Analysis of In-Hospital Mortality From Coronary Artery Bypass Grafting Surgery

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Introduction and objectives. Outcomes research and monitoring are of key importance in efforts to improve health care effectiveness and quality. The aim of this study was to describe in-hospital mortality from coronary artery bypass grafting in Spain. Data in an administrative database were used to estimate the statistical performance of two risk-adjustment methods, the Charlson and Ghali indexes.

Patients and method. From the Spanish Hospital Minimum Basic Data Set corresponding to 1997 and 1998 all records which included a code for coronary artery bypass grafting were selected. With in-hospital mortality as the outcome variable, two risk-adjusted logistic multiple regression models were constructed.

Results. The database included 13,203 cases, of which 80% were men; mean age was 64.5 years. In-hospital mortality was 7.3%. The figure was significantly higher for women and increased with age. A score of one on the Charlson and Ghali indexes was associated, respectively, with a 23 and 20% increase in the risk of mortality. Probability calculated with the Hosmer-Lemeshow goodness of fit test was 0.765 and 0.965, and the C index was 0.66 and 0.67. Values of Nagelkerke's R^2 were 0.051 y 0.058.

Conclusions. In-hospital mortality from coronary artery bypass grafting is much higher in Spain than in other countries. The Minimum Basic Data Set, a low-cost information system that is easy to access, yields interesting and useful information to measure health care quality.

Key words: *Coronary artery bypass. Mortality. Outcome assessment (health care).*

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Análisis de la mortalidad intrahospitalaria de la cirugía de revascularización coronaria

Introducción y objetivos. La investigación y monitorización de resultados constituyen un elemento fundamental para la mejora de la efectividad y calidad asistencial. El objetivo de este trabajo es describir la mortalidad intrahospitalaria en España de la cirugía de revascularización coronaria utilizando una base de datos administrativa, y estimar la capacidad predictiva de dos sistemas de ajuste de riesgo, los índices de Charlson y Ghali.

Pacientes y método. Del Conjunto Mínimo Básico de Datos de los años 1997 y 1998, se han seleccionado las altas posteriores a la cirugía de revascularización coronaria. Se han obtenido dos modelos multivariantes ajustados por el riesgo con la mortalidad intrahospitalaria como variable de resultados.

Resultados. La base de datos incluye 13.023 casos. El 80% son varones y la edad media es 64,5 años. La mortalidad intrahospitalaria es un 7,3%, mayor en las mujeres y aumenta con la edad. Un punto de los índices de Charlson y Ghali se asocia con un incremento del riesgo de muerte de un 23 y de un 20%. Los valores obtenidos mediante el test de Hosmer-Lemeshow fueron p = 0,765 y p = 0,965, y los valores del índice C fueron 0,66 y 0,67. Los valores de la R^2 de Nagelkerke fueron 0,051 y 0,058.

Conclusiones. La mortalidad intrahospitalaria de la cirugía de revascularización coronaria es más alta en España que en otros países. El Conjunto Mínimo Básico de Datos, un sistema de información de fácil accesibilidad y bajo coste, permite obtener información interesante y útil para medir la calidad asistencial.

Palabras clave: *Injerto coronario. Mortalidad. Evaluación de resultados (atención médica).*

INTRODUCTION

Routine outcomes research and monitoring is an essential part of the process for improving healthcare effectiveness and quality. The study of outcome as an indicator of the quality of medical practice was proposed many years ago by Donabedian. One of the key factors is obviously the outcomes to be analyzed. In-hospital

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ABBREVIATIONS

ROC: Receiver Operating Characteristic curve.
CABG: coronary artery bypass grafting.
MBDS: minimum basic data set at hospital discharge.
PCI: percutaneous coronary interventions.

mortality is one of the more traditional indicators, although its validity and precision in measuring the quality of hospital care has been the subject of frequent debate. One of the procedures studied on a fairly regular basis is the in-hospital mortality associated with coronary artery bypass grafting (CABG). Studies conducted in other countries have disclosed significant discrepancies between centers and between geographical areas with regard to quality; for example in the capacity of quality improvement systems developed on the basis of feedback from the information analyzed to reduce mortality at the centers where it was highest. Registries such as those from the Northern New England Cardiovascular Disease Study Group,[1] the State of New York[2-4] and the Veteran's Administration[5,6] combine information collection with mechanisms for improving and changing the health services.

Observational studies with administrative databases can play an important role in evaluating effectiveness and improvements in healthcare quality, as they compile broad, sometimes complete, samples to determine the relationship of a population with the health system, thereby overcoming some of the limitations of clinical trials or clinical databases. These studies do not identify causal relationships, but merely identify the actual use of health services, estimate the outcomes obtained under real conditions, and identify the factors associated with the difference between the maximum potential benefit of an intervention and the actual benefit achieved. By assessing and researching the outcomes, the healthcare processes can be redesigned. The purpose of this study was to describe the in-hospital mortality associated with CABG in Spain using an administrative database, the minimum basic data set (MBDS) at hospital discharge. In addition, this database was used to estimate the predictive capacity of two risk adjustment systems designed to compare outcome.

PATIENTS AND METHODS

The information source used in this study was the MBDS database of the Ministerio de Sanidad y Consumo (Spanish Ministry of Health and Consumer Affairs) from the years 1997 and 1998. The database included sociodemographic information, as well as information on diagnoses and on diagnostic and therapeutic procedures. All records containing the CABG code in any of the procedure fields were retrieved from the database and any patient under 29 or above 100 years of age was excluded. Records were also eliminated if they had wrong or missing values (n=363), e.g., missing gender or uncoded type of discharge. Only records from hospitals with more than 50 cases of CABG per year were included, thereby eliminating 226 cases. The following variables were selected from the set of database variables for analysis: *a)* demographic characteristics, including gender (male or female) and age (years and age group: 30-44, 45-54, 55-64, 65-74 and 75-99 years); *b)* use of services, including type of discharge (death or other reason) and procedures (catheterization, percutaneous coronary interventions [PCI], stent and CABG), and *c)* comorbidity, including information prepared using the codes for the main diagnosis and additional diagnoses. Two risk adjustment systems were applied: a generic statistic (Charlson), and a specific CABG index (Ghali). The characteristics and the method used to calculate these systems have been described previously. The Charlson index was considered a categorical and quantitative variable (0, 1 and ≥2). The Ghali index was also analyzed as a quantitative and categorical variable (0, 1, 2 and ≥3). In both indexes, the higher values indicate greater severity. The results of the continuous variables (age and risk indexes) are expressed as mean with 95% confidence interval. The categorical variables are expressed as percentage. The descriptive tables contain only risk factors above 1%.

To estimate the predictive capacity of the indexes and the risk adjustment variables, we used logistic regression models in which the dependent variable was type of discharge. A bivariate analysis had been previously carried out to estimate the associations between the independent variables (age, gender and comorbidity indexes) and mortality. These models were assessed on the basis of calibration and discrimination. Calibration assesses the degree of correspondence between the estimated probability of mortality given by the model and the observed mortality in patients. The deciles of risk of the Hosmer-Lemeshow statistic, which refers to the fit between the observed and the expected outcome in patients stratified into risk brackets, summarizes the calibration. This statistic is based on a distribution of the χ^2 test with g-2 degrees of freedom, where g is the number of groups, normally 10. A low value in the Hosmer-Lemeshow χ^2 test, with the respective high value for *P*, suggests a good fit. When a model is well-calibrated, there is no association between the risk levels of the estimated probabilities and the actual results. In logistic regression, the probability is predicted for all observations, both those where the outcome occurs and

TABLE 1. **Demographic data, characteristics of the services used and comorbidity in hospitalized patients undergoing CABG**

	Total (n=13 023)	Men (n=10 442)	Women (n=2581)	*P*
Age, years (%)				
30-44	3.2	3.7	1.4	
45-54	12.8	14.7	5.1	
55-64	27.7	29.2	21.8	
65-74	43.2	41.1	51.5	
75-99	13.1	11.3	20.3	<.001
Mean (95% CI)	64.5 (64.4-64.7)	63.7 (63.5-63.9)	68.0 (67.6-68.2)	
Other procedures, %				
Coronary angiography	29.5	25.5	29.8	.722
PCI	1.2	1.1	1.3	.403
Stent	0.4	0.5	0.3	.186
Myocardial infarction (MI), %				
No MI	69.7	67.8	77.6	
MI in another diagnosis	23.3	25.1	16.1	
MI in main diagnosis	7.0	7.2	6.2	<.001
Type of discharge, %				
Death	7.3	6.5	10.4	<.001
Charlson index, %				
0	45.4	45.0	46.7	
1	39.2	39.3	38.9	
≥2	15.4	15.7	14.4	.167
Mean (95% CI)	0.74 (0.73-0.76)	0.75 (0.73-0.77)	0.71 (0.68-0.74)	
Ghali index, %				
0		62.5	60.2	71.9
1	28.4	30.2	21.0	
2	3.7	4.0	2.6	
≥3	5.3	5.5	4.5	<.001
Mean (95% CI)	0.62 (0.60-0.64)	0.65 (0.63-0.68)	0.48 (0.43-0.52)	
Risk factors, %				
Chronic pulmonary disease	6.5	7.2	3.3	<.001
Cerebrovascular disease	1.4	1.4	1.3	.672
Congestive heart failure	1.5	1.4	1.8	.121
Diabetes with chronic complications	1.9	1.7	2.9	<.001
Chronic kidney disease	2.2	2.4	1.7	.026
Peripheral vascular disease	5.4	5.9	3.4	<.001
Mild or moderate diabetes	20.0	17.7	29.4	<.001
Acute myocardial infarction	30.3	32.2	22.4	<.001

those where it does not. If the risk adjustment is adequate, it will predict a greater probability for the observations in which the outcome occurs, on average, than those in which it does not. This indicator is known as discrimination, and is measured by the C statistic, which represents the ROC area under the curve. The line is plotted by obtaining the sensitivity and specificity at various cutoff points for the predicted probabilities. Nagelkerke R^2 will be used to estimate the ratio of actual to expected mortality. Nagelkerke R^2 is a modification of the Cox-Snell R^2. It can range from 0 to 1 and has the same significance as R2 in linear regression. SPSS for Windows, version 10.0, was used for the statistical analysis.

RESULTS

The database of patients who underwent CABG included 13 023 records from 40 hospitals in 1997 and 40 hospitals in 1998 (Table 1). Men accounted for 80% of all records. The mean age was 64.5 years and 56% of patients were 65 years of age or older. Coronary

TABLE 2. **Demographic data and characteristics of the services used by hospitalized patients and non-survivors of CABG according to gender**

	Total (n=945)	p1	Men (n=676)	Women (n=269)	p2
Age, years, %					
30-44	4.1		3.6	8.6	0.157
45-54	2.0		1.9	3.8	0.135
55-64	5.0		4.6	7.7	0.002
65-74	8.6		8.1	10.2	0.017
75-99	13.5	<0.001	12.5	15.9	0.062
Mean (95% CI)	68.8 (68.2-69.3)		68.2 (67.5-68.8)	70.2 (69.3-71.1)	
Other procedures, %					
No coronary angiography	7.2		6.3	10.6	<0.001
With coronary angiography	7.5	0.565	6.8	10.0	0.003
No PCI	7.2		6.4	10.4	<0.001
With PCI	13.9	0.002	14.5	11.8	0.682
Myocardial infarction (MI), %					
Without MI	7.1		6.3	10.0	<0.001
MI in another diagnosis	4.6		4.2	7.2	0.006
MI in main diagnosis	17.7	<0.001	16.5	23.6	0.033
Charlson index, %					
0	6.7		5.8	10.4	<0.001
1	6.5		6.0	8.7	0.002
≥2	10.7	<0.001	9.7	15.1	0.003
Mean (95% CI)	0.90 (0.83-0.96)		0.94 (0.86-1.02)	0.78 (0.68-0.89)	
Ghali index, %	0	6.4	5.5	9.4	<0.001
1	7.2		6.5	11.4	<0.001
2	13.6		12.2	22.1	0.028
≥3	13.3	<0.001	12.8	15.7	0.407
Mean (95% CI)	0.98 (0.87-1.09)		1.08 (0.94-1.22)	0.71 (0.54-0.88)	

p1 indicates results of the statistical tests comparing outcomes between the various categories of one variable;
p2, result of the statistical test comparing outcomes between men and women.

angiography was performed on 29.5% during the same hospitalization, and 1.2% also underwent PCI; 7.3% of the patients died in the hospital. In 7% of the cases, CABG was performed in patients admitted to the hospital for acute myocardial infarction. The mean Charlson index was 0.7 and the mean Ghali index was 0.6. With regard to risk factors, 30% of patients had previous myocardial infarction and 20% had diabetes. The mean age of women (68 years) was significantly higher than that of men (63 years); 72% of women were 65 years of age or older, though only 52% of men were in this age bracket. CABG was more frequent in men than women in myocardial infarction cases. No differences between men and women were observed in the use of procedures. There were also no differences between men and women in the Charlson index, although there were differences in some specific risk factors: diabetes was more frequent in women, whereas previous acute myocardial infarction, peripheral vascular disease, chronic pulmonary disease and chronic kidney disease were more frequent in men. The mean Ghali index was higher in men than women.

Table 2 shows that in-hospital mortality was significantly higher in women than men (10.4% and 6.5%, respectively) and increased with age. The mean age of non-survivors was almost 69 years. The percentage of discharges due to death was higher in patients who underwent PCI during the same hospitalization (13.9%). Increases in the Charlson index and the Ghali index were associated with increased mortality. The means of these two indexes in the non-survivors were 0.9 and 1.0, respectively. Mortality was significantly higher in patients with peripheral vascular disease (12.5%) and chronic kidney disease (21.2%). The mean age of the women who died was 70 years, versus 68 years in men. In patients without PCI, mortality was higher in women (10.4%). In patients with PCI, however, there were no significant differences

TABLE 3. **Odds ratio of mortality by gender, age and comorbidity indexes in patients admitted with CABG**

	Charlson index		Ghali index	
	OR	95% CI	OR	95% CI
Men	1.00		1.00	
Women	1.41	1.21-1.64	1.46	1.25-1.69
30-44 years	1.00		1.00	
45-54 years	0.49	0.27-0.89	0.49	0.27-0.90
55-64 years	1.18	0.71-1.96	1.22	0.73-2.02
65-74 years	2.01	1.22-3.29	2.06	1.26-3.39
75-99 years	3.36	2.02-5.57	3.34	2.01-5.54
+1 point of index	1.23	1.15-1.33	1.20	1.16-1.25

OR indicates odds ratio; 95% CI, 95% confidence interval.

between men and women. Women had higher mortality, regardless of whether or not there had been a previous myocardial infarction. The mortality of women was also higher at all levels of the Charlson index. Mortality was higher in women with a Ghali index of 0, 1 or 2. In general, mortality increased as age increased. This was true for both men and women, except in the age group of 45-54 years, in which mortality was lower in both men (1.9%) and women (3.8%). This tendency was also observed when analyzing mortality according to procedure usage and previous myocardial infarction (data not presented). In this age group, a lower mortality was also observed at all levels of the Charlson and Ghali indexes.

As shown in Table 3, the results of the multivariate tests conducted with the two risk adjustment systems indicate that women have a significantly higher mortality risk of 4.1 (according to the Charlson index) and 4.6 (according to the Ghali index) times that of men. With regard to the age group of 30-44 years, the odds ratios for the age groups (except 55-64 years of age) were statistically significant. An increase of one point in the Charlson and Ghali indexes was associated with a significant increase of 23% and 20%, respectively, in the risk of death. The calibration provided by the two risk adjustment systems was very similar (Table 4). In both systems, there was a correspondence between the expected and observed mortality rates in each of the severity subgroups; Hosmer-Lemeshow χ^2 values had a significance of $P>.005$: 4.13 (Charlson index) and 2.43 (Ghali index). In terms of discrimination, very similar results were obtained from both systems, with a C statistic of 0.66 and 0.67 for Charlson and Ghali, respectively. The Nagelkerke R^2 values were 0.051 and 0.058.

DISCUSSION

Previous publications have reported on the mortality associated with CABG in Spain. This work expands our understanding of this problem by providing information on a large volume of cases from a number of centers, elucidating the epidemiology of CABG and identifying specific risk factors. According to the Spanish MBDS, 20% of these operations were performed in women. The figure for women is relatively lower than the one observed in Canada (23%), and well below the level for the U.S. (28%). Large differences are also observed in the prevalence of myocardial infarction in CABG cases with respect to these countries. The Spanish MBDS database indicates 7%, whereas in Canada it is lower (3%) and in the U.S. it may be two-fold.[12] Using Spanish MBDS data, the calculated mortality was 6.8% in 1997 and 7.7% in 1998. In Canada, the crude mortality in the provinces were between 3.0% and 4.7%.[13] In New York State, the crude mortality for 1996-1998 was 2.15%.[14] In the United Kingdom, mortality was 3.1%, according to the Society for Cardiothoracic Surgeons.[15] In the Sociedad Española de Cirugía Cardiovascular (SECCV; Spanish Society of Cardiovascular Surgery) registry, the in-hospital mortality for 1997, 1998 and 1999 was 6.1%, 6.4% and 5.3%. In Spain, Pons (in a group of 7 hospitals) and Martínez-Alario (with data from one hospital) reported mortalities of 10.9%.[16] and 5.6[17] for all cardiac surgery procedures. Using data from four public and four private centers, Permanyer obtained mortalities of 8.4% for public centers and 3.8% for private.[18] Pons also observed that the mortality associated with cardiac surgery was higher in public (11.7%) versus private (6.7%) centers.[19] The characteristics of the MBDS, which was originally designed to gather information on the performance of hospitals in the Spanish National Health System and mainly collects data on patients in public hospitals, may explain the differences in mortality reported in this article as compared to mortality from other studies. In the MBDS, the percentage of CABG

TABLE 4. **Goodness-of-fit of the risk adjustment systems in patients admitted with CABG**

	Calibration			Discrimination	
	χ^2 of Hosmer-Lemeshow	d.f.	*P*	C statistic	Nagelkerke R^2
Charlson index	4.125	7	.765	0.66	0.051
Ghali index	2.430	8	.965	0.67	0.058

d.f. indicates degrees of freedom.

cases with a Ghali index above 0 was 37.5%, whereas Permanyer reported 24.8%. This series had fewer women (14.6%) and a lower mean age (62.6 years) than the MBDS, which had 19.8% women and a mean age of 64.5 years. Rodríguez analyzed the MBDS for 1994 and obtained a mortality of 4.6% for 3185 cases.[20] The mean age (62.4 years), the percentage of women (16.6%) and the risk measured by the Charlson index (0 in 82.2% of cases) were below the values we found. There was also a mortality gradient between men and women. In the multivariate models, the risk of mortality was around 50% higher in women than men after adjusting for the various risk factors. Ghali obtained a similar excess risk for CABG in women in Canada.[13] The higher risk of mortality in women, particularly in age groups under 50 years of age, has been previously reported by various authors.[21,22] Although several explanations have been proposed, the actual reason for this difference is unknown.

One source for comparing the level of coverage of the MBDS is the Sociedad Española de Cirugía Cardiovascular registry,[23,24] in which a total of 14 554 surgeries were recorded in 1997 and 1998. The MBDS database contains 13 023 cases for both years and it is estimated that around 90% of the coronary surgical procedures performed in Spain are recorded. This source of information is very limited, however, as it does not compile information by age group or gender and does not include clinical information. The MBDS has several limitations: there is a lack of information about the use of medications, it is difficult to differentiate between comorbidity complications and it is impossible to identify the hospitals involved. This type of database has no information on clinical factors not included in the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM), such as body surface area, ejection fraction, grading or severity of clinical status (location of the obstruction), clinical parameters (Killip class, dyspnea, angina), diagnostic test results (enzymes, Q wave, ST segment elevation) or smoking. The absence of this type of variable can cause the discriminant power of these models to be lower than that of indexes such as the EuroSCORE.[25] Furthermore, since this is a database of events, it is not possible to identify individuals and perform longitudinal follow-up of the patients, including possible rehospitalizations. In addition, mortality after hospital discharge cannot be determined.

CABG is one of the surgical areas in which outcome research and monitoring, as well as quality improvement, are most advanced, partly because of the uniformity of patients with respect to risk, the frequency of the procedure and its cost. Many studies on this procedure use clinical databases constructed by compiling specific information from the medical records. However, administrative databases can also provide a large amount of the information for constructing risk systems, including main diagnosis, additional diagnoses, procedures, age, gender, and status at discharge. These databases could be used to screen centers or procedures with quality problems. For example, Krakauer compared a risk adjustment model with an administrative database to a model with a clinical database in a sample of 42 773 patients from 84 hospitals, observing that both models provided similar results when identifying the hospital characteristics associated with mortality, although the sensitivity of the administrative database for detecting process problems was lower.[26] Hannan obtained similar results when comparing an administrative database (Statewide Planning and Research Cooperative System) with a clinical database (Cardiac Surgery Reporting System) in New York State. In this case, the clinical database had a greater capacity to predict mortality, although the mere addition of three clinical variables improved the administrative database capacity substantially.[27] Landon analyzed a sample of 7765 CABG cases using adjustment systems based on administrative and clinical databases,[28] without observing large differences between the predictive capacity of one or the other. In addition, the hospitals with the worst mortality tended to be those with the worst adjusted mortality, regardless of the adjustment method used.[29] Other authors[30] have pointed to the problems of using clinical databases as instruments for evaluating effectiveness because of their dependence on the risk variables compiled.

Despite the limitations of the MBDS, validation of risk adjustment systems to evaluate CABG outcome provides calibration and discrimination results comparable to those obtained by Ghali using administrative databases from Canada.[31] The significance values obtained for the Hosmer-Lemeshow test (0.765 and 0.965) indicate that the models offer good calibration. Discrimination, as measured by the C statistic (0.66 and 0.67), is below the level considered desirable for clinical purposes. In terms of Nagelkerke R^2, the values obtained indicate that expected mortality explains a small part of observed mortality. Databases such as the MBDS make it possible to obtain worthwhile information of an obviously descriptive rather than predictive nature, that is useful for generating hypotheses. Although it does not allow a formal prediction or stratification of risk (this is not its objective), the database provides a general approximation of the risk.

CONCLUSIONS

The in-hospital mortality associated with CABG in Spain is much higher than in other countries. Mortality is significantly higher in women and in patients over 65 years of age, with most cases also in this age group. Some differences also appear to exist in the types of patients who undergo surgery in Spain, in comparison

with other countries. Better health services cannot be provided merely by improving skills, clinical procedures or available technology. A system-based view of health systems that includes outcome measurement is needed to improve healthcare quality and effectiveness.[32]

The MBDS is a low-cost, easy-to-access information system that compiles data on a high volume of the cardiac surgeries performed in Spain. The most important limitation of the system is that it does not include clinical information, although it is not intended to be a formal instrument for surgical risk prediction. Because of their easy access and low cost, administrative databases and observational studies can be very useful systems for routine, systematic use in generating hypotheses for other studies which offer greater capacity to establish causality and better clinical information.

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