

Appendix B. Conference discussion

Dr P. Sergeant *(Leuven, Belgium)*: I understand very clearly how you have made your event definition based on this very nice presentation, in fact how you selected, so it was not totally arbitrarily.

Dr Antunes: No, it wasn't.

Dr Sergeant: It is very clear that the interval between 1.5 and 2.0 mg/dl is a critical span whereby there is nearly an exponential increase if you go from 1.5 to 2.0. Are you not a little bit depressed by the fact that you have just made this crude cut-off of 2.0 and wouldn't it have been nicer if you would have identified, for example, 1.5.

Dr Antunes: This may always be subject to criticism. Traditionally, creatinine levels greater than 2.0 are considered renal dysfunction. Several authors have made similar studies, but they used arbitrarily the values of 1.5. We have studied in our own population without complications the distribution of creatinine levels. That is why we came up with 2.1, with a postoperative variation of 0.9, and those were the factors that we used then for our inclusion criteria. You can't use any values.

To our surprise, however, when we started analysing the results and when we went back to see lower values, even values above 1.2, which in our laboratory is upper limit of normal, even those values had an influence on postoperative outcome.

So the main message, if I can take a message out of this paper, is that even those patients which are just marginally above normal, carry a major influence in the postoperative outcome with regards not only to the appearance of significant renal dysfunction but also of other complications, morbidity and mortality and the prolonged length of stay.

Dr N. Wang *(Loma Linda, California)*: I am just curious, in our study of ischemic cardiomyopathy patients, mitral regurgitation seems to have a significant impact on renal function, in other words, whether

they are reoperations or first time operation, renal function is poor in patients with mitral regurgitation. Did you find a similar kind of observation?

Dr Antunes: I followed your paper with a lot of interest, but unfortunately, mitral valve regurgitation was not one of the variables that we included in this study. We may go back and see if it does, but we did not use that variable. These 28 variables were those that we predicted could make a difference in the outcome. We didn't consider mitral regurgitation. It is perhaps a shortcoming. So I am unable to give you any information on that.

Dr M. Guida *(Valencia, Venezuela)*: I would like to know your opinion about the role of the pump as an operative risk factor on the basis of the comparison of both groups, on-pump and off-pump.

Dr Antunes: We do not do routinely off-pump surgery. We do an average of 5 or 6% of our cases off-pump, and this was not studied. We deliberately included just patients done on-pump. The only thing I can tell you, as it was shown, is that the duration of cardiopulmonary bypass increased the morbidity, the mortality and the incidence of renal dysfunction by a factor of 1.14 for each 10 min of cardiopulmonary bypass time. So even if the values are relatively low, 61 min as a mean, it is important to keep it as short as possible.

Dr M. Albreht *(Lafayette, Colorado)*: It appears that the duration of cardiopulmonary bypass is a risk factor for renal failure postoperatively. Has it been pulsatile in all patients or a continuous flow pump?

Dr Antunes: We use a continuous non-pulsatile flow, yet the incidence of PRD, as seen here, was 5.6, which is the usual incidence that other authors describe for other methods of cardiopulmonary bypass.

Mr K. Rammohan *(Cardiff, UK)*: We also have an interest in this and have just started to look at something along these lines. I was curious to see what you presented about anaemia being a predictive factor. Do you have any numbers on that, and what thereafter would be a transfusion trigger in ITU? Do you address these people differently, because as I am sure you are aware, there was something very recently in the literature as well about this.

Dr Antunes: The definitions for each one of those variables will come in the manuscript. We considered patients with an Hb lower than 12 g, and usually they wouldn't be of any concern to us. In fact, we only use blood in less than 7.5% of our patients because of the non-cardioplegic method.

This is a finding that we have with this study. Obviously we will take all the consequences from these findings and we will look into that more carefully in the future handling of these patients postoperatively.

Because we are concerned about the use of blood, we have allowed our haematocrit values to come to about 20% and then gradually go up during the postoperative stay as we remove fluids from the patients.

Dr L. Testolin *(Padova, Italy)*: In the subset of patients which includes the preoperative risk factors you identified, did you use intraoperative ultrafiltration or any kind of modified ultrafiltration to prevent this complication?

Dr Antunes: No, we don't. As I indicated, we use a non-cardioplegic method, and we try to avoid overloading the patient as much as possible. We use mannitol going on bypass, and if it goes over 45 min we will give another 12.5 g, so it will be either 12.5 or 25 g, and then we will use Lasix.

We are often proud to say to our students who visit us that we use the patient's kidney as an ultrafiltration device. We have used a device in a few patients, but we don't use it routinely now.