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Does Preoperative Coronary Angioplasty Improve Perioperative Cardiac Outcome?

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Background: **Percutaneous coronary intervention (PCI) is performed in patients with coronary artery disease who are undergoing major noncardiac procedures to reduce perioperative cardiac morbidity and mortality. However, the impact of this approach on postoperative outcome remains controversial.**

Methods: **The authors analyzed a cohort of 1,152 patients after abdominal aortic surgery in which 78 patients underwent PCI. A propensity score analysis was performed. Also, using a logistic regression model, the authors determined variables associated with a severe postoperative coronary event or a death in patients without PCI. Then, in patients with PCI, they compared the expected and observed outcome.**

Results: **Five variables (age > 75 yr, blood transfusion > 3 units, repeated surgery, preoperative hemodialysis, and previous cardiac failure) independently predicted (with 94% correctly classified) a severe postoperative coronary event, and five variables (age > 75 yr, repeated surgery, previously abnormal ST segment/T waves, previous hypertension, and previous cardiac failure) independently predicted (with 97% correctly classified) postoperative death. In the PCI group, the observed percentages of patients with a severe postoperative coronary event (9.0% [95% confidence interval, 4.4–17.4]) or death (5.1% [95% confidence interval, 2.0–12.5]) were not significantly different from the expected percentages (8.2 and 6.9%, respectively). When all patients were pooled together, the odds ratios of PCI were not significant. The propensity score analysis provided a similar conclusion.**

Conclusion: **PCI did not seem to limit significantly cardiac risk or death after aortic surgery.**

PATIENTS with coronary artery disease have a high risk of perioperative myocardial infarction, arrhythmias, cardiac failure, and death.[1] Preoperative cardiac evaluation has been recognized as an important objective before major surgery in patients with a high cardiac risk.[2] Based on clinical markers, functional capacity, and/or evidence for high risk of an adverse outcome based on noninvasive test results, coronary angiography may be planned in some patients undergoing aortic surgery, to indicate the need for coronary revascularization before surgery. Coronary artery bypass graft (CABG) surgery has been shown to be effective in reducing perioperative events in patients with significant coronary artery disease and undergoing major noncardiac procedures.[3] Percutaneous coronary intervention (PCI) revascularization is now increasingly used in these patients to reduce perioperative cardiac morbidity and mortality, although few data are available on the impact of this invasive prophylactic strategy on postoperative outcome. PCI is considered less invasive than CABG, but some authors have reported catastrophic cardiac outcome when surgery was performed within 6 weeks after PCI.[4] Others have questioned the beneficial effect of PCI on postoperative outcome.[4–7] A recent controlled trial studying the impact of preoperative coronary revascularization on the outcome of vascular surgery in high-cardiac-risk patients did not report any significant improvement in long-term outcome.[8] Both preoperative CABG and PCI were performed, but only 41% of the patients underwent major abdominal vascular surgery.[8] A higher incidence of perioperative myocardial infarction and cardiac death in patients undergoing aortic vascular surgery has been attributed to the high prevalence of coronary artery disease and to the high surgical stress of this procedure. Therefore, we analyzed a cohort of patients prospectively studied after abdominal aortic surgery in which a subgroup underwent PCI.

We used propensity score analysis, which tends to balance all of the observed covariates associated with the exposure to PCI.[9] However, propensity score analysis does not take into account perioperative or postoperative variables that are at least as important as preoperative variables in predicting postoperative cardiac outcome and death. Therefore, using a logistic regression model, we determined independent predictors of adverse cardiac outcome and death in patients without PCI and then the expected incidence of postoperative cardiac complications and death in patients with PCI. The effect of PCI on postoperative outcome was evaluated by comparing expected and observed cardiac outcomes in patients with preoperative PCI.

Materials and Methods

Patient Characteristics

The Pitié-Salpêtrière Vascular Surgery Registry is a comprehensive, prospectively recorded database describing clinical and surgical characteristics of all patients undergoing vascular surgery at the institution since 1984. We reviewed the database of surgery performed from September 1996 to September 2002. A systematic audit by one of the authors (M.B.) permitted

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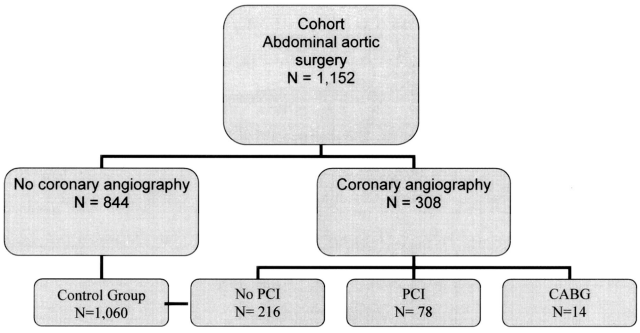

Fig. 1. Flowchart of the cohort studied. CABG = coronary artery bypass graft; PCI = percutaneous coronary intervention.

verification of accuracy in coding data. Missing data were coded as absent. We included all patients who underwent abdominal aortic reconstructive surgery. We excluded patients who underwent emergency procedures and those who underwent combined thoracic aortic surgery. We also excluded patients who underwent CABG surgery before aortic surgery because of the small sample size of this group (n = 14). This study was approved by our institutional review board (Comité Consultatif de Protection des Personnes SE. Prêtant à la Recherche Médicale Pitié-Salpêtrière, Paris, France). Because data were collected while care of patients conformed to standard procedures currently used in our institution, authorization was granted to waive informed consent for the study.

Preoperative Treatment

Since September 1996, patients have been screened preoperatively in accordance with the recommendations proposed by the American College of Cardiology/American Heart Association Task Force.[2] In patients undergoing such a high-risk surgery and with a poor or a nonevaluable functional capacity, a clear history of coronary artery disease without previous assessment, unstable coronary artery disease, and/or positive or equivocal noninvasive test results, coronary angiography was performed. PCI was performed during the same procedure if feasible. Lesions inaccessible to PCI were treated by CABG if indicated. Patients treated by PCI received antithrombotic agents (clopidogrel for 4 weeks and aspirin), which were discontinued 1 week before aortic surgery. Our policy was to perform surgery between 5 and 8 weeks after PCI. Figure 1 summarizes the study groups.

Intraoperative Treatment and Anesthesia

Patients were premedicated with 5 mg midazolam given orally 1 h before surgery. They received their regular cardiovascular medication on the morning before surgery, except for angiotensin-converting enzyme inhibitors and angiotensin II antagonists, which were discontinued the day before surgery.[10,11] Standard intraoperative monitoring included electrocardiography with continuous ST-segment analysis (lead D2, CS5, and V4; monitor type, Marquette, Milwaukee, WI), pulse oximetry, and invasive arterial blood pressure monitoring with a radial catheter inserted during local anesthesia before induction. General anesthesia was induced and maintained with use of propofol and sufentanil, as previously described.[12] All patients received 0.5 mg/kg atracurium for tracheal intubation, and the lungs were ventilated with a mixture of 50% nitrous oxide in 50% oxygen. Baseline systolic arterial pressure and heart rate were defined as the average of three measurements on the day before surgery. Intraoperatively, the anesthesiologist was required to maintain systolic arterial blood pressure and heart rate within 30% of baseline values using fluid administration and vasoconstrictors (ephedrine, phenylephrine). Approximately 30 min before the end of surgery, patients received 2 g propacetamol and 0.1 mg/kg morphine.

Postoperative Care

Postoperatively, patients were transferred to the recovery room. Hemodynamic events such as hypertension (> 30% of control value) were treated with an intravenous bolus of 1 mg nicardipine, by titration with intravenous esmolol or propranolol when associated with increased heart rate (> 80 beats/min), or with clonidine. Postoperative myocardial ischemia, defined as an ST-segment depression greater than 1 mm at 60 ms after the J point, was treated with diltiazem or, in the case of poor left ventricular function evidenced by echocardiography, with nitrates. Postoperative analgesia included intravenous morphine titration followed by subcutaneous morphine administration, as previously described.[13,14] Some patients (13%) received intrathecal morphine (8 μg/kg preservative-free morphine) 10–15 min before general anesthesia was induced, and few patients (1%) received postoperative epidural analgesia (0.25% epidural bupivacaine at a dose of 6–10 ml/h with a catheter inserted *via* the T8–T9 interspace); the decision was made by anesthesiologists in the operating room. Our policy is not to use postoperative epidural analgesia routinely in these patients.[15] All patients received subcutaneous low-molecular-weight heparin after surgery and after hospital discharge, until postoperative day 30 (surgeon follow-up) and aspirin as soon as postoperative day 1 in patients with documented coronary artery disease. Beta blockers were not discontinued during the perioperative period, and statins were given as soon as postoperative day 1 when chronically prescribed.[16]

As part of the protocol, cardiac troponin Ic was measured at recovery and on the first, second, and third postoperative days with use of an immunoenzymofluorometric assay on a Stratus autoanalyzer (Dade-Behring, Paris La Défense, France). Reference values are 0.2 ng/ml or less (except during the period September 1996 to November 1999, in which a reference value of cardiac

troponin I was ≤ 0.5 ng/ml). Electrocardiography was performed on recovery; on the first, second, and third postoperative days; and in case of clinical abnormalities, increased troponin Ic values, or both.

Endpoints

We considered three main endpoints: postoperative myocardial damage, severe postoperative coronary events (including both nonfatal myocardial infarction and unstable angina necessitating emergency coronary revascularization), and death (in the hospital, until postoperative day 30, or both). Postoperative myocardial damage was defined as an increased cardiac troponin I value at any time during the postoperative period. A severe postoperative coronary event was diagnosed in patients with a new Q-wave or ST-segment/T wave abnormality lasting more than 48 h, a troponin Ic value greater than 1.5 ng/ml, or both. Patients who underwent emergency coronary angiography with PCI during the postoperative period were also considered to have had a severe postoperative coronary event, irrespective of their troponin values. Coding of severe postoperative coronary events was performed by two independent experts (G.G., M.B., J.-P.G.). Discrepancy was solved by consensus, a third expert (B.R., P.C.), or both. Death was defined as death from any cause occurring during the hospital stay, within 30 days after surgery, or both.

In addition, we recorded hemorrhagic complications, such as gastrointestinal bleeding, the need for repeated surgery because of hemorrhagic complications, and death related to hemorrhagic complications.

Statistical Analysis

Data are expressed as mean ± SD or median and 95% confidence interval (CI) for nongaussian variables. Comparison of two means was performed with use of the Student *t* test, comparison of two medians was performed with use of the Mann–Whitney test, and comparison of two proportions was performed with use of the Fisher exact method.

Propensity score analysis[9] was performed with regard to the use of PCI. For each patient, a propensity score indicating the likelihood of performing PCI was calculated by forward logistic regression analysis. We used a parsimonious approach and included only the significant preoperative variables in the univariate analysis, except for some variables obviously linked to coronary artery diseases (previous myocardial infarction, previous CABG, clinical coronary disease symptom, previously abnormal ST segment/T waves), which were systematically included. Because quintiles 1 and 2 could not be distinguished, four subgroups were analyzed. Goodness of fit of the propensity score was assessed by Hosmer-Lemeshow statistics.[17] Endpoints were compared in each subgroup (quintiles) based on their propensity score with use of the Fisher exact method and globally with use of the Mantel-Haenszel test. Moreover, a logistic regression was performed to assess the odds ratio associated with PCI in predicting each of the three endpoints when the propensity score was taken into account.

In patients who did not undergo PCI (n = 1,060), we determined the variables significantly associated with the following outcomes: (1) postoperative myocardial damage, (2) severe postoperative coronary event, and (3) death. For each outcome, we first performed a univariate analysis. For significant continuous variables, the receiver operating characteristic (ROC) curve was used to determine the best threshold to predict the outcome. The best threshold was the one that minimized the distance to the ideal point (sensitivity = specificity = 1) on the ROC curve. Then, we performed a multiple forward logistic regression. We used a parsimonious approach and included only the significant preoperative variables in the univariate analysis ($P = 0.05$), except for some variables obviously linked to coronary artery diseases (previous myocardial infarction, previous CABG, clinical coronary disease symptom, previously abnormal ST segment/T waves, and presence of untreatable coronary lesions), which were systematically included. The odds ratios and their 95% CIs were calculated. The percentage of patients correctly classified by the logistic model was calculated. Moreover, the discrimination of the model was assessed using the ROC curve and the calculation of the area under the ROC curve.[18] Calibration of the model was assessed using Hosmer-Lemeshow statistics.[17] The logistic regression model enabled us to calculate the probability of each outcome, using the following equation:

$$\mathrm{P(outcome)} = 1/(1 + \mathrm{Exp}(\beta 0 + \beta 1\mathrm{V}1 + \beta 2\mathrm{V}2 + \ldots + \beta n\mathrm{V}n)), \quad (1)$$

with $\beta 0$ being the intercept, βn being the coefficient associated with the variable Vn, and the value of Vn being either 0 or 1. Therefore, the predicted number of patients with a given outcome in any other group of patients is provided by the following equation:

$$\mathrm{N(outcome)} = \Sigma\, \mathrm{Pi(outcome)}, \quad (2)$$

with Pi being the individual probability of outcome. This procedure was applied to the group of patients who underwent PCI (n = 78). The predicted percentage was compared to the observed percentage using the CI method.

Last, patients who did not undergo PCI and those who did were pooled together, and a forward logistic regression was performed to assess the odds ratio associated with PCI in predicting each of the three endpoints.

All statistical comparisons were two tailed, and a *P* value of less than 0.05 was required to reject the null hypothesis. Statistical analysis was performed using NCSS 6.0 software (Statistical Solutions Ltd., Cork, Ire-

Table 1. Comparison of Patients with or without Preoperative PCI

Variable	Control Group (n = 1060)	PCI Group (n = 78)	*P* Value
Patient characteristics			
Age, yr	67 ± 11	68 ± 11	NS
Male sex	952 (90)	70 (90)	NS
Previous myocardial infarction	184 (17)	19 (24)	NS
Previous CABG	171 (16)	18 (23)	NS
Clinical coronary disease symptoms	116 (11)	28 (36)	< 0.001
Abnormal ST segment/T waves	347 (33)	64 (82)	< 0.001
Cardiac failure	59 (6)	9 (12)	0.04
Atrial fibrillation	48 (5)	8 (10)	0.03
Hypertension	595 (56)	53 (70)	0.04
Diabetes	81 (8)	11 (14)	0.05
Renal failure	73 (7)	7 (9)	NS
Preoperative hemodialysis	16 (2)	1 (1)	NS
COPD	414 (39)	37 (47)	NS
Respiratory failure	99 (9)	9 (12)	NS
Patient treatment			
Trinitrin	129 (12)	26 (33)	< 0.001
β Blockers	272 (26)	42 (54)	< 0.001
ACEI	306 (29)	26 (33)	NS
Calcium inhibitor	350 (33)	35 (45)	0.04
Surgical characteristics			
Aneurysm	732 (69)	60 (77)	NS
Endovascular prosthesis	177 (17)	17 (22)	NS
Perioperative bleeding, l	1.0 (1.0–2.0)	1.1 (0.8–1.5)	NS
Postoperative bleeding, l	0.27 (0.25–0.30)	0.27 (0.19–0.44)	NS
Initial hemoglobin, g/dl	12.5 ± 1.7	12.3 ± 1.7	NS
Final hemoglobin, g/dl	10.1 ± 1.4	9.8 ± 1.0	NS
Surgery duration, h	3.0 (3.0–3.0)	3.0 (2.8–3.8)	NS
Packed erythrocytes, units	2 (2–2)	2 (1–3)	NS
Reoperation (any type)	86 (8)	10 (13)	NS
Anesthetic characteristics			
Intrathecal morphine	141 (13)	10 (13)	NS
Postoperative epidural analgesia	12 (1)	1 (1)	NS

Data are presented as mean ± SD, median (95% confidence interval), or n (%). *P* values refer to between-group differences. Renal failure was defined as a preoperative creatinine value greater than 150 μmol/l.

ACEI = angiotensin-converting enzyme inhibitors; CABG = coronary artery bypass graft; COPD = chronic obstructive pulmonary disease; NS = not significant; PCI = percutaneous coronary intervention.

land). Calculation of the number of patients to include in a trial was performed using Query Advisor 3.0 software (Statistical Solutions Ltd.).

Results

Description of the Cohort

From September 1996 to September 2002, 1,152 patients underwent abdominal aortic surgery and 308 patients underwent coronary angiography (fig. 1). In 224 patients, coronary angiography was performed in accordance with the American College of Cardiology/American Heart Association recommendations. In 45 patients, coronary angiography was indicated because of two or more atheromatous localizations necessitating vascular surgery (*e.g.*, carotid endarterectomy and aortic surgery). For the remaining 39 patients, coronary angiography was requested before the anesthesiologist's consultation, by a practitioner or the surgeon, without any of the previous indications. Fourteen of the 308 patients underwent CABG before surgery and were therefore excluded. In the remaining patients, 78 underwent PCI and 1,060 did not. PCI was performed between 5 and 8 weeks (mean, 5 weeks) before aortic surgery.

Table 1 describes the main characteristics of patients with and without PCI. The PCI population had worse baseline characteristics than the population that did not undergo PCI. No patient had a major complication in relation to coronary angiography, PCI, or both (radial false aneurysm, stroke, myocardial infarction, coronary dissection necessitating emergency CABG, and death). A coronary stent was used in 75 of 78 patients with PCI. Table 2 describes the main outcomes in these two groups of patients. No significant differences in cardiac outcome and hemorrhagic complications were observed between groups. Patients who underwent coronary angiography without PCI had either minor coronary lesions (n = 13) or untreatable severe coronary lesions (n = 123). This last group of patients had a very high cardiac risk as shown by the incidence of severe postoperative coronary events (n = 18; 14.5%) and death (n = 10; 8.1%).

Table 2. Comparison of the Outcome of Patients with or without Preoperative PCI

Variable	Control Group (n = 1,060)	PCI Group (n = 78)	*P* Value
Cardiac prognosis			
Postoperative myocardial damage	247 (23)	23 (29)	NS
Severe postoperative coronary event	67 (6)	7 (9)	NS
Death	44 (4)	4 (5)	NS
Hemorrhagic complications			
Gastrointestinal bleeding	24 (2)	3 (4)	NS
Reoperation for hemorrhage	20 (2)	2 (1)	NS
Death from hemorrhage	6 (1)	1 (1)	NS
All hemorrhagic complications	43 (4)	5 (6)	NS

Data are presented as n (%). *P* values refer to between-group differences.
NS = not significant; PCI = percutaneous coronary intervention.

Propensity Score Analysis

Variables significantly associated with the performance of PCI by logistic regression were history of angina, treatment with a β-blocking agent, diabetes mellitus, and previously abnormal ST segment/T wave. The area under the ROC curve was 0.82 ± 0.11 ($P < 0.05$), the Hosmer-Lemeshow statistic was 275.7 ($P < 0.001$), and there were no missing values in the selected variables. There were no significant differences in the propensity scores between groups, within each quintile (table 3). The three main outcomes were not significantly different between groups in each of the propensity score quintiles (table 3). We also pooled together patients who underwent PCI and those who did not (n = 1,158) and performed logistic regression to predict each endpoint, using the propensity score and adding PCI as a covariate. The odds ratios of PCI were not significant (NS) for prediction of postoperative myocardial damage (1.03 [95% CI, 0.60–1.77]; NS), a severe postoperative coronary event (0.90 [95% CI, 0.39–2.12]; NS), or death (0.69 [95% CI, 0.23–2.03]; NS).

Risk Adjustment Model

We determined the variables significantly associated with the three main outcomes (postoperative myocardial damage, severe postoperative coronary event, and death) only in patients who did not undergo PCI. Four variables independently predicted postoperative myocardial damage: age older than 75 yr, blood transfusion of more than 3 units, any type of repeated surgery, and previous cardiac failure. The model correctly classified 78% of the patients (chi-square = 56.0, $P < 0.001$). The area under the ROC curve was 0.64 ± 0.06, the Hosmer-Lemeshow statistic was 0.59 (NS), and there were no missing values in the selected variables. Five variables independently predicted severe postoperative coronary event: age older than 75 yr, blood transfusion of more than 3 units, any type of repeated surgery, preoperative hemodialysis, and previous cardiac failure. The model correctly classified 94% of the patients (chi-square = 80.4, $P < 0.001$). The area under the ROC curve was 0.79 ± 0.02, the Hosmer-Lemeshow statistic was 1.19 (NS), and there were no missing values in the selected variables. Five variables independently predicted postoperative death: age older than 75 yr, any type of repeated surgery, previously abnormal ST segment/T wave, previous hypertension, and previous cardiac failure. The model correctly classified 97% of the patients (chi-square = 134.8, $P < 0.001$). The area under the ROC curve was 0.90 ± 0.15, the Hosmer-Lemeshow statistic was 2.71 (NS), and there were no missing values in the selected variables. Table 4 summarizes these variables and provides their odds ratio.

With use of the logistic regression models, we calculated the predicted percentage of patients having bad outcomes in the PCI group and compared them to the

Table 3. Propensity Score Analysis in Patients with or without Preoperative PCI

	Quintile				
	1–2	3	4	5	*P* Value
Number of patients					
Control group	553 (52.1)	146 (13.8)	195 (18.4)	166 (15.7)	NS
PCI group	5 (6.4)	6 (7.7)	17 (21.8)	50 (64.1)	
Propensity score					
Control group	0.16 ± 0.00	0.30 ± 0.01	0.50 ± 0.08	0.78 ± 0.07	NS
PCI group	0.16 ± 0.00	0.29 ± 0.01	0.52 ± 0.09	0.80 ± 0.08	
Postoperative myocardial damage					
Control group	109 (19.7)	31 (21.2)	60 (30.8)	47 (28.3)	NS
PCI group	0 (0)	2 (33.3)	3 (17.6)	18 (36.0)	
Severe postoperative coronary event					
Control group	20 (3.6)	9 (6.2)	25 (12.8)	13 (7.8)	NS
PCI group	0 (0)	1 (16.7)	1 (5.9)	5 (10.0)	
Death					
Control group	9 (1.6)	7 (4.8)	17 (8.7)	11 (6.6)	NS
PCI group	1 (20.0)	0 (0)	11 (6.6)	2 (4.2)	

P values refer to global comparison between control and PCI groups. No significant difference between groups for each quintile.
NS = not significant; PCI = percutaneous coronary intervention.

Table 4. Independent Variables Associated with Postoperative Myocardial Damage, Severe Postoperative Coronary Event, and Death in Patients Who Did Not Undergo Preoperative PCI (n = 1,060)

Outcome and Variables	Odds Ratio (95% Confidence Interval)	*P* Value
Postoperative myocardial damage		
PE > 3 units	2.2 (1.6–3.0)	< 0.001
Cardiac failure	2.2 (1.3–3.9)	0.004
Reoperation (any type)	1.9 (1.2–3.1)	0.008
Age > 75 yr	1.5 (1.1–2.0)	0.02
Severe postoperative coronary event		
Preoperative hemodialysis	7.6 (2.4–23.8)	< 0.001
PE > 3 units	4.3 (2.3–7.8)	< 0.001
Reoperation (any type)	3.6 (1.9–6.8)	< 0.001
Age > 75 yr	2.5 (1.5–4.4)	0.001
Hypertension	2.0 (1.1–3.6)	0.03
Death		
Reoperation (any type)	39.7 (18.3–86.1)	< 0.001
Cardiac failure	7.3 (2.8–18.8)	< 0.001
Age > 75 yr	3.5 (1.6–7.6)	0.001
Hypertension	2.5 (1.1–5.7)	0.03

PCI = percutaneous coronary intervention; PE = packed erythrocyte units.

observed outcomes (table 5). No significant difference was noted, and the observed values were very close to the predicted ones.

Last, we pooled together patients who underwent PCI and those who did not (n = 1,158) and performed logistic regression to predict each endpoint, using the significant variables indicated above and adding PCI as a covariate. The odds ratios of PCI were not significant for prediction of myocardial damage (1.14 [95% CI, 0.67–1.94]; NS), a severe postoperative coronary event (1.09 [95% CI, 0.45–2.62]; NS), or death (1.49 [95% CI, 0.42–5.25]; NS).

Sample Size Calculation for Future Trial

According to the differences between the observed and predicted outcomes in patients undergoing PCI (table 5), we calculated the number of patients who should be included in a prospective randomized trial to demonstrate that PCI significantly modifies the incidence of postoperative myocardial infarction and death. Assuming an α risk of 0.05 and a β risk of 0.20, these numbers were 14,500 and 4,500, respectively. Because PCI was performed in only 7% of our patients, we can postulate that this randomized study should be performed by screening populations of patients undergoing abdominal aortic surgery of 207,000 and 65,000, respectively.

Table 5. Comparison of Predicted and Observed Incidence of Postoperative Myocardial Damage, Severe Postoperative Coronary Event, and Death in Patients Who Underwent Preoperative PCI (n = 78)

Outcome	Predicted, %	Observed, % (95% Confidence Interval)
Postoperative myocardial damage	27.1	23.3 (20.5–40.4)
Severe postoperative coronary event	8.2	9.0 (4.4–17.4)
Death	6.9	5.1 (2.0–12.5)

PCI = percutaneous coronary intervention.

Discussion

Our study suggests that preoperative PCI does not seem to influence short-term cardiac outcome after aortic surgery significantly.

Percutaneous coronary intervention has become one of the tools used to improve outcome after aortic surgery. This is a result of the high risk of development of postoperative cardiac complications in this population and the belief that PCI may improve survival and outcome in these patients.[19] However, a recent randomized controlled trial did not find that preoperative PCI favorably influenced outcome in these patients.[8] Cardiac risk in noncardiac surgery may be related to three important factors, namely the severity of coronary artery disease, the type of surgery, and the degree of hemodynamic stress associated with the surgical procedure. Among the vascular procedures, aortic surgery is considered to be associated with a high cardiac risk. Cardiac events such as myocardial infarction, left heart failure, arrhythmia, and cardiac death are a concern after aortic surgery. Improving cardiac morbidity and mortality in patients undergoing aortic reconstruction surgery is an important goal, and an accurate preoperative cardiac evaluation is considered to be crucial. Since 1996, guidelines for such an evaluation have been published and updated by the American College of Cardiology/American Heart Association Task Force. Based on clinical markers, functional capacity, and/or evidence of a high risk of adverse outcome based on noninvasive test results, patients undergoing aortic surgery may undergo coronary angiography.[2,3] Apart from CABG surgery, PCI is now proposed in these patients to reduce perioperative cardiac morbidity and mortality. If CABG has shown to be effective in reducing perioperative events in patients with significant coronary artery disease and undergoing major noncardiac procedures,[3] few data are available on the role of PCI in this setting.

Some studies reported that patients undergoing PCI have a low incidence of perioperative cardiac morbidity,[5,6,20,21] whereas others reported a catastrophic outcome[22] with surgery performed too early after PCI, the cessation of antiplatelet agents leading to stent thrombosis. However, these studies did not make any adjustment according to the estimated preoperative cardiac risk. Posner *et al.*[23] reported that patients undergoing PCI were twice as likely as healthy patients to have

an adverse cardiac outcome, whereas their risk was reduced by half compared with patients with untreated coronary artery disease. Nevertheless, this study matched variables that may not be clinically relevant (age, sex, type of surgery, year) and missed some important risk factors, such as hemorrhage or repeated surgery. In a randomized study comparing PCI to CABG, Hassan *et al.*[7] did not observe significant differences in the rates of myocardial infarction or death after noncardiac surgery. Recently, in a retrospective study, Landesberg *et al.*[19] analyzed the improvement in long-term survival after major vascular surgery. Based on the results of preoperative thallium scanning performed in 407 patients, they performed preoperative coronary revascularization (PCI or CABG) in 74 patients and concluded that long-term survival after major vascular surgery was significantly improved in patients undergoing coronary revascularization. However, several important criticisms can be made about this study: (1) Its power was low because only 74 patients underwent coronary revascularization; (2) the propensity score analysis used did not take into account important variables occurring during or after the surgical procedure (major bleeding, repeated surgery) that are associated with a poor cardiac outcome; and (3) the goodness of fit of the propensity score was significant, as in our study, indicating inappropriate fit of the model.

McFalls *et al.*[8] performed a well-designed controlled trial of the impact of preoperative coronary revascularization on the outcome of vascular surgery in high-cardiac-risk patients and did not find any significant improvement in long-term outcome. It should be emphasized that because both preoperative CABG and PCI were allowed, the proportion of patients undergoing PCI was relatively low (n = 142), and only 41% of the patients underwent major abdominal vascular surgery, with the others undergoing peripheral vascular surgery, which is associated with a lower incidence of major operative events.

The logistic model used in our study was very accurate to predict adverse coronary events and death but less accurate to predict myocardial damage. However, it should be emphasized that most of the variables associated with these adverse outcomes were not directly related to the severity of coronary artery disease but merely reflected the difficulties and complications of surgery (blood transfusion, repeated surgery, hemodialysis), whereas others reflected the frailty of the patient (old age, previous cardiac failure). This point is important because it suggests that prevention of postoperative cardiac risk should be directed more to these factors than those usually claimed, maybe because the quality of the perioperative management of the patient with coronary artery disease has greatly improved. It also could partly explain why PCI seems not to modify postoperative risk significantly in these patients. In a randomized study (which is considered very difficult here), the intraoperative variables cannot be entered but are thought to be equally distributed in both groups (PCI *vs.* control). However, three important issues should be emphasized: (1) Because outcomes are relatively rare (at least death and severe postoperative coronary adverse events) and because perioperative complications (such as repeated surgery) are also relatively rare, there are some difficulties to obtain an exact adjustment even after randomization, leading to potential heterogeneity[24,25]; (2) it is difficult to statistically prove this heterogeneity when it is suspected to have occurred[25,26]; (3) it is difficult to properly power randomized trials in patients with very different prognoses.[25]

Although we tried to obtain the most clinically relevant information from the population of patients without PCI in our logistic model, we cannot completely rule out the possibility of a severity bias leading to the selection of patients with a higher cardiac risk in the PCI group (table 1). Three arguments are not in favor of this hypothesis. First, the propensity score analysis provided the same conclusion (table 3). Second, some of the patients in the non-PCI group had a higher cardiac risk than patients in the PCI group. Third, when we pooled all patients, the odds ratios associated with PCI remained nonsignificant. Nevertheless, it should be recognized that the evidence provided by a nonrandomized study is always lower than that obtained in a randomized study, whatever the quality of the methods used.

In the current study, we used three endpoints: death, severe postoperative coronary event, and myocardial damage. Death and severe postoperative coronary event might be considered stronger endpoints than myocardial damage reflected by an increase of cardiac troponin I. However, analysis of cardiac troponin I is now the accepted standard method to diagnose myocardial damage, particularly in the postoperative period.[27] Moreover, an increased cardiac troponin I value in the postoperative period has recently been shown to be an important prognostic marker indicating a higher probability of death in the hospital[28] and within 2 yr after cardiac surgery.[29]

Some remarks must be included to assess the relevance of our study. First, there is still uncertainty regarding the ideal time that should elapse between PCI and noncardiac surgical procedures. Second, although the variables associated with an adverse coronary outcome were determined in a large population, the power of our study remains low because of the relatively small sample size of patients undergoing PCI. However, our study enables us to calculate the number of patients that should be included in a randomized study. For example, taking postoperative severe coronary events as the main endpoint, 65,000 patients should be included in such a trial. This high number of patients required means that such a randomized study will be very difficult to conduct and

that physicians will have to rely on studies such as ours for some time to come. However, our study is in agreement with the recent controlled trial studying the impact of preoperative coronary revascularization on the outcome of vascular surgery.[8]

In conclusion, in our prospective study including only high-risk surgery, preoperative PCI, when necessary, can be performed safely but does not seem to modify significantly the immediate postoperative cardiac risk.

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