Aortic Valve Replacement in Patients Over 70 Years Old:
Determinants of Early Death

Rafael García Fuster, José A. Montero, Oscar Gil, Fernando Hornero, José Buendía, Rafael Payá, Sergio J. Cánovas, María J. Dalmau, and María Bueno

Introduction and objectives. There is controversy regarding the risk factors associated with early death in geriatric patients undergoing aortic valve replacement. We analyzed the risks in these patients and established an accurate model for predicting in-hospital mortality.

Patients and method. Univariate and multivariate analyses were made of the risk factors associated with early death in a group of 129 patients older than 70 years who underwent aortic valve replacement (May 1994-June 2001). The variables obtained by multivariate logistic regression were combined to produce an equation for the prediction of early death. The equation was tested using a receiver operating characteristic curve.

Results. Univariate analysis identified four factors related to early death: NYHA III-IV (p < 0.0001), ejection fraction < 40% (p < 0.05), aortic regurgitation (p < 0.05) and high left ventricular mass index (p < 0.05). Multivariate analysis revealed three independent risk factors: NYHA III-IV (p < 0.01), aortic regurgitation (p < 0.05), and small body surface area (p < 0.05). A lower mortality was observed in patients with a larger body surface area (0% for > 1.90 m^2, 20% for < 1.40 m^2). The estimated mortality with the predictive model was 7.06%, which was similar to the observed mortality of 7.80% (area under the ROC curve 0.87) and better than estimates obtained with the EuroSCORE (6.5%; area under the ROC curve 0.56).

Conclusions. Risk factors associated with early death after aortic valve replacement in geriatric patients include functional status, aortic regurgitation, and small body surface area. Our model based on these factors accurately predicted operative mortality in our patients. Gender, prosthesis size, and pump time were not identified as risk factors.

Key words: Aging. Surgery. Morbidity.

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INTRODUCTION

In past years, the age of patients who undergo heart surgery has significantly increased. The greater longevity of the population, together with the increase in the incidence of heart disease and aortic degenerative val-
ve disease are the principal factors involved in this phenomenon. The latter factor is responsible for a substantial percentage of the interventions performed in patients of more than 70 years of age.

There is still controversy regarding the most important risk factors associated with early mortality in septuagenarian and octogenarian patients who undergo aortic valve replacement. The use of small valve prostheses has been one of the classically accepted determinants of nosocomial death. Other studies have downplayed this, giving greater relevance to female sex, reduced body surface (BS), or a prosthesis-patient mismatch. Extracorporeal circulation (ECC) time is another factor that has been implicated in such mortality.

We performed a retrospective study in which we analyzed all patients of 70 years of age or older who underwent aortic valve replacement in our hospital. Our aim was to find out the principal pre- and post-operative risk factors that had the most decisive influence on early mortality. In addition, we proposed the creation of a predictive model for nosocomial death that was applicable to our patients.

**PATIENTS AND METHODS**

We included in our study 129 patients of age 70 years or greater from a total of 614 patients who underwent aortic valve replacement in our hospital during the period from May 1994 to June 2001. We excluded from the study those patients who underwent other associated valve procedures, such as replacement or repair of the mitral valve. The majority of the interventions were elective and repeat surgeries were not included. All the procedures were performed with ECC and moderate hypothermia (28 to 32°C). In the majority of cases a combination of anterograde cardioplegia via the aortic root and coronary ostium, or both, were used, and retrograd via the coronary sinus.

Among the pre-surgical variables analyzed were cardiovascular risk factors and associated morbidity. Similarly, we included other variables that were considered to be related to higher mortality rates in other studies. Principal among these were: age, sex, BS, arterial hypertension (AHT), diabetes, smoking, dyslipidemia, chronic obstructive pulmonary disease (COPD), previous chronic renal insufficiency, peripheral valve disease, old cerebrovascular accident (CVA), previous chronic atrial fibrillation (AF), associated heart disease, New York Heart Association (NYHA) functional class, level of angina according to the Canadian Cardiology Society, old myocardial infarct, ejection fraction, left ventricular mass index (LVMI), type of aortic valve dysfunction and its etiology, associated mitral insufficiency, and size of the valve prosthesis. The BS (m²) was calculated based on the patient’s weight and height. Previous COPD was confirmed via the pre-surgery performance of respiratory function tests on all patients. Chronic renal insufficiency was considered to exist in patients with a creatinine value higher than 2 mg/dL maintained indefinitely pre-surgery. Previous chronic AF was considered to be present when the arrhythmia lasted more than 6 months. The LVMI was calculated by using the Devereux formula applied to the data concerning the thickness and diameter of the left ventricle which were obtained from preoperative electrocardiograms. The LVMI was considered to be elevated when it had a value greater than the tenth highest in the series. We did not use the cut point proposed by Devereaux (134 g/m² in men and 110 g/m² in women) as the majority of our patients (82.9%) were had an LVMI higher than this point (107). This probably had an effect on the low BS in our patients. The selection of the valve prosthesis was based on the personal choice of the surgeon. In general terms, mechanical prostheses were used in younger patients and bioprostheses were used in older patients (with regard to the range of ages of the patients included in this study). The different types of prostheses used are summarized in Table 1. The size of the prosthesis used was determined in the operating room via the direct measurement of the valve ring.

On the other hand, peri-operative factors analyzed were: ECC time, duration of the myocardial ischemia by aortic clamp, and the principal complications that occurred during the early post-operative period.

From among all these variables we looked for those that had a significan relationship with nosocomial death and, later, we created a predictive model of said mortality. Finally, we evaluated the discriminatory capability of the model in our patients and compared it with the EuroSCORE, study, which has been considered the reference source for risk scales.

The majority of patient data was obtained from the Cormedica® (Pales Group®) database, in which patient data was entered prospectively. The echocardiographic data had been obtained from the Filemaker® informatics files in the echocardiography department of our hospital. The rest of the information was obtained from patient clinical histories.
Definitions

With regard to cardiovascular risk factors, we made the following determinations. AHT was considered to exist when this had been documented in the patient’s personal history or when the systolic arterial pressure (SAP) was greater than 140 mm Hg or the diastolic arterial pressure (DAP) was greater than 90 mm Hg on at least 2 different occasions; diabetes when this was confirmed in the history regardless of its duration or the need for treatment; smoking if the habit existed previously and had been maintained at least up to a month prior to surgery; and dyslipidemia if there was a history of hypercholesterolemia or hypertriglyceridemia diagnosed or treated, or both, by a physician.

With respect to prior co-morbidity, chronic renal insufficiency was considered to exist when creatinine values were higher than 2 mg/dL or 2 or more occasions during the year prior to surgery. Peripheral vasculopathy was considered present in the setting of any of the following: intermittent claudication, results that were positive for ischemia on non-invasive tests, a diagnosis of aneurysm of the abdominal aorta, or a history of surgery or intervention for peripheral vascular disease. The old term CVA included a history of aortic valve stenosis in 90 patients (69.8%), aortic insufficiency in 12 patients (9.3%), and double lesion in 27 patients (20.9%). The most frequent origin of valve disease was degenerative (9.3%), and double lesion in 27 patients (20.9%). The most frequent origin of valve disease was degenerative (9.3%), and double lesion in 27 patients (20.9%). The most frequent origin of valve disease was degenerative (9.3%), and double lesion in 27 patients (20.9%).

Statistical analysis

Sample description was expressed as mean and standard deviation for continuous variables and the distribution of frequencies in absolute numbers and percentages for the categorical variables. In later univariate analysis we applied the $\chi^2$ test corrected with the exact Fisher test when necessary. In this analysis we compared individual risk factors with nosocomial death (death during the post-operative hospital stay). Later multivariate analysis included all variables that had a value of $P$=.1. This analysis was based on binomial logistical regression with the progressive inclusion of variables. All values of $P$<.05 were considered significant, and we calculated the odds ratio and confidence interval (CI) of 95% for each variable. Following this analysis we created a model that could predict the occurrence of the phenomenon of nosocomial death for our patients. This predictive model was compared to that of EuroSCORE, and both were evaluated by using ROC (Receiver Operating Characteristic) curves.

For statistical analysis we used the SPSS informatics package version 9.0.

RESULTS

Pre-operative characteristics

The mean patient age was 74.3 years±3.1 years (range, 70 to 88 years), with the following distribution by sex: 68 women (52.7%) and 61 men (47.3%). Mean estimated overall patient body surface was 1.65 m$^2$±0.15 m$^2$ (range, 1.32 to 2.06 m$^2$), this being significantly larger in men when estimating the difference by sex: 1.74 m$^2$±0.14 m$^2$ (1.44 to 2.06 m$^2$) versus 1.58 m$^2$±0.12 m$^2$ (1.32 to 1.80 m$^2$), $P$<.01.

The distribution of patients according to baseline disease can be summarized as: aortic valve stenosis in 90 patients (69.8%), aortic insufficiency in 12 patients (9.3%), and double lesion in 27 patients (20.9%). The most frequent origin of valve disease was degenerative in 87 patients (67.4%), followed by rheumatic in 40 patients (31%), and congenital in 2 patients (1.6%). In 28 patients associated coronary disease was found.

Peri- and post-operative data

Mean surgical times were: ECC time 112.05 minutes±35.41 minutes (range, 44 to 216 minutes) and aortic clamping time 75.89 minutes±27.72 minutes (range, 29 to 152 minutes). Mean length of stay in the CCU was 5.11 days±3.70 days and the post-operative hospital stay was 12.76±7.07 days. Nosocomial death in the overall group was 7.8% (10 patients).

Variables associated with mortality (univariate analysis)

The results of the univariate analysis are shown in tables 2 and 3. This analysis identified the following variables as being related to mortality: NYHA functional class III to IV ($P$<.0001), ejection fraction (EF)=40% ($P$<.05), aortic valve insufficiency ($P$<.05), and elevated LVMI ($P$<.05). In absolute terms, the mean LVMI of the patients who died was significantly greater than that of the surviving patients: 257.23

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**TABLE 1. Types of prostheses implanted**

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Table 2. Univariate analysis; preoperative variables

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AHT indicates arterial hypertension; CRI, chronic renal insufficiency; D AoL, double aortic lesion; AoS, aortic stenosis; EF, ejection fraction; Aol, aortic insufficiency; Ml, mitral insufficiency; No. AMI, number
TABLE 3. Univariate analysis: peri- and post-operative variables

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<th>Variable</th>
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<td>7.8</td>
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<td>1</td>
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<td>126</td>
<td>9</td>
<td>7.1</td>
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ECC indicates extracorporeal circulation time; AF, atrial fibrillation.

With regard to the size of the prosthesis, a higher mortality rate was seen in those patients with the smallest prostheses, but this was without significant differences. The numbers obtained for prostheses size 19 mm, 21 mm, and 23 to 27 mm were 10.7%, 6.3%, and 7.9%, respectively. To estimate the possible relationship between small prosthesis size and reduced BS in our patients, we calculated the correlation between the 2 variables. The valve size and the BS had a high correlation (r<.001). The mean BS of patients who received a prosthesis size 19 mm, 21 mm, and 23 to 27 mm was 1.62 m²±0.14 m², 1.63 m²±0.14 m², and 1.73 m²±0.15 m², respectively.

With regard to sex, mortality was no greater in women in spite of the fact that they had, in overall terms, a smaller mean BS. Taking into account sex and prostheses of size 19 mm, 21 mm, and 23 to 27 mm, the mean BS in women was 1.57 m²±0.12 m² (range 1.32 to 1.77 m²), 1.59 m²±0.13 m² (range 1.35 to 1.80 m²), and 1.57 m²±0.11 m² (range 1.40 to 1.70 m²), respectively, and in men was 1.76 m²±0.13 m² (range 1.55 to 1.95 m²), 1.71 m²±0.14 m² (range 1.44 to 1.91 m²), and 1.76 m²±0.14 m² (range 1.54 to 2.06 m²).
Therefore, the disproportion in the prosthesis to patient relationship (prosthesis size to patient BS) was greater in men; in other words, for the same size prosthesis the BS was always greater in men, as was the case in the patients overall. The mortality rate according to sex for the smallest prostheses (19 mm) was also greater for men: 14.3% versus 9.5%. For 21 mm prostheses, the proportion of higher mortality rates was maintained in men: 13.6% versus 2.4%, but was inverted with larger prostheses (23 to 27 mm): 6.3% versus 16.7% in men and women. The 21 mm size prosthesis was used most often in women, and in men prostheses of size 23 to 27 mm were most often used. The distribution summary by sex and prostheses was: 21 patients (30.9%) for the 19 mm prosthesis, 41 patients (60.3%) for the 21 mm prosthesis, and 6 patients (8.8%) for the 23 to 27 mm prosthesis in the group of women (n=68), and 7 patients (11.5%) for the 19 mm prosthesis, 22 patients (36.1%) for the 21 mm prosthesis, and 32 patients (52.4%) for the 23 to 27 mm prosthesis in the group of men (n=61).

Regression model and equation predictive of mortality

Multivariate analysis identified 3 pre-operative risk factors that were predictive of nosocomial death: being in NYHA functional class III-IV ($P<.01$), the existence of aortic valve insufficiency ($P<.05$), and low BS or $\leq 1.4~\text{m}^2$ ($P<.05$; Table 4).

These variables are included in an equation for predicting mortality:

\[
\text{Estimated mortality} (%) = \frac{100}{1+e^{-x}}
\]

with $x$ being $7.317 + 3.218 \times \text{NYHA} + 2.939 \times \text{AoI} - 12.453 \times \text{BS}$.

NYHA is the functional class (with a value of 1, 2, 3, and 4 for NYHA I, NYHA II, NYHA III, and NYHA IV, respectively), AoI is aortic insufficiency (with a value of 1 if present or 0 if absent), and BS is the body surface calculated from patient height and weight (value in m$^2$).

The mean mortality rate calculated with this formula was 7.06%, very close to the mortality rate reported (7.8%). This predictive model for mortality, the only one in existence following this analysis, was measured by using an ROC curve (Figure 2), with the area below the curve being 0.87, indicating a higher power of discrimination in our patients. We did the same by applying EuroSCORE, which predicted a mortality rate in our series of patients of 6.50%, and obtained an area below the curve of only 0.56 (Figure 3).

DISCUSSION

The age of patients undergoing cardiac surgery has increased significantly over the last decade. In a parallel manner, studies have been performed to evaluate the surgical results obtained in elderly patients.\textsuperscript{10-16} Age is, in and of itself, a surgical risk factor and has
In the group of elderly patients who underwent surgery with ECC studied by Poveda et al,1 the pre-operative variables with prognostic value were previous surgery and the urgency of the procedure, with the patient being in NYHA functional class IV also found to be significant in the aortic subgroup.

In the Bloomstein2 study, the only risk factors for nosocomial death in elderly patients who underwent aortic valve replacement were reduced BS and prolonged ECC times, and no negative influence was found with the use of small prostheses. Thus, the relationship between the prosthesis size and the size of the patient (BS) could have greater repercussions than the simple consideration of the «small prosthesis» factor. In our patients, BS also had an influence on early mortality, with there being a clear tendency toward higher mortality rates in those patients with lower BS values (20% mortality in the subgroup of patients with a BS ≤ 1.40 m²). Conversely, when prosthesis size was considered we did not find significant differences in the mortality rate, even though this was higher when prostheses smaller than 19 mm were used. With regard to sex, overall mortality was no greater in women, in spite of the fact that they had a smaller mean BS. This data contradicts the findings of other authors.3,4,6 In our study, overall mortality was greater in men, especially in those men in whom a small valve prosthesis was implanted (mortality rate of 14.3% in men versus 9.5% in women for the 19 mm prosthesis, and 13.6% versus 2.4% for the 21 mm prosthesis). In men, BS was significantly greater than in women, both in the group overall and in the subgroups according to prosthesis size; therefore the great prosthesis to patient disproportion seen in men may explain the higher mortality rate.

In the same manner, ECC time also did not have greater repercussions on the mortality rate of our patients, in contrast to the findings of other authors.1,4,15 From the results of the study by Poveda et al it seems that the aortic group was the one that had a higher mortality rate in relation to longer surgical times (ischemia time > 60 minutes and ECC time > 90 minutes), although the authors emphasize that the references reflect longer times associated with an increase in mortality. In our study, the mean ischemia and ECC times were 75.89 minutes ± 27.72 minutes and 112.05 minutes ± 35.41 minutes, with wide ranges (29 to 152 minutes and 44 to 216 minutes, respectively); in spite of this, they did not have a significant influence on patient mortality. Although it is difficult to attribute this finding to our particular surgical activation protocol, it is obvious that improvements in myocardial protection and peri-operative management of these patients allow the performance of more complex procedures without a substantial increase in morbidity-mortality.

The third factor associated with greater mortality in our patients was the existence of significant aortic valve insufficiency. Its greatest deleterious effect was on

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**Fig. 3.** ROC curve applied to EuroSCORE. Area below the curve 0.56.
the volume and function of the left ventricle as revealed by predominantly aortic valve stenosis, which may explain this association. In fact, in the majority of patients, its presence resulted in a worse functional class and lower pre-operative EF.

Associated heart disease resulted in greater mortality, which is in accordance with other studies. Nevertheless, in our studies this did not reach statistical significance (Table 2). This may be due to the reduced sample size (only 28 patients had associated heart disease).

Finally, we took into account an aspect that we consider to be of great interest in our day-to-day surgical activity. This regards the particular characteristics of the population in our environment that undergoes this type of surgery. In contrast to other countries and studies found in the literature, our elderly patients with aortic valve disease tend to have a reduced BS, especially where women are concerned, as well as frequent co-morbidity, which puts them at special surgical risk. In fact, when we considered the pre-operative LVMI of our patients, we found values much higher than those reported by other authors, possibly due to the lower BS, together with other potential factors, such as a greater incidence of ventricular hypertrophy secondary to more developed valvulopathy at the time of surgery. When we applied the cut point proposed by Devereux8 to define an elevated LVMI (134 g/m² in men and 110 g/m² in women) to our patients, we noticed that the majority of them had numbers higher than said cut point (107 patients, 82.9%), which means increased surgical risk from the start. Therefore, in our study we took as a cut point the highest tenth of the Devereaux series (270 g/m² in the group overall). Given that the risk scales most often used in heart surgery do not take into account the BS of patients as a potential risk factor, we wanted to create a predictive model for mortality to be used in conjunction with other predictive factors obtained by multivariate analysis (NYHA functional class and presence of significant aortic insufficiency). The mortality rate predicted by the model was 7.06%, versus an observed mortality rate of 7.8%. Upon application of the EuroSCORE to this group of patients, we found an underestimation of the mortality rate (the mortality estimated by EuroSCORE was 6.50%), confirming its scant value upon application of analysis via ROC curves, obtaining an area below the curve of only 0.56. Our model achieved an area below the curve of 0.87, indicating a higher discriminatory power.

Study limitations

Although our study involved an overall group of patients of more than 70 years of age who consecutively underwent aortic valve replacement in our hospital, it is prone to all the problems of a retrospective analysis. The study was also limited by the relatively small sample size, given the reduced number of patients in this age range who undergo primary replacement of the aortic valve.

CONCLUSIONS

1. The pre-operative variables predictive of nosocomial death in patients of more than 70 years of age who undergo aortic valve replacement are NYHA functional class III-IV, aortic valve insufficiency, and reduced BS.

2. Other variables associated with said mortality are an EF ≤ 40% and an elevated pre-operative LVMI.

3. Disproportionate prosthesis to patient size also had repercussions on mortality, especially in the group of male patients.

4. Smaller prosthesis size, prolonged ECC time, and female sex did not have a particular influence on said mortality rate.

5. The model for predicting the risk of mortality that we developed taking into consideration the variables of NYHA functional class, aortic insufficiency, and BS achieved a good prediction rate in our patients.

REFERENCES


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