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Risk index for death by infective endocarditis: a multivariate logistic model

Índice de risco de mortalidade por endocardite infecciosa: um modelo logístico multivariado

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Abstract

Objective: **This study aimed at identifying predictive variables for in-hospital mortality, calculating the probability of death and creating a risk index for death by infective endocarditis by comparing two methods using a Receiver Operating Characteristic (ROC) curve.**

Methods: **A retrospective study was conducted of 186 consecutive cases of confirmed infective endocarditis divided into two groups: discharged (137) and in-hospital death (49). Based on the odds ratios obtained by multivariate analysis, the probability of death was calculated and a mortality risk index created.**

Results: **Factors predictive of higher mortality (multivariate analysis) and the risk index, with their respective weights were: age ≥ 40 years (OR = 4.16; 95%CI [1.63-10.80] - 4 points), class IV heart failure or cardiovascular shock (OR = 4.93; 95%CI [1.86-13.05] - 5 points), uncontrolled sepsis (OR = 5.97; 95%CI [1.95-18.35] - 6 points), conduction disorder (OR = 5.07; 95%CI [1.67-15.35] - 5 points), arrhythmia (OR = 8.17; 95%CI [2.60-25.71] - 8 points), valve with extensive damage or abscess or prosthesis (OR = 4.77; 95%CI [1.44-15.76] - 5 points) and large and mobile vegetation (OR = 4.36; 95%CI [1.55-12.90] - 4 points). Patients with scores between 0 and 10 had a mortality of 5.26% and scores over 20 of 78.9%.**

Conclusions: **The higher the score, the higher the mortality rate. The mortality risk index may be used to estimate mortality in Infective Endocarditis.**

Descriptors: **Endocarditis. Mortality. Prognosis.**

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Resumo

Objetivo: **Os objetivos do presente trabalho foram identificar variáveis preditivas de mortalidade hospitalar em endocardite infecciosa e criar fórmula matemática para cálculo do risco de óbito e um escore de risco, comparando os dois métodos com a curva ROC.**

Método: **Foram estudados, retrospectivamente, 186 casos consecutivos de endocardite infecciosa (EI) confirmados, divididos em dois grupos: alta (137) e óbito hospitalar (49). A partir das razões das chances obtidas em análise multivariada, foram criados: uma fórmula para cálculo do risco de óbito e um escore de risco.**

Resultados: **Fatores preditivos de maior mortalidade (análise multivariada) e o escore de risco com seus respectivos pesos foram: idade ≥ 40 anos (RC = 4.16-95%I.C. [1.63,10.80] - 4 pontos), insuficiência cardíaca classe IV ou choque cardiovascular (RC = 4.93 - 95%I.C. [1.86,13.05] - 5 pontos), sepsis não-controlada (RC =5.97 - 95%I.C. [1.95,18.35] - 6 pontos), distúrbio de condução (RC = 5.07-95%I.C. [1.67,15.35] - 5 pontos), arritmia (RC = 8.17 - 95%I.C. [2.60,25.71] - 8 pontos), valva com grande destruição ou abscesso ou prótese (RC = 4.77-95%I.C. [1.44,15.76] - 5 pontos), e vegetação grande e móvel (RC = 4.36-95%I.C. [1.55,12.90] - 4 pontos). Pacientes com escore entre 0 e 10 tiveram 5,26% de MT e maior que 20: 78,9%.**

Conclusões: **Quanto maior o escore, maior é a mortalidade, complemente-se, ainda, que a estimativa de mortalidade obtida por cálculo ou pelo escore é semelhante. É possível utilizar software para facilitar a aplicação do escore e calcular risco de mortalidade por endocardite infecciosa.**

Descritores: **Endocardite. Mortalidade. Prognóstico.**

INTRODUCTION

In the pre-antibiotic era, infective endocarditis (IE) used to be the cause of death of virtually all affected patients [1]. Over time, some facts changed the presentation of the disease including the development of new microbiological techniques, antibiotic therapy, heart surgery and more recently ultrasound evaluation. Nevertheless, mortality due to IE continues to be high, varying from 13% to 40% [1].

Considering the great variability of mortality owing to IE and the wide range of clinical presentations and its seriousness, it is very important to create a methodology that allows classification of patients according to the severity and risk of death due to the disease. A predictive model should be both simple and statistically accurate, in order for it to be easily used by physicians [2]. Thus far, world literature has no predictive models for death by IE presented as an index. This methodology would make several kinds of analyses possible such as stratification of patients according to severity and prognosis; follow-up of patients' response to the adopted therapy; comparison of the outcomes of similar patients submitted to different treatments including evaluation of the efficiency of different healthcare services in treating this disease, evaluation of the expected and the observed mortality and indirect assessment of the cost/benefit ratio of certain procedures in patients at different stages of the disease [3].

The objectives of this present study are: 1) to identify variables of predictive value for in-hospital mortality due to IE; 2) to create a calculation of the probability of death and a risk index using multivariate analysis; 3) to stratify the present cohort by risk of death; 4) to compare the two methods, using a Receiver Operating Characteristic (ROC) curve.

METHODS

Patients

A retrospective study was conducted of 186 consecutive episodes of IE, confirmed using the Duke University criteria, in 179 patients (some patients had more than one infectious episode) admitted into Hospital das Clínicas of the Federal University of Paraná, from January 1988 through December 1998 [4]. Their ages ranged from 7 to 70 years old with a mean age of 33.9 years. Sixty percent of the cases (112) were male. The main predisposing factors for IE were the presence of prostheses (56 cases) and rheumatic disease (45 cases). Seventy-three percent of the patients had some degree of heart failure; 20.4% of them were in functional class IV (NYHA) and 5.4% in cardiovascular shock. Approximately one fifth (20%) of the patients developed sepsis that was not responsive to antibiotic therapy.

In 40% of the cases, blood and/or vegetation cultures were negative. The most commonly isolated microorganisms were Streptococcus viridans and Staphylococcus aureus. The native aortic valve was the most affected, followed by the mitral valve; aortic and mitral valve prostheses presented very similar incidences. About

30% of the IE cases occurred in prostheses. In 26.9% of the cases, there was a native valve with complications due to valve apparatus destruction or to abscess. Neurological, renal, and pulmonary complications occurred in 13.4%, 14.5%, and 19.2% of the cases, respectively.

Sixty-four percent of the patients were submitted to surgery during the acute phase (prior to resolution of IE), and 36% were treated with drugs only. The most common surgical indication was major valve dysfunction.

Patient evaluation consisted of clinical history and physical examination, followed by complementary tests: complete blood test, creatinine measurement, partial urine test, cultures of blood and surgically removed material (in operated patients), chest X-rays and electrocardiography. All patients were submitted to transthoracic bidimensional Doppler echocardiography. From 1988 until 1992, the echocardiographic equipment used was Interpec XL with conventional Doppler. From 1992 until 1998, HP Sonos 1000 echocardiographic equipment with color flow was used and, at the same time, the transesophageal technique was introduced for all instances in which the transthoracic technique left any diagnostic doubt. Computed tomography (CT) was performed in patients with clinical evidence of neurological complications. Abdominal ultrasound was carried out in patients with suspected complications affecting abdominal organs.

Clinical treatment consisted of antibiotic therapy, treatment of the heart failure, if present, and of associated complications or other diseases.

All the surviving patients received parenteral antibiotic therapy for at least four weeks; in patients with prosthesis IE, the standard duration of antibiotic therapy was six weeks.

Surgical indication

For surgical indication to be considered, a division into major and minor criteria was made; criteria with strong support in the literature such as surgical indication criteria were considered major [5]: a) heart failure refractive to medicinal treatment; b) severe or moderate valvular disease causing heart failure, as seen by echocardiography; c) sepsis not responsive to antibiotic therapy; d) abscess identified on echocardiogram; e) recent conduction disorder; f) fungus infection; g) recurrent IE, defined as a second infectious outbreak by the same microorganism within two months after an IE episode was considered resolved [6]. Criteria that are still being discussed in the literature regarding their importance as surgical indication criteria were considered minor criteria: a) presence of embolic events; b) large and mobile vegetations seen at echocardiography, defined as the presence of a cardiac mass larger than or equal to 10 mm, oscillating in a valve or support structure, in the path of a regurgitant jet or on implanted material, in the absence of any other anatomic explanation [7] and c) prosthetic infections.

Surgical indication was based on the presence of one major criterion or of at least two minor criteria. The most frequently performed surgery was aortic valve replacement, often associated with other procedures. Mitral valvuloplasty with vegetectomy was carried out in only one case, and vegetectomy with tricuspid valvuloplasty was performed in 4 cases.

Definition of variables

The patients were followed-up until hospital discharge and divided into two groups (dependent variables): Group 1: patients who were discharged and Group 2: patients who died.

Independent variables, which were potentially predictive of mortality, were divided, for teaching purposes, into six groups:

1. Epidemiological variables: gender, age, predisposing factors;

2. Medical variables: heart failure, cardiovascular shock (patients needing vasoactive drugs to maintain adequate pressure and cardiac output), and the presence of sepsis not responsive to antibiotic therapy (the persistence of fever for more than three days or persistently positive blood cultures after starting adequate antibiotic therapy);

3. Laboratory variables: confirmed infective microorganisms, leukocyte and rod counts;

4. Electrocardiographic variables: presence of any kind of conduction disorder or arrhythmia at electrocardiography;

5. Echocardiographic variables: echocardiographic classification (a. uncomplicated; b. complicated: presence of ruptured chordae tendineae, cuspid perforation or the presence of an abscess; and c. prosthesis); size of the heart cavities; percentage of shortening; presence of vegetation measuring 10 mm or more;

6. Variables related to distant manifestations: neurological complications (stroke, hemorrhagic events, and infections confirmed clinically and by complementary tests: computed skull tomography, liquor test); renal failure (patients with creatinine values higher than 2.0 mg/dL); pulmonary infection confirmed by clinical and X-ray examination.

Furthermore, qualitative and quantitative variables were included for each group when deemed necessary. The quantitative variables were studied quantitatively, then transformed into qualitative variables, and submitted to another statistical evaluation. Transformation into qualitative variables was made by categorizing the cases

Braz J Cardiovasc Surg 2007; 22(2): 192-200

into numerical intervals. The cutoff point of the intervals was based on the median values of patients who died and/ or on the normality values for that variable.

Statistical analysis

The statistical analysis applied consisted of six steps: (1) descriptive analysis; (2) univariate inference analysis, including the chi-square test, Fishers exact test, logistic regression and the Mann-Whitney U test, with values of $p<0.05$ considered statistically significant; (3) multivariate inference analysis, using logistic regression with the stepwise procedure by the forward method; to be included in the model, the independent variables had to be significant at a level of $p<0.20$; to remain in the model, independent variables had to be significant at a level of $p<0.05$; (4) development of a formula for the calculation of the risk of death; (5) risk index creation and statistical analysis of this risk index; once the odds ratio values were calculated, they were rounded out to full values, which became the weight of each variable for the construction of a mortality risk index [2]; and (6) development of a Receiver Operating Characteristic (ROC) curve. Regarding the interpretation of the ROC curve, it is considered that, the bigger the area below the curve, the more accurate the method; in our case, of the risk index and calculation of probability of death. A good model is one as close as possible to 100% of the graph area. Curves occupying 50% or less of the graph area indicate that the accuracy of the model is not greater than a result obtained by chance.

RESULTS

Forty-nine patients (26.3%) of this series died. Mortality was 31.9% in the operated patients, and 16.4% in those on medicinal treatment. The most common cause of death was cardiogenic shock.

Univariate analysis

Table 1 shows the univariate analysis of the qualitative variables, the higher mortality determining those with: age 40 years old or more, class IV heart failure or cardiovascular shock, sepsis not responsive to antibiotic therapy, presence of conduction disorders or arrhythmia, presence of valve destruction or abscess or prosthesis, enlarged left atrium, and presence of acute renal failure. The continuous variables shown in Table 2 presented a statistically significant difference regarding the medians of age and left atrium size.

Multivariate analysis

The following variables were included in the multivariate model: age, functional class (NYHA), sepsis, renal complications, neurological complications, leukocyte count, arrhythmia, conduction disorders, enlarged left atrium, pathologic anatomic classification and large and mobile vegetations. Only renal complications, neurological complications, leukocyte count, and enlarged left atrium were not predictive of higher mortality (Table 3).

Calculation of the probability of death

Probability of death can be calculated as follows:

Step 1: calculation of the value of Y

$$Y = -5.428 + 1.426\,AG + 1.595\,FC + 2.101\,AR + 1.622\,CD + 1.562\,AC + 1.787\,S + 1.473\,V$$

Where: AG = variable for age above 40 years; FC = variable for functional class IV or shock; AR = variable for presence of arrhythmia; CD = variable for presence of conduction disorders; AC = variable for anatomic classification (valve with extensive destruction or prosthesis); S = variable for presence of sepsis not responsive to antibiotic therapy; V= variable for presence of large and mobile vegetations.

In order to calculate the risk score, all variables in the model need to be redefined to correspond to the values 0 (absence) or 1 (presence, risk). For example, under 40-year-old patients are allocated the value 0 for the Age Variable, and patients aged 40 years old or more are allocated the value 1.

Step 2: Probability calculation:

$$Prob = \exp(Y) / [1 + \exp(Y)]$$

Note: The abbreviation "exp" represents the exponential function.

Mortality risk index

Table 4 presents the mortality risk index. Absence of a risk factor corresponds to score zero; the presence of a risk factor corresponds to a score given by the weight of the variable in determining the risk of death.

Table 5 demonstrates the risk index applied to our cohort, showing that, with scores of up to 10, mortality is low (low risk); scores over 10 the mortality is high (high risk), and values over 15 are related to very high mortality (very high risk).

Development of the ROC curve

Figure 1 presents the ROC curve, showing an overlapping of the risk curve and the curve to calculate the probability of death. The areas under the curves were 0.835 for risk index and 0.872 for the probability of death, showing that very little of the predictive performance is lost by using the risk index.

Table 1. Mortality in univariated analysis of quantitative variables.

Clinical Characteristics	Total N=186	Discharge n=137	Deat n=49	Mortalit (%)	p	Odds ratio	Confidence interval
Age							
< 40 years old	133	110	23	9.1	<0.0001	4.61	[2.28:9.29]
40 or over	53	27	26	49.1			
Gender							
Male	12	83	29	25.9	0.867		
Female	74	54	20	27.0			
Predisposing factors							
Absent	50	36	14	28.0			
Prosthesis	56	36	20	35.7	0.3965		
Rheumatic fever	45	36	9	20.0	0.3652		
Others	35	29	6	17.1	0.2496		
Functional class (NYHA)(HF/shock)							
Without HF up to class III	138	114	24	17.4	<0.0001	5.16	[2.52 ; 10.58]
Class IV and shock	48	23	35	52.1			
Sepsis non-responsive to antibiotic therapy							
Present	37	21	16	43.2	0.0125	2.68	[1.26 ; 5.71]
Absent	149	116	33	22.1			
Microrganism							
Staphylococci	44	32	12	27.3	0.8446		
Streptococci	45	35	10	22.2			
Gram-negative	22	15	7	31.8			
Fungi	1	0	1	100.0			
Unknown	74	55	19	25.7			
Leukocyte>13.000/mm3							
Present	73	49	24	32.9	0.0891		
Absent	112	88	24	21.4			
Rod counts (>20%)							
Present	85	60	25	29.4	0.2350		
Absent	98	77	21	21.4			
Conduction disorder							
Present	32	17	15	46.9	0.0069	3.11	[1.41 ; 6.88]
Absent	154	120	34	22.1			
Arrhythmia							
Present	35	16	19	54.3	<0.0001	4.79	[2.20 ; 10.41]
Absent	151	121	30	19.9			
Echocarbiographic classification							
Uncomplicated	81	72	9	11.1			
Complicated	50	30	20	40.0	0.0002	5.33	[2.18 ; 13.05]
Prosthesis	55	35	20	36.4	0.0008	4.57	[1.89 ; 11.07]
Increased LA (>40mm) n=177							
Present	112	76	36	32.1	0.0037	3.38	[1.46 ; 7.81]
Absent	65	57	8	12.3			
Increased LV (>56mm) n=174							
Present	83	60	23	27.7	0.4912		
Absent	91	70	21	23.1			
Increased RV (>26mm) n=170							
Present	14	10	4	28.6	0.7536		
Absent	156	117	39	25.0			
Shortening percentage <30% n=180							
Present	21	14	7	33.3	0.4266		
Absent	159	120	39	24.5			
Vegetation measuring 10mm or more							
Present	79	53	26	32.9	0.093		
Absent	107	84	23	21.5			
Pulmonary infection*							
Present	36	26	10	27.8	0.8350		
Absent	150	111	39	26.0			
Neurological complications*							
Present	25	15	10	40.0	0.1405		
Absent	161	122	39	24.2			
Acute renal failure*							
Present	27	15	12	44.4	0.0318	2.64	[1.14 ; 6.13]
Absent	159	122	37	23.3			

Abbreviations: HF: heart failure; NYHA: New York Heart Association; LA: left atrium; LV: left ventricle; RV: right ventricle.
**Complications occurred up to the 7th day after admission, except for those caused by treatment (surgery or antibiotics)*

Table 2. Mortality in univariated analysis of continuous variables

Characteristics (medians)	Total n=186	Discharge n=137	Death n=49	p
Age	32.5	31	41	<0.0001
Leukocytes	11500	11400	13000	0.2197
Rod counts	20	18	21.5	0.5527
Left atrium size (n=162)	44	42	50	0.0004
Left ventricle size (n=161)	56	55	58	0.2170
Right ventricle size (n=153)	19	20	19	0.2780
Shortening percentage (n=156)	38	38	33	1.0000

Table 3. Mortality in multivariated analysis

Clinical Characteristics	p	Odds ratio	Confidence interval
Age ≥ 40 years	0.0030	4.16	[1.63 ; 10.80]
Class IV heart failure or shock	0.0010	4.93	[1.86 ; 13.05]
Arrhythmia	<0.0001	8.17	[2.60 ; 25.71]
Conduction disorders	0.0040	5.07	[1.67 ; 15.35]
Complicated valve or prosthesis	0.0100	4.77	[1.44 ; 15.76]
Sepsis non-responsive to antibiotic therapy	0.0020	5.97	[1.95 ; 18.35]
Vegetation measuring 10 mm or more	0.0050	4.36	[1.55 ; 12.90]

Table 4. Mortality risk index

Characteristic	Weight
Age	
< 40 years	0
≥ 40 years	4
Heart failure (NYHA)	
Without heart failure, class I, II, III	0
Class IV or shock	5
Sepsis non-responsive to antibiotic therapy	
Absent	0
Present	6
Conduction disorders	
Absent	0
Present	5
Arrhytmias	
Absent	0
Present	8
Echocardiographic classification	
Uncomplicated	0
Complicated	5
Prosthesis	5
Vegetation measuring 10 mm or more	
Absent	0
Present	4

Table 5. Mortality by risk index

Score	Cases	Percentage	Death	Mortality (%)
0 a 10	95	51,07	5	5,26
11 a 15	49	26,34	16	32,70
16 a 20	23	12,37	13	56,50
>20	19	10,22	15	78,90

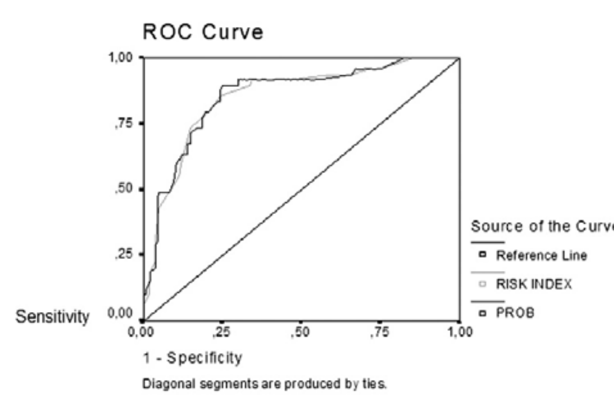

Fig. 1 - Risk index roc curve and calculation of the probability of death

DISCUSSION

Mortality due to IE has been decreasing, but it remains high varying from 13% to 40% [1]. The causes which determine a poorer prognosis are not yet well defined. Different studies show different factors as mortality predictors. To date, there is no study in the literature broad enough to assess IE in its different aspects, considering all forms of the disease, including right and left IE, native valve and prosthesis IE, and correlating mortality with epidemiological, medical, laboratory, electrocardiographic and echocardiographic aspects, and manifestations at distance. Moreover, there is no calculation for the probability of death or a risk index to predict mortality that encompasses all the disease manifestations, in order to predict the risk of death of patients with IE in a quick and practical manner.

The overall mortality for our cohort during the study period was 26.3%, which is within the range of mortality rates found in the literature [1,5,8]. Sixty-four percent of IE cases at our center were surgically treated, a proportion that is higher than the proportion observed in the literature [9-10]. During the study period, no patient with indication for surgery was refused an operation based on the risks of the intervention, demonstrating the wide use of surgery even under unfavorable circumstances.

Patients aged 40 years old or more had a higher mortality, both by univariate ($p<0.0001$, OR = 4.61) and by multivariate analysis ($p=0.0030$, OR = 4.16), as has been reported in other studies [12-15]. Some other authors, however, did not find an age-related difference [1,9,16].

In this series, like in others, we found no significant differences in mortality in regards to gender and predisposing factors for IE [1,9,17]. Some authors reported higher mortality in patients with prosthesis IE [12,17].

In this study, a higher mortality was found in patients with class IV heart failure and with cardiogenic shock when compared to patients without or with less severe heart failure, both by univariate ($p<0.0001$, OR = 5.16) and by multivariate analysis ($p=0.0010$, OR = 4.93). Most studies show only some influence of heart failure on mortality [1,10-15,18,19].

There was a difference in mortality regarding the presence of persistent sepsis, by both univariate ($p=0.0125$, OR = 2.68) and multivariate analysis ($p=0.0020$, OR = 4.77), as observed by others [11,12,19].

In this study, there was no difference in mortality regarding the infectious agent, although some authors have demonstrated higher mortality in IE caused by Staphylococcus aureus [8,11,12,20,21]. Other authors corroborate the results of the present study, as they found no relationship between the infectious agent and death [1,9,10,16,22].

There was no difference in mortality in this series regarding the leukocyte count, supporting the findings of Conlon et al. [17]. Wallace et al. and Aoun et al. observed a higher mortality in patients with more than 10,000 leukocytes/mm3 [9,22]. In our cohort, the values of the relative rod count were higher in patients who died, but the difference was not statistically significant.

A higher mortality was observed by univariate ($p=0.0069$, OR = 3.11) and multivariate analysis ($p=0.0040$, OR = 5.07) in patients with a conduction disorder as has been reported in other studies [11,13,14]. There was also a higher mortality by both univariate and multivariate analysis in patients with arrhythmia. Kimose, Lund & Kromann-Hansen reported a poorer prognosis over the long-term, in patients with supraventricular arrhythmia [14] and Wallace et al. showed a higher mortality in patients with abnormal rhythms [9].

In regards to the anatomopathological classification, there was higher mortality, by both univariate ($p = 0.0002$, OR = 5.33 / $p = 0.0008$, OR = 4.57) and multivariate analysis ($p = 0.0100$, OR = 4.77), in patients with extensive valve destruction or abscesses and prostheses. Some authors demonstrated that the presence of abscesses or destruction of the annulus determined a higher mortality [11,14,17,19,23]. There are other studies showing a higher mortality in prosthetic endocarditis [12,13].

The presence of major valve dysfunction did not affect mortality, as ratified by Karalis et al. [24]. However, the presence of large and mobile vegetations was related to higher mortality by multivariate analysis ($p = 0.0050$, OR = 4.36), but not by univariate analysis.

It is worthwhile mentioning that univariate analysis showed a higher mortality ($p = 0.0037$, OR = 3.38) in patients with the left atrium larger than 40 mm. There is no reference in the literature regarding enlarged left atrium and higher mortality due to IE. Other echocardiographic measurements had no relationship with increased mortality.

When the complications of IE at distance were studied, it was found that neurological complications were not associated with higher mortality. Other studies demonstrated a higher mortality in patients who suffered from strokes and in patients with neurological complications [1,8,20]. According to John et al. however, the presence of neurological complications does not increase mortality [25].

In addition, the presence of acute renal failure was associated with a higher mortality, as shown by univariate analysis ($p = 0.0318$, OR = 2.64). Conlon et al., in a study designed to evaluate renal failure in IE, demonstrated by multivariate analysis that the presence of acute renal failure during the course of the disease is a predictor of higher mortality [18]. Other authors ratified the findings of Conlon et al. [9-11,18,19]. On the other hand, Oyonarte et al. did not observe any relationship between creatinine levels and mortality [1]. In most studies, the presence of pulmonary complications has not been mentioned as a cause of increased mortality.

CONCLUSION

Multivariate analysis identified seven mortality-predicting variables: age equal to or greater than 40 years old; class IV heart failure or shock; presence of arrhythmia; presence of conduction disorders; presence of a valve with extensive destruction or abscess or prosthesis; sepsis not responsive to antibiotic therapy, and large (over 10mm) and mobile vegetations. The odds ratios of each variable were rounded out and transformed into a risk index (Table 4). Based on this risk index, four risk groups were identified, starting with patients with scores up to 10 and a mortality rate of 5.26% and ending with patients with scores over 20 and a mortality rate of 78.9%, showing that it is possible to predict mortality in IE in a quick and objective manner by means of a risk index. It was also possible to calculate the risk of death, for each patient, using probability calculations. The ROC curve shows that the risk index curve and the curve for the calculation of the probability of death overlap, demonstrating the reliability of the data. This allows physicians and surgeons to use either method according to personal preferences, without loss of reliability. To our knowledge, there are no other published studies suggesting the use of a risk index or formula to calculate the probability of death due to IE.

In order to validate the calculation of the probability of death and the risk index for infective endocarditis, a multicenter prospective study is ongoing.

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