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Use of comorbidity measures to predict the risk of death in Brazilian in-patients

ABSTRACT

OBJECTIVE: To assess the use of comorbidity measures to predict the risk of death in Brazilian in-patients.

METHODS: Data from the Sistema de Informações Hospitalares do Sistema Único de Saúde (Unified Health System Hospital Information System) were used, which enables only one secondary diagnosis to be recorded. A total of 1,607,697 hospitalizations were selected, all of which occurred in Brazil, between 2003 and 2004, and whose main diagnoses were: ischemic heart disease, congestive cardiac failure, stroke and pneumonia. Charlson Index and Elixhauser comorbidities were the comorbidity measures used. In addition, the simple record of a certain secondary diagnosis was also used. Logistic regression was applied to assess the impact of comorbidity measures on the estimate of risk of death. The baseline model included the following variables: age, sex and main diagnosis. Models to predict death were assessed, based on C-statistic and Hosmer-Lemeshow test.

RESULTS: Hospital mortality rate was 10.4% and mean length of stay was 5.7 days. The majority (52%) of hospitalizations occurred among men and mean age was 62.6 years. Of all hospitalizations, 5.4% included a recorded secondary diagnosis, although the odds ratio between death and presence of comorbidity was 1.93. The baseline model showed a discriminatory capacity (C-statistic) of 0.685. The improvement in the models, attributed to the introduction of comorbidity indices, was poor, equivalent to zero when C-statistic with only two digits was considered.

CONCLUSIONS: Although the introduction of three comorbidity measures in distinct models to predict death improved the predictive capacity of the baseline model, the values obtained are still considered insufficient. The accuracy of this type of measure is influenced by the completeness of the source of information. In this sense, high underreporting of secondary diagnosis, in addition to the well-known lack of space to note down this type of information in the Sistema de Informações Hospitalares, are the main explanatory factors for the results found.

DESCRIPTORS: Comorbidity. Hospital Mortality. Risk Adjustment. Health Services Evaluation.

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INTRODUCTION

Concerns about quality of care have triggered comparative analyses of health service performance indicators, especially hospital care. In several countries, governmental agencies, hospital associations, health insurance companies and consumer associations perform and publish comparative assessments of hospital performance, using mortality rates and other indicators.[4] The availability of large computerized administrative databases has promoted this type of approach.[17] It is necessary to consider the difference in prevalence of risk factors that change the prognosis and therapeutic response in inpatient care to assess quality of performance.[6]

The risk of a patient is associated with the severity of the case, and greater severity means higher risk or probability of occurrence of an undesirable outcome. Risk is a multidimensional concept that includes several attributes of a patient, such as age, sex, clinical instability, primary diagnosis, extension and severity of comorbidities and patient attitudes and preferences.[6]

Several methods to measure the severity of cases have been developed to enable the comparison of indicators from the case mix adjustment. The intensity (number and severity) of coexisting pathologies is one of the predictive factors of unfavorable outcomes and complications in in-patients.[6] Methodologies that use comorbidities to weigh their effect on patient prognosis can be applied to administrative databases, once they usually include diagnostic information exclusively.[5]

However, the quality and value of this type of method depend on the completeness and accuracy of diagnostic codes. With such characteristics, the Charlson Comorbidity Index (CCI)[2] and the methodology developed by Elixhauser et al[3] are used as the approach to risk adjustment in several studies.[5] These two methods differ from each other mostly in terms of the number of comorbidities included and attribution of weights to weigh their prognostic effect. This weighing is present in 19 clinical conditions comprising the CCI.[2] Elixhauser's methodology does not attribute any weight to the 30 comorbidities defined, focusing exclusively on the number of pathologies present.[3] Indications of the validity of such comorbidity indices to measure the severity of cases have been reported in the literature.[5,11]

The use of risk measures to adjust performance indicators is uncommon in Brazil, as are studies on the validity of such measures.[7,12,13] Results from studies that used the *Sistema de Informação Hospitalar do Sistema Único de Saúde* (SIH/SUS – National Health System Hospital Information System) were limited to either the analysis of hospitalizations in specific cities (Rio de Janeiro)[7] or to the surgical procedure selected (myocardial revascularization).[12,13] The SIH/SUS enables the record of only one secondary diagnosis, which is not mandatory for payment of hospital services.

The objective of the present study was to assess the use of comorbidity measures to predict the risk of death in in-patients, using the SIH/SUS databases and methodologies proposed by Charlson[2] and Elixhauser.[3]

METHODS

The SIH/SUS includes anonymous information about the following variables: demographic profile of patients (sex and age); primary and secondary diagnoses; surgical, therapeutic and diagnostic procedures; medical specialty of the case treated (general or specialized surgery and obstetrics, among others); days of stay; discharge status and hospital unit. First, 4,086,329 hospitalizations resulting from respiratory and circulatory problems, based on the International Classification of Diseases, 10th revision (ICD-10), and funded by the *Sistema Único de Saúde* (SUS – National Health System) in Brazil, between 2003 and 2004, were included to define the universe of study. These two health problems were selected according to the following criteria: volume of hospitalizations in the period higher than 500,000, hospital mortality rate higher than 4.9%, and volume of deaths in the period higher than 99,000. The mean value of reimbursement for hospitalization and length of stay were used as secondary criteria, once they show the importance of hospitalizations in terms of use of hospital resources. For this selection, tabulations based on the SUS hospital morbidity were constructed, according to information available on the website of the *Sistema de Informática do SUS* (DATASUS – SUS Information Technology System).[a]

The primary diagnosis of a patient is an essential dimension to risk adjustment, once severity may differ considerably among diagnostic categories. However, also at this stage, specific reasons for admission were selected to comprise the universe of study, considering the volume of hospitalizations and deaths per pathology as selection criteria. The hospitalizations selected were those whose ICD-10 codes were registered as primary diagnosis: ischemic heart disease (ICD-10: I21 and I25); congestive cardiac failure (ICD-10: I50); stroke (ICD-10: I60-I62, I64, I67, I69) and pneumonia (J15, J18). Hospitalizations of patients aged less than 18 years and those who provided incorrect information about sex, i.e. who used inexistent SIH/SUS codes, and had a length of stay above 30 days were excluded. The result of this process totaled 1,607,697 hospitalizations.

[a] Ministério da Saúde. Datasus. Morbidade hospitalar do SUS por local de internação - Brasil [internet]. [citado 2007 jan 16]. Disponível em: http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sih/cnv/miuf.def

Frequency measures and bivariate and multivariate analyses were used to assess the use of comorbidity measures. Logistic regression was employed to assess the impact of comorbidity measures on the estimate of risk of death. The deaths occurred during hospitalization were the dependent dichotomous variable. The impact of introduction of each of the comorbidity measures was tested to predict death in the baseline model. Considering the information available in the SIH/SUS databases, the baseline model included the following variables: age, sex and primary diagnosis. Age was treated as a continuous variable; the sex variable as a dichotomous variable and the male sex was the reference category. The primary diagnosis variable was considered a categorical variable with 11 groups and the reference category was chronic ischemic heart disease (ICD-10: I25), as it showed the lowest mortality rate.

The algorithm developed by Quan et al,[14] which defines the ICD-10 codes for each comorbidity included in Charlson's[2] and Elixhauser's[3] methodologies, was used to calculate the severity score. This choice is justified because it is a proposal that aims to adopt a standardized coding for international use. These authors reviewed the different adaptations for ICD-10 available in the literature at that moment and made them compatible.

A total of three comorbidity measures were analyzed: (1) the CCI,[2] codified according to Quan's[14] algorithm for ICD-10; (2) Elixhauser comorbidities,[3] also codified according to Quan's[14] algorithm; and (3) the presence of comorbidity (secondary diagnoses – yes/no). Comorbidity measures were introduced in the models tested as an independent categorical variable and regrouped according to the distribution of frequency, based on CCI weighing. Weights were grouped into the following categories: category (1) weight equal to 0; category (2) weight equal to 1; category (3) weight equal to or higher than 2. Weight equal to zero (category 1) was used as reference category, because a score equal to zero means absence of severity. The other two comorbidity measures were considered dichotomous variables (0 = absence and 1 = presence).

The adequacy of the death prediction model was assessed based on the capacity to discriminate and on the adjustment of models. The statistics used were the percentage of improvement of the model in relation to the initial likelihood (χ^2), C-statistic and Hosmer-Lemeshow goodness of fit test. Statistical analyses were processed in the Stata software, version 10.0.

RESULTS

In the period of study, 1,607,697 hospitalizations occurred due to ischemic heart disease, congestive cardiac failure, stroke and pneumonia. Mean age of patients was 62.6 years and the percentage of hospitalizations in men was 51.9% (Table 1). The majority of hospitalizations occurred in private hospitals (63.9%). Patients remained hospitalized for 5.7 days and surgical interventions totaled 5.5% of cases (Table 1). Hospitalizations with a recorded secondary diagnosis (comorbidity) corresponded to 5.4% (Table 1). State-owned hospitals were those that showed the highest percentage of recorded secondary diagnosis (18.7%). For the diagnoses selected, a hospital mortality rate of 10.4% was observed, of which 14.8% were associated with acute myocardial infarction (I21) and 7.2% with congestive cardiac failure (I50). As regards stroke, mortality varied between 6.4% and 32.0%, according to the diagnostic category. In cases of pneumonia, this variation was lower, between 6% and 8% (Table 1).

Tables 2 and 3 show the odds ratio (OR) between death and comorbidity measures. Of all clinical conditions that comprise the Charlson Index, 14 showed a statistically significant OR. However, the OR was below 1.20 for four clinical conditions. Cases with ulcer showed an OR equal to 3.15 (Table 2). As regards the 30 comorbidities defined by Elixhauser, at least one third had an OR significantly associated with the occurrence of deaths (Table 3). Of all these 30 comorbidities, 13 showed an OR higher than 1.50; of these, coagulopathies, weight loss, hydro-electrolytic imbalance and alcohol abuse are not included in the CCI (Table 3).

The percentage of cases with a score different from zero, i.e. with a certain level of severity, was low for both the CCI and Elixhauser comorbidities (Table 4). Mortality rates increased and were statistically significant, indicating an association between these two comorbidity measures and the risk of death (Table 4). The mortality rate is higher due to the recording of comorbidity – patients without a comorbidity showed a mortality rate of 10%, whereas this rate was 17.6% among patients with one comorbidity (Table 4).

OR between comorbidity and death was 1.93 (95% CI: 1.89;1.96, $p < 0.000$). As regards other measures, OR was 1.68 (95% CI: 1.63;1.73) for CCI, and 1.63 (95% CI: 1.58;1.68) for Elixhauser comorbidities. All OR were statistically significant ($p < 0.001$).

Of all models for hospital death prediction tested, model 4 showed the best discriminatory capacity (C-statistic = 0.691), incorporating the simple presence of comorbidity (Table 5). The effect on the discriminatory capacity of the baseline model (model 1), attributed to the incorporation of comorbidity measures, was insignificant in all models tested. Finally, all models tested showed calibration problems (Table 5).

DISCUSSION

The present study used information about secondary diagnosis recorded in the SIH/SUS to assess the severity of cases, based on comorbidity measures. In

Table 1. Characteristics of hospitalizations analyzed. Brazil, 2003-2004.

Characteristic	n	
Number of cases	1,607,697	
Demographic		
Mean age (years, SD)	62,6 (17,4)	
Mode	73	
Male (%)	51.9	
Use of Intensive Care Unit (%)	10.0	
Hospitalizations in Surgical Clinic (%)	5.5	
Primary diagnosis (Number of cases; mortality rate)		
Ischemic heart disease		
I21	101,576	14.8%
I25	23,768	4.4%
Congestive cardiac failure		
I50	678,663	7.2%
Stroke		
I60	45,228	19.1%
I61	35,257	32.2 %
I62	20,078	23.5%
I64	239,633	17.9%
I67	12,289	6.4%
I69	8,255	7.4%
Pneumonia		
J15	161,552	6.1%
J18	281,398	8.2%
Comorbidity		
Record of one secondary diagnosis (%)	5.4	
Type of hospital		
Not for profit private (%)	2.7	
Private (%)	3.0	
City-owned (%)	4.3	
State-owned (%)	18.7	
Length of stay		
Mean (days)	5.7	
Median (days)	4.0	
Result of health care		
Discharge (%)	85.8	
Transfer (%)	2.9	
Death (%)	10.4	
Type of hospital		
Hospitalizations		
Not-for-profit private	41.3	
Private (%)	22.7	
City-owned (%)	18.2	
State-owned (%)	13.5	
Total value of reimbursement (R$)		
Mean (SD)	691.2 (1265.3)	
Mode and median	429.5	
Variation	0-65.569.2	

this assessment, the use of Elixhauser comorbidities,[3] which includes other pathologies previously excluded from the CCI, did not increase the predictive capacity, which was even lower than that observed for the CCI. The improvement in the predictive capacity of the baseline model (C-statistic = 0.685), attributed to the comorbidity measures, was poor – equal to zero, when considering C-statistic with only two digits, i.e. all models showed C-statistic equal to 0.69. The record of any secondary diagnosis (C-statistic of 0.691) was more important than other comorbidity measures assessed. In addition, an OR equal to 1.93 was found between presence of comorbidity and death, a value higher than that obtained for the other two comorbidity measures.

The validity of use of severity score measures, such as the CCI,[2] or those that use the presence or not of a pathology for admission, such as Elixhauser comorbidities,[3] depends on the completeness and accuracy of diagnostic codes recorded in the databases. Underreporting also interferes with the discriminatory capacity of these measures. In the data analyzed, the percentage of recording of secondary diagnosis in national hospitalizations was low (5%). The results found seem to indicate disregard for or unawareness of the importance of this type of information. A previous study[9] applied the CCI to hospitalizations occurred in 1993-1994, in the city of Rio de Janeiro, Southeastern Brazil, and obtained a score equal to zero in 94.3% of cases. This percentage is similar to that observed in this study for the CCI and Elixhauser comorbidities, whose values were higher than 95%.

As regards the completeness of diagnoses, the SIH/SUS databases enable only one secondary diagnosis to be recorded. In addition, this information is irrelevant for hospitalizations payments, resulting in underreporting. The main impact of this situation is reflected in the results of comparison of death prediction models – all of them showed a discriminatory capacity lower than 0.70, which is considered insufficient.[1] A Brazilian study that assessed the validity of use of the CCI with hospital data from the city of Ribeirão Preto, Southeastern Brazil, which recorded one primary diagnosis and two secondary diagnoses at that time, showed and compared models to predict death with a higher predictive capacity (C-statistic of 0.72).[8] However, although the result was comparatively better when data from Ribeirão Preto were used, rather than SIH/SUS data, the C-statistics obtained were still lower than those reported in international studies. These studies tested the effect of the CCI, using databases with records of up to 15 diagnoses, and obtained better discriminatory capacity of death prediction models (C-statistics higher than 0.80).[11,16]

Among the study limitations, although including SUS-funded Brazilian hospitalizations, the population studied is restricted to specific diseases of the respiratory and circulatory systems. Even considering that the discriminatory capacity (C-statistic) is more

Table 2. Charlson Comorbidity Index for hospitalizations studied. Brazil, 2003-2004.

Weight	Clinical condition	n	Deaths (%)	Odds ratio
1	Myocardial infarction	3,755	11.7	1.14**
	Congestive cardiac failure	8,151	11.6	1.13*
	Peripheral vascular disease	166	14.5	1.46***
	Stroke	4,982	22.7	2.53*
	Dementia	220	28.2	3.38*
	Chronic pulmonary disease	4,574	11.4	1.11***
	Connective tissue disease (rheumatic)	149	8.1	0.75
	Ulcer	157	26.8	3.15*
	Chronic liver disease and Cirrhosis	515	21.4	2.34*
	Diabetes without complications	6,019	14.5	1.47*
2	Hemiplegia or paraplegia	47	10.6	1.03
	Moderate renal disease	1,498	25.4	2.94*
	Diabetes with complications	492	11.2	1.08
	Tumor, Leukemia, Lymphomaa	1,263	39.4	5.60*
3	Moderate or severe liver disease	64	37.5	5.17*
6	Malignant tumor, metastasis	85	45.9	7.30*
	AIDS	548	15.1	1.54*

[a] These three clinical conditions were jointly codified by Quan et al[14]
*p < 0.005
**p < 0.025
*** p < 0.10

Table 3. Elixhauser comorbidities for hospitalizations studied. Brazil, 2003-2004.

Comorbidity	n	Deaths (%)	Odds ratio
Congestive cardiac failure	8488	11.5	1.12*
Cardiac arrhythmia	1622	16.8	1.74*
Valvular disease	294	9.2	0.87
Pulmonary circulation disease	214	25.7	2.98*
Peripheral vascular disease	168	14.3	1.44***
Arterial hypertension	16808	12.8	1.26*
Arterial hypertension with complications	1352	10.6	1.02
Paralysis	47	10.6	1.03
Other neurological disease	539	14.3	1.44*
Chronic pulmonary disease	4574	11.4	1.11***
Hypothyroidism	58	5.2	0.47
Kidney failure	1497	25.5	2.94*
AIDS	548	15.1	1.54*
Lymphoma	182	29.1	3.54*
Cancer with metastasis	85	45.9	7.30*
Tumor	1184	41.8	6.20*
Rheumatic diseases	150	8.0	0.75
Coagulopathies	44	20.5	2.21***
Obesity	51	11.8	1.15
Weight loss	857	32.2	4.10*
Hydro-electrolytic imbalance	724	25.0	2.87*
Iron-deficiency anemia	705	13.0	1.29**
Alcohol abuse	867	15.2	1.55*
Drug abuse	22	9.1	0.86
Psychosis	38	5.3	0.48
Depression	29	3.4	0.31
Diabetes	1686	12.9	1.28*
Diabetes with complications	3800	15.6	1.60*
Liver disease	634	23.8	2.69*
Peptic ulcer without bleeding	51	5.9	0.54
Anemia due to bleeding	52	7.7	0.72

*$p < 0.005$
**$p < 0.025$
*** $p < 0.10$

important when the model is constructed to predict individual results,[6] all models showed adjustment problems, assessed by the Hosmer-Lemeshow test. The high number of hospitalizations analyzed may be the main explanation for this problem of adjustment of models, once previous Brazilian studies did not report this type of finding.[8,9,12] In view of the previously known limitations of the SIH/SUS, which encouraged researchers to perform the present study, and the magnitude of underreporting of secondary diagnoses found in the population analyzed, other studies are necessary. Future studies should be aimed at finding out the magnitude of underreporting, using medical records as source of information. Analyses of this type could help to assess the potential measurement bias resulting from the use of an administrative database. Considering the lack of studies on validity of comorbidity measures in the Brazilian population,[8] initiatives in this area are also important, especially in terms of Elixhauser et al's methodology,[3] which has not yet been validated in Brazil.

The results obtained do not promote the use of comorbidity measures, such as the proposals by Charlson[2] and Elixhauser,[3] based on the SIH/SUS. However, despite the limited effect on the capacity to predict death, probably associated with the quality of diagnostic information available in the national databases, the use of

Table 4. Distribution of frequency and percentage of deaths, according to comorbidity measures. Brazil, 2003-2004.

Comorbidity measure	Comorbidity (n)	%	Deaths (n)	%
Charlson Comorbidity Index[a]				
0	1,574,515	97.9	161,913	10.3
1	28,940	1.8	4,176	14.4
≥2	4,242	0.3	1,186	28.0
Elixhauser Comorbidity[b]				
0	1,577,749	98.1	162,553	10.3
1	29,948	1.9	4,722	15.8
Presence of comorbidity[c]				
0	1,520,974	94.6	152,017	10.0
1	86,723	5.4	15,258	17.6
Total	1,607,697	100	167,275	10.4

[a] Charlson Comorbidity Index codified according to Quan et al's algorithm14 $\chi 2$: 1930,02, gl 2, $p < 0.000$
[b] All the 30 comorbidities of this methodology, codified according to Quan et al's algorithm14 do not constitute an index and were counted as present (1) or absent (0). $\chi 2$: 941,43, gl 1, $p < 0.000$.
[c] Presence of comorbidity was counted as present (1) and absent (0). $\chi 2$: 5082,52,02, gl 1, $p < 0.000$

measures based on the presence of comorbidities is still recommended to adjust the risk of death or other performance indicators, as done in other countries. Thus, the CCI[2] and Elixhauser comorbidities[3] are still considered useful, especially with the adaptations to the ICD-10 performed by Quan et al.[14] The diagnostic information available in the Brazilian databases, particularly that from the SIH/SUS, need to be enriched. In other countries, discharge summaries enable secondary diagnoses to be recorded, including between 15 and 25 spaces[6,16] for this purpose. In addition, educational strategies for clinical professionals should be developed, aiming to promote recording of such information. Together with educational actions, the creation of mechanisms to monitor the quality of information recorded in different sources is important, whether in the patient's medical chart or in specific information system forms, such as the administrative database of hospital production.

In conclusion, findings from the present study indicate the importance of allowing a higher number of spaces to record comorbidities of Brazilian in-patients, as reported by previous studies.[8,10,15] Although the SIH/SUS was conceived in the 1980s, opportunities for improvement have not been identified or implemented, differently from the hospital information systems of other countries. This situation partly results from the difficult debate between type of payment for hospital services and the information system. Until now, there has not been an information system in Brazil that enables a complete description of hospital morbidity, when compared to those present in other countries, thus limiting the use of such information to assess the performance of services, among other things. This will require human and financial investments, but it will result in the construction of more valid performance indicators, which enable monitoring and improvement of the health care provided by the Brazilian health system.

Table 5. Discriminatory capacity and adjustment of death prediction models, according to comorbidity measures. Brazil, 2003-2004.

Model	χ^2 model[a]	Hosmer-Lemeshow Test	C-statistic (95% CI)
Baseline model: primary diagnosis, age and sex	64015.16 (gl 12, p = 0.000)	1427.99 (p = 0.000)	0.685 (0.684;0.687)
Baseline model + CCI	65752.08 (gl 16, p = 0.000)	1604.16 (p = 0.000)	0.688 (0.687;0.689)
Baseline model + Elixhauser comorbidities	65416.19 (gl 13, p = 0.000)	1486.15 (p = 0.000)	0.687 (0.686;0.689)
Baseline model + presence of comorbidity	68192.95 (gl 13, p = 0.000)	1812.12 (p= 0.000)	0.691 (0.690;0.693)

[a] Likelihood $\chi 2$ only for the intercept = 694745.46
CCI: Charlson Comorbidity Index

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