ORIGINAL ARTICLE

Evaluation of Risk-Adjusted Hospital Mortality After Coronary Artery Bypass Graft Surgery in the Catalan Public Healthcare System. Influence of Hospital Management Type (ARCA Study)

Aida Ribera,[a,b] Ignacio Ferreira-González,[a,c] Purificación Cascant,[a] Joan M.V. Pons,[d] and Gaietà Permanyer-Miralda,[a] for the ARCA study investigators

[a]Unidad de Epidemiología, Servicio de Cardiología, Hospital Universitario Vall d'Hebron, Barcelona, Spain.
[b]Departament de Ciències Experimentals i de la Salut, Universitat Pompeu Fabra, Barcelona, Spain.
[c]Departament de Medicina, Universitat Autònoma, Barcelona, Spain.
[d]Agència d'Avaluació de Tecnologia i Recerca Mèdiques, Barcelona, Spain.

Introduction and objectives. Previous studies suggest that the effectiveness of coronary surgery is influenced by the type of management at the healthcare centre where the intervention is performed. The present study assessed the risk-adjusted hospital mortality of coronary surgery in the Catalan healthcare system in hospitals under either private or public management.

Methods. We carried out a prospective study of all consecutive patients receiving a first coronary artery bypass graft, with public financial support, in a period of 2 years at 5 hospitals under either public or private management. Preoperative risk was assessed using the EuroSCORE and Catalan Agency for Health Technology Assessment (CAHTA) predictive models.

Results. Overall, 1605 patients underwent interventions, 21% of which were at private hospitals. The percentage of patients undergoing non-elective surgery was higher at private hospitals (64% vs 50%), as was the percentage needing intravenous nitrates (17% vs 11%) and the percentage in functional class IV (20% vs 11%). The odds ratio for in-hospital mortality in private compared with public hospitals was 0.56 (95% CI, 0.29-1.06) when adjusted for EuroSCORE, 0.56 (95% CI, 0.29-1.07) when adjusted for CAHTA score, and 0.43 (95% CI, 0.21-0.87) when adjusted for patient characteristics. The mortality observed, 4.8% (95% CI 3.8-5.6), was not significantly higher than that predicted.

Conclusions. *a)* Hospital mortality was equivalent to or lower than that expected after adjustment for the 2 risk scores; *b)* after adjustment for baseline patient characteristics, the results favored privately managed centers; and *c)* comparison with previous results suggests that coronary surgery effectiveness has improved in recent years.

Key words: *Coronary artery bypass graft. Hospital mortality. Risk assessment.*

SEE EDITORIAL ON PAGES 414-7

Evaluación de la mortalidad hospitalaria ajustada al riesgo de la cirugía coronaria en la sanidad pública catalana. Influencia del tipo de gestión del centro (estudio ARCA)

Introducción y objetivos. En estudios previos se señala que hay diferencias en la efectividad de la cirugía coronaria según si la intervención se realiza en centros de gestión pública o privada. Este estudio evalúa la mortalidad hospitalaria de la cirugía coronaria en ambos tipos de centro, ajustada al riesgo preoperatorio, en pacientes de la sanidad pública catalana.

Métodos. Se incluyó prospectivamente a todos los pacientes intervenidos de un primer *bypass* coronario durante 2 años, con financiación pública, en 5 hospitales de gestión pública y privada. Se evaluó el riesgo mediante el EuroSCORE y el modelo de la AATRM.

Resultados. Se intervino a 1.605 pacientes (el 21% en hospitales privados). En centros privados se operó a más pacientes no electivos (el 64 frente al 50%), con angina inestable (el 17 frente al 11%) y grado funcional IV (el 20 frente al 11%). La *odds ratio* (OR) para la mortalidad hospitalaria en centros privados frente a públicos fue de 0,56 (intervalo de confianza [IC] del 95%, 0,29-1,06) tras ajustar por el EuroSCORE, y de 0,56 (IC del 95%, 0,29-1,07) tras ajustar por la escala de la AATRM. La mortalidad observada (el 4,8%; IC del 95%, 3,8-5,6) no era significativamente distinta de la esperada. Al ajustar por las características basales de los pacientes, la gestión privada del centro se asoció con una menor mortalidad (OR = 0,43; IC del 95%, 0,21-0,87).

Conclusiones. *a)* La mortalidad hospitalaria es equivalente o inferior a la esperada según 2 instrumentos

The investigators for the ARCA study are listed at the end of this article.

This study was funded by the Agència d'Avaluació de Tecnologia i Recerca Mèdiques of Catalonia (Medical Technology and Research Evaluation Agency of Catalonia, AATRM: 061/22/2000) and partially by the Instituto de Salud Carlos III (Carlos III Health Institute) (IRYSS Network: G03/202).

Correspondence: Dr. C. Permanyer-Miralda.
Unidad de Epidemiología. Servicio de Cardiología. Hospital Universitario Vall d'Hebron.
P.º Vall d'Hebron, 119-129. 08035 Barcelona. España.
E-mail: gpermany@vhebron.net

Received October 7, 2005.
Accepted for publication March 2, 2006.

ABBREVIATIONS

AATRM: Agència d'Avaluació de Tecnologia i Recerca Mèdiques (Medical Technology and Research Evaluation Agency of Catalonia).
ARCA: Avaluació del Risc de la Cirurgia Coronària a Catalunya (Coronary Surgery Risk Assessment in Catalonia).
AMI: acute myocardial infarction.
CCS: Canadian Cardiovascular Society.
CI: confidence interval.
OR: odds ratio.
SMR: standard mortality ratio.

de ajuste de riesgo; *b)* el ajuste según las características de los pacientes indica que hay una diferencia favorable a los centros de gestión privada, y *c)* la comparación con resultados previos evidencia una mejora de la efectividad de la cirugía coronaria en los últimos años.

Palabras clave: *Injerto aortocoronario. Mortalidad hospitalaria. Evaluación del riesgo.*

Full English text available from: www.revespcardiol.org

INTRODUCTION

The use of risk prediction systems is becoming routine practice in many medical care procedures, particularly cardiac surgery, thus allowing an adequate assessment of results in actual clinical practice. Randomized clinical trials have shown that coronary surgery improves survival, symptoms, and quality of life,[1,2] and interest is now increasingly focused on factors that affect its effectiveness. Hospital mortality risk prediction tools are also a good way to assess risk/benefit and healthcare quality, as is shown by the proliferation of models for this purpose and their widespread use.[3-6]

In Catalan public health, coronary surgery is performed primarily at publicly managed hospitals, although a considerable percentage of patients are sent to privately managed centers. The CIRCORCA study,[7,8] conducted in 1997, found that the mortality associated with this type of surgery was high at that time and significantly higher in publicly-funded healthcare than in private care. However, it was not possible to rule out that this difference might be attributable to variations in the baseline characteristics of the populations treated in these two systems of healthcare funding. When patients from public healthcare were analyzed separately and the results compared between publicly and privately managed centers, the difference was small and not significant, in keeping with another study conducted by the Agència d'Avaluació de Tecnologia i Recerca Mèdiques (AATRM, Medical Technology and Research Evaluation Agency).[9] Nevertheless, since the aim of that study was not a comparison by management type, the sample was not large enough for that purpose and specific methods were not applied for risk adjustment.

The purpose of the present study was to compare hospital mortality rates adjusted for the surgical risk and the preoperative risk characteristics of patients seen in the Catalan public health system who underwent isolated coronary bypass surgery for the first time in publicly or privately managed hospitals.

METHODS

Data Collection

From October 2001 to October 2003, data were prospectively collected for all patients covered by the public healthcare system in whom a coronary artery bypass graft (CABG) was indicated as first surgery with no other associated procedures. This was done at three publicly managed hospitals (the other 2 hospitals where CABG is performed were not included for logistic reasons) and 2 privately managed hospitals in Catalonia (the only 2 private centers in Catalonia

TABLE 1. **Structural Characteristics for Participating Centers During the Study Period**

	Center 1	Center 2	Center 3	Center 4	Center 5
Number of coronary bypass surgeries*	579	479	518	267	353
Management type	Public	Public	Public	Private	Private
Type	General	General	General	General	Specialist
Resident teaching program	Yes	Yes	Yes	No	No
No. of beds	715	638	634	270	63
No. of surgeons	5	5	5	1	2
Median wait, days	75	49	33	33	18
Median total hospitalization, days	19	14	9	20	23
Median postoperative period, days	8	8	6	11	11

*Including patients from private healthcare, repeat surgeries, and procedures combined with valvular surgery.

where patients referred from the public health system are operated). The characteristics of the 5 participating centers are shown in Table 1. Only 1 of the surgeons in the private hospitals is also a team member at a public center.

At each center, a member of the surgical team or cardiology department was responsible for reviewing the CABG schedules and completing the data collection questionnaire by interviewing the patient and reviewing the medical history and discharge reports.

Data collection quality controls were performed by a random review of 10% of the medical histories by an outside investigator and a comparison with the Minimum Basic Data Set at hospital discharge.

Surgical Risk Assessment

Surgical risk was assessed with 2 predictive models developed from logistic regression models and validated in different settings. The description of the models is shown in Table 2, along with the scores assigned to each predictive risk factor. The AATRM model was developed in Catalonia in 1994[10] to predict cardiac surgery mortality in valvular, coronary and combination surgery. Of the 11 variables considered, information was collected on 9 that are applicable to a first, isolated CABG: age, recent history (less than 4 weeks) of myocardial infarction, functional class III or IV according to the Canadian Cardiovascular Society classification, presence of liver disease, left ventricular aneurysm, renal failure with creatinine value ≥1.5 mg/dL and cardiogenic shock, need for preoperative mechanical ventilation, and urgent or emergency indication. The presence of each of these factors is cumulative when scoring the resulting risk, which can be stratified into five risk levels: low when the score is between 0 and 10, moderate between 11 and 15, high between 16 and 20, very high between 21 and 30, and extreme when ≥31.

The EuroSCORE was developed and validated[6,11] in Europe. As with the previous scale, it was developed to predict the surgical risk of cardiac surgery and is a cumulative scale that involves the following variables (after excluding those referring to reoperation and valvular or combined surgeries): age, sex, chronic pulmonary disease, presence of extracardiac arteriopathy and neurological dysfunction, creatinine >200 µmol/L, unstable angina (need for intravenous nitrates before anesthesia), moderate or severe left ventricular dysfunction, recent history (<90 days) of myocardial infarction, systolic pulmonary hypertension, emergency indication, and critical preoperative condition. The resulting score can be stratified into three risk levels: low (0-2), moderate (3-5), and high (≥6).

Hospital mortality was defined as death due to any cause during or after the procedure and up to hospital discharge, or within 30 days following the procedure.

The comparison considered the baseline characteristics of the patients, the characteristics of the surgical procedure, and the stratified hospital mortality according to risk levels defined by both models between the hospitals grouped according to public or

TABLE 2. **Risk and Score Prediction Models***

AATRM scale		EuroSCORE	
Age, y		Age (every 5 years above 60)	1
70–79	7	Female	1
≥80	17	Chronic pulmonary disease	1
Recent AMI (<4 weeks)	10	Extracardiac arteriopathy	2
Functional class		Neurological dysfunction	2
III	4	Previous cardiac surgery	3
IV	10	Creatinine >200 µmol/L	2
Liver disease	8	Endocarditis	3
Left ventricular aneurysm	11	Critical preoperative state	3
Creatinine ≥1.5 mg/dL	8	Unstable angina (intravenous nitrates)	2
Cardiogenic shock	13	Left ventricular dysfunction	
Preoperative mechanical ventilation	7	Moderate	1
Priority (emergency or urgent)	4	Severe	3
Reoperation		Recent AMI (<90 days)	2
First	9	Pulmonary hypertension	2
Second	15	Emergency	2
Mitral valve surgery	6	Surgery other than or in addition to CABG	2
Tricuspid valve surgery	10		
Thoracic aorta surgery	12	Thoracic aorta surgery	3
Combined valvular and coronary surgery	7	Postinfarct septal rupture	4

*AATRM indicates Agència d'Avaluació de Tecnologia i Recerca Mèdiques; AMI: acute myocardial infarction.

TABLE 3. **Baseline Characteristics of the Study Population***

	Public Centers (n=1267)	Private Centers (n=338)
Sociodemographic characteristics		
Women	19%	20%
Mean age, limits	65 (32-85)	65 (33-84)
Active employment	30%	27%
Elementary school completed	38%	39%
Cardiovascular risk factors		
Hypertension	64%	59%
Hypercholesterolemia	66%	63%
Diabetes	41%	35%
Smoking	25%	27%
History		
Ischemic heart disease (angina or AMI)	74%	72%
Previous percutaneous revascularization	11%	11%
Heart failure	12%	8%
Cerebrovascular disease	7%	7%
Vessels affected		
Three-vessel	72%	63%†
Left main coronary artery	28%	27%
Proximal left anterior descending artery	55%	46%†
Characteristics of surgery		
Number of grafts per patient		
1	8%	9%
2	30%	39%
3 or more	62%	53%
Number of arterial grafts per patient		
1	71%	87%
2	21%	2%
3 or more	4%	1%‡
Off-pump surgery	50%	22%‡

*AMI indicates acute myocardial infarction.
†$P<.05$. ‡$P<.01$.

TABLE 4. **Determinants of Surgical Risk According to AATRM Scale and EuroSCORE***

Surgical Risk Factors	Public Centers (n=1267)	Private Centers (n=338)
Urgent or emergent surgery	50%	64%‡
Resting angina in previous 72 h	12%	17%‡
Need for intravenous nitrates	11%	17%‡
CCS functional class		
II	61%	59%
III	25%	17%
IV	11%	20%‡
Creatinine ≥1.5 mg/dL	9%	15%‡
Chronic obstructive pulmonary disease	17%	12%‡
Extracardiac vascular disease	24%	28%
Recent myocardial infarction		
(in previous 29 days)	19%	22%
Critical preoperative condition	3%	6%‡
Left ventricular dysfunction		
Moderate	20%	27%
Severe	4%	6%‡

*AATRM indicates Agència d'Avaluació de Tecnologia i Recerca Mèdiques; CCS, Canadian Cardiovascular Society classification. Class 0 was assigned to patients with no angina or restriction of daily tasks. Patients without angina, but with restrictions in daily physical activity, were assigned the functional class corresponding to this restriction.
†$P<.05$. ‡$P<.01$.

private management. The risk-adjusted mortality rate was calculated from the standardized mortality ratio (SMR), which is the quotient between observed deaths and expected deaths. To obtain the expected deaths, the logistic equation was adjusted according to the risk characteristics of the study population. The logistic equation for the EuroSCORE was obtained from Roques et al,[12] and the AATRM model equation[10] was obtained from the authors (JMVP and VM).

The baseline predictors of hospital mortality were analyzed using a logistic regression model. In order to construct the model, the variables presenting an association with hospital mortality at a significance level <.1 were selected, along with the independent variables that presented a high level of collinearity and could be assumed to have more objective results during the data collection.

Additionally, the prevalences of the risk factors and hospital mortality rate for the hospitals that participated in this study were compared to those from a previous study,[7,8] in order to assess the changes that have occurred in the risk profile and surgical mortality in Catalonia.

RESULTS

Among the 1640 patients scheduled for surgery during the study period, 1605 actually underwent surgery; 1267 at publicly managed centers and 338 at privately managed centers. The median waiting time for the 751 patients with an elective indication was 43 days (25th percentile, 22 days; 75th percentile, 69 days). Table 3 contains the patients' baseline characteristics at the time of the procedure, according to surgery at publicly or privately managed hospitals. No differences were found between patients treated at the 2 types of centers in demographic characteristics, cardiovascular risk factors, or history of cardiovascular disease. The public hospitals performed a significantly higher number of off-pump multiple arterial graft procedures. However, the privately managed hospitals were more likely to operate on patients in emergency situations, with unstable angina, poorer functional class, or renal dysfunction (Table 4). The risk score according to both scales was higher at privately managed centers (Figure 1).

There were no statistically significant differences in the crude figures for hospital mortality (Table 5): 5.13% (95% confidence interval [CI], 3.9-6.63) in

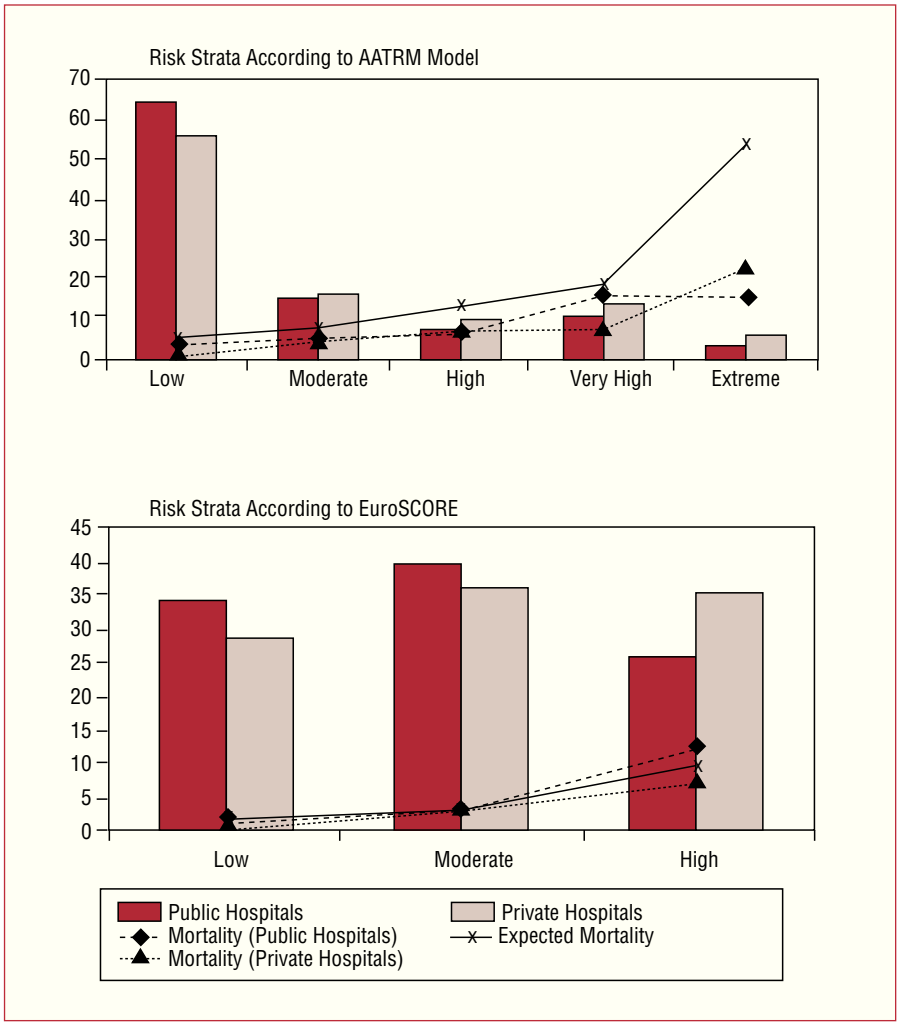

Figure 1. Percentage of patients and hospital mortality in each risk strata defined according to both adjustment scales, in publicly and privately managed hospitals. AATRM indicates Agència d'Avaluació de Tecnologia i Recerca Mèdiques.

public centers and 3.55% (95% CI, 1.7-5.5) in private (crude odds ratio [OR] =0.68; 95% CI, 0.36-1.28). The OR adjusted for the risk levels was 0.56 (95% CI, 0.29-1.06) as defined by the EuroSCORE and 0.56 (95% CI, 0.29-1.07) according to the AATRM scale.

TABLE 5. **Observed and Expected Hospital Mortality According to AATRM and EuroSCORE Scales***

Hospital Mortality	Public Centers (n=1267)	Private centers (n=338)
Observed mortality (95% CI)	5.13% (3.9-6.3)	3.55% (1.7-5.5)
Expected mortality according to AATRM scale	6.8%	8.8%
Expected mortality according to EuroSCORE	4.2%	5.2%

*AATRM indicates Agència d'Avaluació de Tecnologia i Recerca Mèdiques; CI, confidence interval.

Although the SMR was lower in the two privately managed hospitals, the difference compared to the SMR for the 3 public hospitals was not statistically significant (Figure 2). Because the AATRM scale was used to adjust the risk, all estimations and respective confidence intervals were below 1, which indicates a significantly lower observed mortality than expected.

The independent predictors of hospital mortality in the study population (Table 6) were age, severely depressed ventricular function, critical preoperative state, renal failure, recent history of acute myocardial infarction, presence of chronic obstructive pulmonary disease, presence of peripheral artery disease, and presence of angina (defined as the need for intravenous nitrates at the time of surgery or presence of an angina crisis at rest within 72 h before surgery). When adjusting for these risk factors, the hospital management type had a significant influence on hospital mortality, with private management a predictor of greater survival (OR=0.43; 95% CI, 0.21-0.87). When a variable to indicate the surgeon's

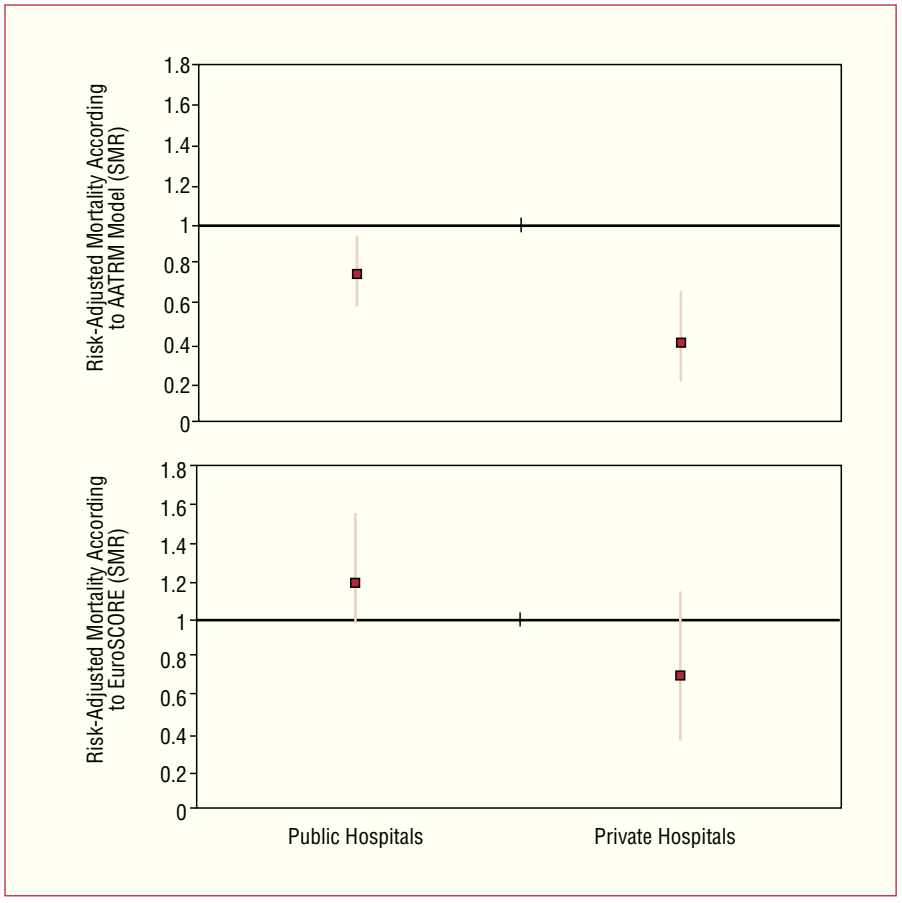

Figure 2. Observed, expected, and adjusted (observed/expected) mortality according to both adjustment scales in publicly and privately managed hospitals. AATRM indicates Agència d'Avaluació de Tecnologia i Recerca Mèdiques.

activity (number of surgeries performed by each surgeon in study patients) was introduced in the model, this variable was also associated with greater survival when the number of surgeries was higher (OR for every 10 surgeries =0.95; 95% CI, 0.90-1) and did not significantly modify the estimation of the parameters for the other variables included in the model. The OR for private management rose from 0.43 to 0.49 (95% CI, 0.24-1).

The results of a comparison among the four hospitals participating in this study that also participated in a previous study (Table 7) showed the following: whereas the prevalence of most risk indicators was similar in both study periods (e.g., 65 vs 63 years of age, 55% vs 56% urgent indication; 14% vs 16% patients with chronic obstructive pulmonary disease), the crude incidence of hospital mortality was halved, from 10% to 4.9%.

TABLE 6. **Independent Predictors of Hospital Mortality***

	Crude OR	95% CI	Adjusted OR	95% CI
Age, y	1.07	1.04-1.1	1.05	1.02-1.09
Moderately depressed ventricular function	1.64	0.96-2.79	1	0.55-1.82
Severely depressed ventricular function	5.09	2.5-10.39	3.48	1.56-7.8
Critical preoperative condition	5.41	2.6-11.26	2.87	1.19-6.95
Creatinine ≥1.5 mg/dL	5.22	3.15-8.64	3	1.7-5.29
Recent myocardial infarction (in previous 28 days)	2.65	1.64-4.27	1.92	1.12-3.13
Chronic obstructive pulmonary disease	2.96	1.81-4.86	2.25	1.31-3.86
Extracardiac vascular disease	2.77	1.74-4.4	1.73	1.03-2.89
Unstable angina (need for intravenous nitrates)	4.52	2.78-7.36	2.9	1.66-5.09
Privately managed center	0.68	0.36-1.28	0.43	0.21-0.87

*CI indicates confidence interval; OR, odds ratio.

TABLE 7. **Comparison of Risk Indicators With a Previous Study***

	CIRCORCA Study (n=290)	ARCA Study (n=1211)
Data collection period	December 1996 to June 1997	October 2001 to October 2003
Women	17%	20%
Age, mean ± SD, y	63±9.8	65±10††
CCS III-IV	55%	41%†
Urgent or emergency indication	56%	55%
Chronic renal failure	8%	11%
Chronic obstructive pulmonary disease	16%	14%
Extracardiac vascular disease	19%	25%†
Cerebrovascular disease	7%	7%
Patients operated at public hospitals	74%	72%
Recent myocardial infarction (in previous 28 days)	11%	20%††
Hospital mortality	10%	4.9%††

*CCS indicates functional class according to Canadian Cardiovascular Society; SD, standard deviation.
†$P<.05$. ††$P<.01$.

DISCUSSION

The purpose of this study was specifically to analyze whether or not the type of hospital management (public or private) in Catalonia is associated with different hospital mortality rates. We first posed this question in a previous study,[7,8] which suggested that this difference might exist. The existence of this previous study conducted in the same population base and with comparable definitions of risk characteristics also allowed us to analyze changes in the risk profile and hospital mortality over a 7-year period.

The main finding of this study is that there are no differences in mortality rates between the 2 groups of hospitals, although there are differences in some of the risk characteristics, which were somewhat higher in patients undergoing surgery in private hospitals. The differences were not related to baseline risk factors such as age, history of cardiovascular disease, or presence of other concomitant diseases and therefore, we may assume that patients from the public health sent to privately managed hospitals for surgery are not selected according to baseline risk status or sociodemographic characteristics.

Although the public centers operated on patients with more severe coronary disease (higher percentage of patients with 3-vessel or proximal anterior descending artery disease), the factors that contributed most to the difference in risk were poorer functional class, greater need for intravenous nitrates, and greater frequency of angina crises at rest within 72 h before surgery in the patients referred to privately managed hospitals, with an urgent or emergency indication in 66% of the cases. All of these factors indicate a more unstable status at the time of surgery and, unlike factors related to coronary anatomy (3-vessel, left main coronary artery or proximal anterior descending disease) appear in most risk scales as predictors of hospital mortality.

These differences (already confirmed by the CIRCORCA study) are unlikely to be random, but are probably the result of healthcare characteristics rather than differences in the patients' baseline situation: we can assume that, in the private hospitals analyzed, the healthcare policy allows or leads to earlier surgery in unstable patients, which, in itself, will mean a shorter time from the last angina crisis and a more frequent need for intravenous nitrates. Although it can be argued that the differences in nitrate use could reflect differing therapeutic habits rather than a genuine difference in risk, it is well accepted that an operation closer in time to an unstable phase (angina crisis at rest) involves greater surgical risk.[6,10] This higher risk is well illustrated by the finding that, regardless of the type of management at the center, surgery on patients who require intravenous nitrates was the predictor of highest mortality (adjusted OR=2.9, Table 4).

Due to this difference in risk profile, the adjusted mortality was higher (although not statistically significant) in public versus privately managed hospitals, and the variable defined as private management appeared to be a predictor of better survival after adjusting for the baseline characteristics that influence hospital mortality. Although small, this difference is consistent with that observed in our previous study and indicates dissimilar healthcare processes at the 2 types of hospitals.

Overall, the observed mortality rate was low (4.7%) and did not differ from what would be expected when applying the EuroSCORE risk equation to both publicly and privately managed hospitals. The expected mortality estimated from the AATRM equation was noticeably higher than that observed at all sites.

An important finding is the evidence for an apparent improvement in CABG results in recent years, consistent with the trends observed in other autonomous communities.[13] The data show that the 4 hospitals (2 public and 2 private) participating in both studies, the first in 1997, now have lower surgical mortality rates, even though the operated populations have a similar (or higher) prevalence of the most important risk indicators. This finding would be difficult to interpret without assuming a considerable improvement in the quality of the healthcare process, an improvement that can be related to interventions in health management and the dissemination of results from studies such as this one.

In addition to the risk factors considered, mortality estimation based on risk models depends on the results of surgery in the cohort used to derive the risk model. The EuroSCORE was developed from the data voluntarily collected at 128 centers in 8 European countries in 1995. The hospital mortality observed for CABG in the participating Spanish hospitals was 6.8%, whereas in the remaining countries it ranged from 1.5% in Finland to 3.7% in the United Kingdom.[14]

In contrast, the AATRM risk scale was developed from the data collected at all the centers (public and private) in Catalonia that performed more than 150 cardiac surgeries in 1993. In this period, a hospital mortality (at 30 days) of 8.1% was observed for isolated CABG. When the risk is equal, the Catalan scale estimates an expected mortality similar to the results obtained in the autonomous community of Catalonia in 1994 and therefore, overestimates the current risk of the surgery. This finding indicates the need to update the adjustment models[15] as well as the usefulness of local models for historic comparisons and global models for international comparisons or comparisons between health systems.[16]

Despite the potential limitations of risk adjustment systems,[17] the strong consistency between the results obtained by 3 different strategies to calculate the association between management type and hospital mortality (the use of 2 risk models, one of local scope and another of European, and the adjustment for baseline characteristics of the study population) indicates that there must be an actual association between management type and hospital mortality of an unknown magnitude, estimated at an OR of about 0.50. This magnitude is not negligible, but should be interpreted in light of the limitations related to the study population discussed below. It should be pointed out that this study makes no attempt at a detailed investigation of the nature of this association, which should probably be addressed in more specific studies.

First, although the privately managed participating hospitals include all the centers of this type where public patients undergo surgery under an agreement with the Instituto Catalán de la Salud (Catalan Health Institute), there are only 2 hospitals. Hence, it cannot be ruled out that the type of management might be another characteristic among the differences in the care process.

Second, for logistic reasons, only 3 of the 5 Catalan public hospitals that perform CABG could be included. There were no changes in the infrastructure of the 2 remaining hospitals since our previous study, in which they did participate.

Third, the study sample sufficed for the basic objective, but it is possible that other differences might have been revealed if more centers were included or the observation period were longer. Furthermore, the hierarchical nature of the data (patients operated at different centers with various care characteristics) should be taken into account, although the smaller number of centers did not allow a multilevel model to be created to adjust for the "center" effect.[18] However, a preliminary analysis was performed to introduce the categorical variable "center", although this showed no significant effect in hospital mortality.

Other circumstances could certainly explain the findings of this study, such as the different number of surgeries per surgeon (Table 1) or the various postoperative care practices, although these are not necessarily external to the management model. In particular, a previous study[7,8] found a more efficient distribution of surgeons per patient in the private centers, an aspect often associated with the results of the procedure.[19] Also in this study, the volume of patients operated by each surgeon is associated with higher survival, as well as a slight decrease in the association between management type and hospital mortality. This fact indicates that the surgeon's activity may be one of the factors, among many others, that explains the difference between public and private hospitals.

Similarly, the teaching status of the public centers may make them prone to inequalities in care quality,[20,21] due to the involvement of less experienced professionals and the stronger trend toward using more innovative and technically more complex procedures. In contrast, Table 2 shows that the publicly managed centers where there are more surgeries with off-pump multiple arterial grafts may be indicators of better care quality. Moreover, the decision to operate on patients in more unstable status in private hospitals is another example that the care process depends on professional criteria and management type. The differences in the structure or the care process between public and private hospitals that could explain differences in the result should be the subject of other studies specifically designed for this purpose.

The interest in correlating the various management modalities (determinants for the characteristics of the patient population and the care process) and the

differences in the results is not new. In other contexts and in relation to other procedures,[22,23] there are several examples of this type of comparison. However, a conceptual framework for consistent interpretation of these findings has not yet been developed, in particular for the field of myocardial revascularization, where important changes have been made in recent years. A recent study compared the results of cardiac revascularization procedures between specialized centers and the overall results for a broad sample of patients.[24] Eighty percent of the specialized centers were private, for-profit institutions, whereas 70% of the general hospitals were non-profit, with the OR for post-CABG mortality favoring the former. This effect, however, was weaker when the volume of procedures was considered, a fact that has been associated with the outcome in other studies.[25]

CONCLUSIONS

The Avaluació del Risc de la Cirurgia Coronària a Catalunya (ARCA, Coronary Surgery Risk Assessment in Catalonia) study concluded the following: *a)* hospital mortality at both public and private hospitals for a first CABG among public healthcare patients in Catalonia is equal to or lower than the expected level according to two risk-adjustment tools; *b)* nevertheless, adjustment for patient characteristics indicates a difference that is favorable for privately managed hospitals and consistent with differences in the care process; and *c)* the decline in hospital mortality with respect to a previous study indicates a general trend toward improved post-CABG healthcare in Catalonia in recent years.

ACKNOWLEDGEMENTS

The authors would like to thank Josep Ramon Marsal for his review of the statistical methodology for the final version of the manuscript.

INVESTIGATORS FOR THE ARCA STUDY

M. Murtra: Servicio de Cirugía Cardiaca, Hospital Universitario Vall d'Hebron, Barcelona. C. Sureda, M.A. Castro, X. Ruyra: Servicio de Cirugía Cardiaca, Hospital Germans Trias i Pujol, Badalona. B. Romero, F. Callejo, A. Arís: Hospital de la Santa Creu i Sant Pau, Barcelona. C. Martínez-Useros, J. Mulet: Hospital General de Catalunya, Sant Cugat del Vallès. M. Sanz, O. Solé. Centre Cardiovascular Sant Jordi, Barcelona.

REFERENCES

1. Yusuf S, Zucker D, Peduzzi P, Fisher LD, Takaro T, Kennedy JW, et al. Effect of coronary artery bypass graft surgery on survival: overview of 10-year results from randomised trials by the Coronary Artery Bypass Graft Surgery Trialists Collaboration. Lancet. 1974;344:563-70.
2. Five-year clinical and functional outcome comparing bypass surgery and angioplasty in patients with multivessel coronary disease. A multicenter randomized trial (BARI trial). JAMA. 1997; 277:715-21.
3. Hannan EL, Kilburn H, Racz M, Shields E, Chassin MR. Improving the outcomes of coronary artery bypass surgery in New York State. JAMA. 1994;271:761-6.
4. Hannan EL, Kilburn H, O'Donnell JF, Lukacik G, Shields EP. Adult open heart surgery in New York State: an analysis of risk factors and hospital mortality rates. JAMA. 1990;256:2768-74.
5. 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 Suppl I:3-12.
6. Nashef SAM, Roques F, Michel P, Gauducheau E, Lemeshow S, Salamon R. European System for Cardiac Operative Risk Evaluation (EuroSCORE). Eur J Cardiothorac Surg. 1999;16:9-13.
7. Permanyer-Miralda G, Brotons C, Ribera A, Cascant P, Pons JMV, Alonso J, et al. Desigual perfil clínico, calidad de vida y mortalidad hospitalaria en pacientes operados de injerto aortocoronario en centros públicos y privados de Cataluña. Rev Esp Cardiol. 1998;51:806-15.
8. Permanyer-Miralda G, Brotons C, Ribera A, Alonso J, Cascant P, Moral I. Resultados después de cirugía coronaria: determinantes de calidad de vida relacionada con la salud postoperatoria. Rev Esp Cardiol. 2001;54:607-16.
9. Pons JMV, Moreno V, Borràs J, Espinàs J, Almazán C, Granados A. Open heart surgery in public and private practice. J Health Serv Res Policy. 1999;4:73-8.
10. Pons JMV, Granados A, Espinas JA, Borrás JM, Martín I, Moreno V. Assessing open heart surgery mortality in Catalonia (Spain) through a predictive risk model. Eur J Cardiothoracic Surg. 1997; 11:415-23.
11. Roques F, Nashef P, Michel P, Pinna Pintor P, David M, Baudet E, for the EuroSCORE study group. Does EuroSCORE work in individual European countries? Eur J Cardiothorac Surg. 2000; 18:27-30.
12. Roques F, Michel P, Goldstone AR, Nashef SAM. The logistic EuroSCORE. Eur Heart J. 2003;24:1-2.
13. García-Fuster R, Montero JA, Gil O, Hornero F, Cánovas S, Bueno M, et al. Tendencias en cirugía coronaria: cambios en el perfil del paciente quirúrgico. Rev Esp Cardiol. 2005;58:512-22.
14. Nashef SAM, Roques F, Michel P, Cortina J, Faichney A, Gams E, et al. Coronary surgery in Europe: comparison of the national subsets of the European System for Cardiac Operative Risk Evaluation database. Eur J Cardiothorac Surg. 2000;17:396-9.
15. Ivanov J, Tu JV, Naylor D. Ready-made, recalibrated, or remodeled? Issues in the use of risk indexes for assessing mortality after coronary artery bypass graft surgery. Circulation. 1999;99:2098-104.
16. Pitkänen O, Niskanen M, Rehnberg S, Hippeläinen M, Hynynen M. Intra-institutional prediction of outcome after cardiac surgery: comparison between a locally derived model and the EuroSCORE. Eur J Cardiothorac Surg. 2000;18:703-10.
17. Cortina-Romero JM. Scores de gravedad y complejidad en cirugía cardíaca. Usos y limitaciones. Rev Esp Cardiol. 2005;58:473-6.
18. Catalán-Reyes MJ, Galindo-Villardón MP. Utilización de los modelos multinivel en investigación sanitaria. Gac Sanit. 2003;17 Supl 3:35-52.
19. Birkmeyer JD, Stukel TA, Siewers AE, Goodney PP, Wennberg DE, Lucas FL. Surgeon volume and operative mortality in the United States. N Engl J Med. 2003;349:2117-27.
20. Khuri SF, Najjar SF, Daley J, Krasnicka B, Hossain M, Henderson WG, et al. VA National Surgical Quality Improvement Program. Comparison of surgical outcomes between teaching and nonteaching hospitals in the Department of Veterans Affairs. Ann Surg. 2001;234:370-82.

21. Carbonell AM, Lincourt AE, Kercher KW, Matthews BD, Cobb WS, Sing RF, et al. Do patient or hospital demographics predict cholecystectomy outcomes? A nationwide study of 93,578 patients. Surg Endosc. 2005;19:767-73.
22. Devereaux PJ, Schunemann HJ, Ravindran N, Bhandari M, Garg AX, Choi PT et al. Comparison of mortality between private for-profit and private not-for-profit hemodialysis centers: a systematic review and meta-analysis. JAMA. 2002; 288:2449-57.
23. Shortell SM, Zimmerman JE, Rousseau DM, Gillies RR, Wagner DP, Draper EA, et al. The performance of intensive care units: does good management make a difference? Med Care. 1994;32:508-25.
24. Cram P, Rosenthal GE, Vaughan-Sarrazin MS. Cardiac revascularization in specialty and general hospitals. N Engl J Med. 2005;352:1454-62.
25. Rosenthal GE, Vaughan-Sarrazin M, Hannan EL. In-hospital mortality following coronary artery bypass graft surgery in veterans health administration and private sector hospitals. Med Care. 2003;41:522-35.