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Comorbidity adjustment index for the International Classification of Diseases, 10th revision

Índice de ajuste de comorbidade para a 10ª revisão da Classificação Internacional de Doenças

ABSTRACT

OBJECTIVE: To develop a Charlson-like comorbidity index based on clinical conditions and weights of the original Charlson comorbidity index.

METHODS: Clinical conditions and weights were adapted from the International Classification of Diseases, 10th revision and applied to a single hospital admission diagnosis. The study included 3,733 patients over 18 years of age who were admitted to a public general hospital in the city of Rio de Janeiro, southeast Brazil, between Jan 2001 and Jan 2003. The index distribution was analyzed by gender, type of admission, blood transfusion, intensive care unit admission, age and length of hospital stay. Two logistic regression models were developed to predict in-hospital mortality including: a) the aforementioned variables and the risk-adjustment index (full model); and b) the risk-adjustment index and patient's age (reduced model).

RESULTS: Of all patients analyzed, 22.3% had risk scores ≥1, and their mortality rate was 4.5% (66.0% of them had scores ≥1). Except for gender and type of admission, all variables were retained in the logistic regression. The models including the developed risk index had an area under the receiver operating characteristic curve of 0.86 (full model), and 0.76 (reduced model). Each unit increase in the risk score was associated with nearly 50% increase in the odds of in-hospital death.

CONCLUSIONS: The risk index developed was able to effectively discriminate the odds of in-hospital death which can be useful when limited information is available from hospital databases.

DESCRIPTORS: Comorbidity. International Classification of Diseases. Hospital Mortality. Medical Records. Models, Statistic. Life Tables. Epidemiological Models. Mathematic Models.

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RESUMO

OBJETIVO: Desenvolver um índice de co-morbidade a partir das condições clínicas e dos pesos do índice de co-morbidade de Charlson.

MÉTODOS: As condições clínicas e pesos do índice de Charlson foram adaptados segundo a Classificação Internacional de Doenças – 10ª Revisão, e aplicados ao diagnóstico principal de internação hospitalar. Foram estudados 3.733 pacientes acima de 18 anos hospitalizados em hospital geral público do município do Rio de Janeiro, RJ, 2001-2003. A distribuição do índice foi de acordo com o gênero, tipo da admissão, presença de transfusão de sangue, admissão à unidade de terapia intensiva, idade e tempo de internação. Dois modelos de regressão logística foram desenvolvidos com o objetivo de prever a mortalidade hospitalar desses pacientes: a) com as variáveis acima e o índice de co-morbidade (modelo completo); e b) contendo apenas o índice e a idade dos pacientes (modelo reduzido).

RESULTADOS: Dentre o total de pacientes analisados, 22,3% possuíam escores ≥1 para o índice e sua taxa de mortalidade foi 4,5% (66,0% dos quais com escores ≥1). Exceto gênero e do tipo de admissão, todas as variáveis foram retidas na regressão. Os modelos tiveram uma área sob a curva característica ROC igual a 0,86 (modelo completo) e 0,76 (modelo reduzido). Cada aumento de uma unidade nos escores do índice foi associado com um aumento de quase 50% na probabilidade de mortalidade hospitalar.

CONCLUSÕES: O índice desenvolvido pôde discriminar probabilidades de mortalidade com uma eficácia aceitável, o que pode ser útil ao lidar-se com bancos de dados hospitalares com informação limitada.

DESCRITORES: Comorbidade. Classificação Internacional de Doenças. Mortalidade Hospitalar. Registros Médicos. Modelos Estatísticos. Tábuas de Vida. Modelos Epidemiológicos. Modelos Matemáticos.

INTRODUCTION

Hospital administrative databases are frequently used for estimating clinical or epidemiological empirical models and these models should consider, as much as possible, the inclusion of variables controlling for patients' health status. These variables, known as risk-adjustment indexes,[21] are also useful for predicting patient outcome (e.g., mortality) in a variety of settings.[4]

One of these indexes is the Charlson Comorbidity Index,[3] which essentially classifies patients by weighting the severity of their clinical conditions. The Charlson index was originally proposed for longitudinal mortality studies, but there is evidence of its validity in a large number of clinical situations.[7,8] Although the most recent (10th) revision of the International Classification of Diseases (ICD) has been available for more than ten years,[a] applications of the Charlson index are frequently based on standardized coding of co-morbidities according to the ICD, 9th revision (ICD-9).[13] In addition, the number of conditions to be weighed for a sensitive index is not clear, and, in some countries, detailed and reliable records of patient co-morbidities are not even available from administrative hospital databases.

The objective of the present study was to assess an adapted version of the Charlson index updated for the ICD-10 coding scheme.

METHODS

A public general hospital in the city of Rio de Janeiro, Southeastern Brazil, was studied. General surgery and outpatient treatment were the most prevalent hospital services, and no emergency room care was available. The 200-bed hospital had a staff of about 1,300 persons and provided approximately 12,700 outpatient consultations a month. The main hospital departments were general surgery, internal medicine, cardiology, orthopedics, gynecology, thoracic surgery and urology.

[a] World Health Organization. International Statistical Classification of Diseases and Related Health Problems – 10th Revision. [cited 2007 Jan 11]. Available from: http://www.who.int/classifications/icd/en/,

Data were obtained from an information system developed by the Brazilian Ministry of Health for administrative/reimbursement purposes (*Sistema de Informações Ambulatoriais do Sistema Único de Saúde* – National Health System Information System Database, SIA-SUS). Besides patient data such as age and home address, this system includes information concerning patients' admissions in public hospitals, and their main admission diagnosis.[2] All patients over 18 years of age admitted in the hospitals during the period between January 2001 and January 2003 were included in the analysis (N=3,733).

For the computation of the original Charlson index, weights (0, 1, 2, 3 and 6) had to be applied to the patients' selected clinical conditions. These weights were defined according to the relative mortality risks of the conditions studied, and were estimated from a cohort admitted to two hospitals in the United States.[3] The clinical conditions of the Charlson index were adapted from the ICD-10 codes.[23] This adaptation was based on the list of clinical conditions and their descriptions,[3] which were translated into the ICD-10 with the help of existing Charlson index based on ICD-9 mappings and standard medical references.[1,5,6,11,17] The codes and their respective weights were applied to the patient's main admission diagnosis, yielding a Charlson index-like risk adjustment index that consisted of a clinical condition and its weight.

The index distribution among patients admitted to the hospital was analyzed (for each one of the departments previously mentioned) by gender, type of admission, blood transfusion, intensive care unit admission, age and length of hospital stay. These variables, together with the developed risk index, were then included in two logistic models to predict in-hospital mortality for the patients studied. For the first (full) model, all aforementioned independent variables were included in the regression, and the non-statistically significant ones were excluded, yielding a final model with all p-values below 0.05. In this final model, variable interactions were tested in the usual manner.[10] For the second model (the reduced one), only patient's age and the risk-adjustment index were included as predictors. In addition, both basic models were replicated with an existing alternative ICD-10 Charlson index mapping.[22]

Gender, type of admission, blood transfusion and intensive care unit admission were defined as binary (male/female or yes/no), age was measured in years and length of hospital stay in days. Model goodness-of-fit was assessed using the omnibus test for model coefficients and the ***c*** (area under the receiver operating characteristic (ROC) curve) statistic.[10] The R Software was used for data manipulation and analysis.[a]

RESULTS

Table 1 shows a summary of the clinical conditions studied and their coding according to the ICD-10 mapping developed. In the period studied, 22.3% of the patients had their risk-adjustment index equal or above 1. Their mortality rate was 4.5% (168 cases), and 66% of them had risk-adjustment index scores equal or above 1. In 29.2% of the deaths, the main diagnosis was malignant neoplasm (score 2); 19.0% were primarily diagnosed with congestive heart failure and acute myocardial infarction (score 1); 9.5% with HIV-related disease (score 6) and 5.4% with chronic respiratory diseases (score 1).

Table 2 shows the index scores distribution according to hospital departments and selected variables (values not presented for cells with less than five patients). In general, higher scores were associated with urgent admissions, blood transfusions and intensive care unit admission. Similarly, score increase was associated with an increase in the variables age and length of hospital stay. Notably, in the internal medicine department, score increases (scores above 2) were associated with decreasing age.

For all models, the omnibus test of model coefficients had a p-value below 0.001. Except for gender and type of admission, all independent variables could be retained in the full logistic model (Table 3). In this model, the c parameter was 0.86 (95% CI: 0.83;0.89), intensive care unit admission and blood transfusion were the strongest odds predictors and each unit increase in the risk-adjustment score was associated with nearly 50% increase in the odds of in-hospital death. In the reduced model, both predictors (age and risk-adjustment index) were statistically significant, and the c statistic decreased to 0.76 (95% CI: 0.72;0.80). The replicated models with the alternative ICD-10 coding had a somewhat poorer performance, with *c* parameters of 0.83 and 0.70, respectively.

DISCUSSION

Table 2 shows that, in general, score increases were associated to increased odds of urgent admission, blood transfusion, intensive care unit admission and death, and increased average age and length of hospital stay. The exception to thatwas the internal medicine department where care was provided to AIDS patients, who accounted for 95% of all cases with risk score ≥3. This bias can explain the inconsistency between age and risk score found in this department since it is well-known that HIV-related diseases usually occur at relatively younger ages.

[a] Vienna University of Economics and Business Administration. The R Project for Statistical Computing. [cited 2007 Jan 11]. Available from: <http://www.r-project.org>

Table 1. Clinical conditions, CCI-adapted ICD, 10th Revision. Rio de Janeiro, Southeastern Brazil, 2001–2003.

Condition	Weight	ICD-10	Description
Myocardial infarction	1	I21/I22/I25.2	Acute/Subsequent/Old myocardial infarction
Congestive heart failure	1	I50	Heart failure
Peripheral vascular diseases	1	I71	Aortic aneurysm and dissection
		I73	Other peripheral vascular diseases
		R02	Gangrene, nec
		Z958, Z959	Presence of cardiac and vascular implants and grafts
Cerebrovascular diseases	1	I60-I61	Subarachnoid or intracerebral hemorrhage
		I62	Other nontraumatic intracranial hemorrhage
		I63	Cerebral infarction
		I64	Stroke, not specified as hemorrhage or infarction
		I670	Dissection of cerebral arteries, nonruptured
		I676	Nonpyogenic thrombosis of intracranial venous system
		I678	Other specified cerebrovascular diseases
		I69	Sequelae of cerebrovascular disease
		G45	Transient cerebral ischemic attacks and related syndromes
		G46	Vascular syndromes of brain in cerebrovascular diseases
Dementia	1	F00-F03/F051	Mental disorders/Delirium superimposed on dementia
Chronic pulmonary disease	1	J40-J47	Chronic lower respiratory diseases
		J96.1	Chronic respiratory failure
		J84.1	Other interstitial pulmonary diseases with fibrosis
		I27.9	Pulmonary heart disease, unspecified
		J60-J65	Pneumoconiosis
		J66	Airway disease due to specific organic dust
		J67	Hypersensitivity pneumonitis due to organic dust
		J68	Respiratory conditions due to inhalation of chemicals, gases, fumes, vapors
Connective tissue disease	1	L93	Lupus erythematosus
		M32	Systemic lupus erythematosus
		M33	Dermatopolymyositis
		M34	Systemic sclerosis
		M05	Inflammatory polyarthropathies
		M06	Other rheumatoid arthritis
		M08	Juvenile arthritis
		M35.3	Polymyalgia rheumatica
Ulcer disease	1	K25/K26/K27/K28	Gastric/Duodenal/Peptic (site unspecified)/Gastrojejunal ulcer
Mild liver disease	1	K70/K74/K73	Alcoholic liver disease/Fibrosis and cirrhosis of liver/Chronic hepatitis nec
Diabetes	1	E10-E14	Diabetes mellitus, excluding subdivisions 2, 3, 4 e 5.
Diabetes w/end organ damage	2	E10-E14	Diabetes mellitus, subdivisions 2, 3, 4 e 5.
Hemiplegia or Paraplegia	2	G81/G82	Hemiplegia/Paraplegia and tetraplegia
Renal disease	2	N01/N03	Rapidly progressive nephritic syndrome/Chronic nephritic syndrome
		N18/N19	Chronic renal failure/Unspecified renal failure
		N25	Disorders from impaired renal tubular function
		N052-N056	Unspecified nephritic syndrome
		N072-N074	Hereditary nephropathy, nec
Any tumor, including leukemia and lymphoma	2	C00-C76	Malignant neoplasms
		C80	Malignant neoplasm without specification of site
		C81-C97	Malignant neoplasms, stated or presumed to be primary
Moderate or severe liver disease	3	K76.6/I85	Portal hypertension/Esophageal varices
Metastatic solid tumor	6	C77-C79	Secondary and unspecified malignant neoplasm
AIDS	6	B20, B22-B24	Human immunodeficiency virus [HIV]
AIDS + Any tumor, including leukemia and lymphoma	8	B21	[HIV]-related disease resulting in malignant neoplasms

nec: not elsewhere classified

Two sets of models were developed for validating the newly developed index. Besides a model including classical predictors of in-hospital mortality, readily available from administrative databases, a "reduced" model was developed allowing better comparability of similar studies that sought to predict in-hospital mortality. This reduced model included patient's age, since a variation of the Charlson index consists in adding the value "1" for every 10 years of life beyond the age of 50.

The widely used area under the ROC curve and its derived *c* parameter were applied to assess model performance. In logistic regression (binary classifier), the ROC curve is a plot of false-positive rates (x axis) versus true-positive rates (y axis) for many prediction thresholds of the model. The *c* statistic, in turn, is simply the area under the curve obtained, so that when $c=1$ indicates a perfect classifier (100% true-positive and 0% false-positive rates).[10] In the present analysis, however, the discriminatory power was lost when a single patient diagnosis was used. Thus, the *c* parameter was 0.86 for the full model, decreasing to 0.76 when only age and risk index were included as mortality predictors. A classifier is usually deemed acceptable with *c* is above 0.70 and excellent when *c* is above 0.80.[10]

Administrative data are relatively easily available for large numbers of patients and thus have been frequently used in clinical and epidemiological studies. In this sense, having available an index for the evaluation and control of patient's condition severity is a key approach, and the Charlson index is one of the most studied indexes.[13,14,19,20] Its correlation with costs or odds of death has been investigated in both in-hospital and follow-up settings. An extensive literature review of 13 comorbidity classification indexes concluded the Charlson index was one of the four "(…) valid and reliable methods to measure comorbidity that can be used in clinical research".[4] A recent review of studies on Charlson index applications can be found in Needham et al 2005.[13]

However, most applications of this index have been described in countries with well-established patient recording systems, and in some cases these administrative databases may contain up to 40 patient ICD codes.[a] But there is little research on the sensitivity of risk-adjustment indexes to the number of comorbidities used in their construction. In addition, it is well-known the quality of comorbidity recording varies widely even in countries with well-established hospital data collection,[12] and, therefore, the extent to which these factors actually affect the discriminatory power of the index is not clear. In the present study, the database also included a secondary admission diagnosis but this (non-mandatory) record is usually considered unreliable, and this information was missing in about 90% of the patients.

As for the translation of clinical conditions into standardized codes, one of the first attempts to convert the clinical conditions described by Charlson[3] into ICD codes (9th revision) was made in 1992 with Medicare claims data (Deyo et al adaptation).[5,6] Another adaptation was made by the Dartmouth-Manitoba group, resulting in an ICD-9 coding scheme that the authors considered as"slightly"[17] different from the former, and the main differences were due to a less rigid interpretation of the Charlson index basic clinical conditions.[5,6,17,18] Another option is the mapping developed by D'Hoore et al,[7,8] which main difference from the previous translations[3,5,6] was the use of three-digit ICD codes. In the present study, the Charlson index was adapted from the ICD-10 disease classification scheme. The ICD-9 has 6,969 diagnosis codes while the ICD-10 has 12,420 (14,199 when including Chapter XX – External causes of death). The most important changes in the ICD-10 classification are the use of alphanumeric codes, the inclusion of B20-B24 HIV-related codes and more detailed description of some conditions, e.g. myocardial infarction codes (six codes versus one in the ICD-9).

In the newly developed coding scheme for the ICD-10 Charlson index representation (Table 1), it should be noted that: 1) two-digit codes in this table include all corresponding coding subdivisions; 2) HIV-related malignant neoplasm (ICD-10 B21) was assigned the weight "8" as it includes a condition with weight "2" (malignant neoplasm) and another one with weight "6"; 3) the weight "2" was assigned to both diabetes with end-organ damage – retinopathy, neuropathy, or nephropathy – and diabetes mellitus with peripheral circulatory complications (E10-14 subdivisions 2, 3, 4 and 5); and the weight "1" was assigned to the remaining E10-14 codes); 4) following the originally proposed Charlson index, i) the ICD-10 code Z-95 presence of cardiac and vascular implants and grafts includes patients who had bypass for arterial insufficiency, ii) any tumor, including leukemia and lymphoma includes patients with metastatic solid tumors (breast, lung, colon, and other tumors), iii) rheumatologic diseases includes L93 (lupus erythematosus) and M08 (juvenile arthritis), iv) pulmonary disease includes patients with or without treatment who are dyspneic with or without attacks, represented by the codes J96.1 (chronic respiratory failure), J84.1 (other interstitial pulmonary diseases with fibrosis), I27.9 (pulmonary heart disease, unspecified) and J68 (respiratory conditions due to inhalation of chemicals, gases, fumes, vapors) and v) cerebrovascular disease does not include the codes I671, I672, I674,

[a] Department of Human Services, Victorian Government. The Victorian Admitted Episodes Dataset, 17th Edition Users Manual. March 18 2008. Department of Human Services, Health Data Standards and Systems Unit. Victoria, Australia. [cited 2008 Jun 30]. Available from: http://www.health.vic.gov.au/hdss/vaed/2007-08/manual/index.htm

Table 2. Risk index score distribution according to hospital departments and selected variables. Rio de Janeiro, Southeastern Brazil, 2001–2003.

Department	CCI score	Patients (%)	Female (%)	Admission urgency (%)	Transfusion (%)	ICU (%)	Death (%)	Age	Hospital stay
Cardiology	0	316 (49.0)	177 (56.0)	147 (46.5)	7 (2.2)	42 (13.3)	14 (4.4)	64	9
(n = 540)	1	224 (51.0)	84 (37.5)	138 (61.6)	10 (4.5)	65 (29.0)	20 (8.9)	63	15
	2	-	-	-	-	-	-	-	-
	≥3	-	-	-	-	-	-	-	-
Internal medicine	0	293(44.7)	167 (57.0)	166 (56.7)	48 (16.4)	24 (8.2)	39 (13.3)	52	14
(n = 655)	1	122 (18.6)	70 (57.3)	67 (54.9)	8 (6.6)	11 (9.0)	18 (14.7)	55	13
	2	162 (24.7)	78 (48. 1)	70 (43.2)	38 (23.5)	2 (1.2)	44 (27.2)	60	18
	≥3	78 (11.9)	26 (33.3)	35 (44.9)	15 (19.2)	8 (10.3)	18 (23.1)	42	23
Neurology	0	72 (62.6)	37 (51.4)	40 (55.6)	2 (2.8)	4 (5.6)	1 (1.4)	43	11
(n = 115)	1	43 (37.4)	24 (55.8)	26 (60.5)	1 (2.3)	6 (13.9)	3 (7.0)	62	17
	2	-	-	-	-	-	-	-	-
	≥3	-	-	-	-	-	-	-	-
General surgery	0	776 (93.4)	381 (49.1)	371 (47.8)	13 (1.7)	10 (1.3)	3 (0.4)	50	5
(n = 816)	1	-	-	-	-	-	-	-	-
	2	40 (4.8)	25 (62.5)	-	8 (20.0)	2 (5.0)	4 (10.0)	56	16
	≥3	-	-	-	-	-	-	-	-
Gynecology	0	265 (80.5)	265 (100)	151 (57.0)	7 (2.6)	1 (0.4)	-	49	6
(n = 329)	1	-	-	-	-	-	-	-	-
	2	64 (19.5)	64 (100)	-	1 (1.6)	-	1 (1.6)	51	13
	≥3	-	-	-	-	-	-	-	-
Thoracic surgery	0	68 (79.1)	55 (80.9)	45 (66.2)	2 (2.9)	10 (14.7)	-	46	6
(n = 84)	1	-	-	-	-	-	-	-	-
	2	16 (18.6)	16 (100)	-	-	-	-	60	9
	≥3	-	-	-	-	-	-	-	-
Orthopedics	0	329 (94.8)	161 (48.9)	150 (45.6)	11 (3.3)	1 (0.3)	1 (0.3)	45	5
(n = 346)	1	-	-	-	-	-	-	-	-
	2	17 (4.9)	7 (41.5)	15 (88.2)	2 (11.8)	2 (11.8)	2 (11.8)	56	23
	≥3	-	-	-	-	-	-	-	-
Urology	0	174 (89.2)	36 (20.7)	88 (50.6)	11 (6.3)	3 (1.7)	-	59	11
(n = 195)	1	-	-	-	-	-	-	-	-
	2	21 (10.8)	1 (4.7)	14 (66.7)	5 (23.8)	1 (4.8)	-	67	22
	≥3	-	-	-	-	-	-	-	-

Cells with less than five patients were included in the models but are here represented as "-".

Table 3. Logistic regression models for in-hospital patient death. Rio de Janeiro, Southeastern Brazil, 2001–2003.

Model	beta	p-values	OR [95% CI]
ICD-10 developed adaptation			
Full model (c: 0.86; 95% CI [0.83;0.89])			
ICU admission	1.44	0.000	4.21 [2.75;6.44]
Blood transfusion	1.57	0.000	4.78 [3.12;7.32]
Age	0.03	0.000	1.03 [1.02;1.04]
Length of hospital stay	0.02	0.000	1.02 [1.01;1.03]
Risk-adjustment index	0.44	0.000	1.56 [1.41;1.72]
Constant	-5.58	0.000	
Reduced model (c: 0.76; 95% CI [0.72;0.80])			
Age	0.03	0.000	1.03 [1.02;1.04]
Risk-adjustment index	0.54	0.000	1.72 [1.58;1.88]
Constant	-5.34	0.000	
Replicated			
Full model (c: 0.83; 95% CI [0.80;0.87])			
ICU admission	1.31	0.000	3.72 [2.44;5.65]
Blood transfusion	1.67	0.000	5.29 [3.48;8.05]
Age	0.02	0.000	1.02 [1.01;1.04]
Length of hospital stay	0.02	0.000	1.02 [1.01;1.03]
Risk-adjustment index	0.30	0.000	1.35 [1.21;1.52]
Constant	-5.26	0.000	
Reduced model (c: 0.70; 95% CI [0.66;0.74])			
Age	0.03	0.000	1.03 [1.02;1.04]
Risk-adjustment index	0.44	0.000	1.56 [1.41;1.72]
Constant	-5.03	0.000	

P-value for omnibus test of model coefficients < 0.001, coefficient p-values rounded up to three decimal places

I675, I677 and I679 since only patients with history of cerebrovascular accident with minor or no residua and transient ischemic attacks are included; 5) following Deyo et al adaptation, Alzheimer disease (G30) is not included in the dementia category.

Values found for the *c* parameter in the logistic models developed are not different from the results of studies with similar applications of the Charlson index or its variations. For example, reported *c* values for Charlson index performance in the prediction of in-hospital mortality include either the low 0.64;0.70,[9,15] the acceptable 0.74; 0.76[9] and the very high 0.83;0.87.[7,8,22]

In the present study, models including the risk index developed had a better performance than those with an alternative scheme for the Charlson index ICD-10 mapping[22] (c= 0.76 vs. 0.70 for the reduced model). Further studies are required to investigate whether the identified predictive advantage is specific of the present application (that is, the use of a single admission diagnosis) or it is a more general characteristic of the mapping. The literature has described that only small Charlson index performance differences are detectable between ICD-9 and ICD-10 revisions.[16,22]

Ideally, co-morbidities indexes of the Charlson index-type should be developed for specific populations, since its weight definition is basically cohort-driven.[9] This is, however, obviously impractical, and a simple, robust and reliable (albeit not optimal) index is arguably more useful. This is the case of the adaptation proposed in the present study, which was able to effectively discriminate the odds of in-hospital death. The adaptation can be a valid approach in settings where limited information (single reliable patient diagnosis) is available from hospital administrative databases.

REFERENCES

1. Anderson RN, Miniño AM, Hoyert D, Rosemberg HM. Comparability of cause of death between ICD-9 and ICD-10: preliminary estimates. *Natl Vital Stat Rep*. 2001;49(2):1-32.

2. Carvalhosa-Mello PC, Almeida RMVR, Pereira WCA. A computerized information system for the analysis of hospital admission flow. *Int J Medical Inf.* 2001;61(1):11-20. doi:10.1016/S1386-5056(00)00129-5

3. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidty in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40(5):373-83. doi:10.1016/0021-9681(87)90171-8

4. Groot BH, Beckerman H, Lankhorst GJ, Bouter LM. How to measure comorbidity: a critical review of available methods. *J Clin Epidemiol*. 2003; 56(3):221-9. doi:10.1016/S0895-4356(02)00585-1

5. Deyo R, Cherkin D, Ciol MA. Adapting a clinical comorbidity index for use with ICD-9CM administrative databases. *J Clin Epidemiol.* 1992;45(6):613-9. doi:10.1016/0895-4356(92)90133-8

6. Deyo RA. Adapting a clinical comorbidity index for use with ICD-9-CM administrative data: a response. *J Clin Epidemiol.* 1993;46(10):1081-2. doi:10.1016/0895-4356(93)90104-9

7. D'Hoore W, Sicotte C, Tilquim C. Risk adjustment in outcome assessment: the Charlson comorbidity index. *Methods Inf Med.* 1993;32(5):382-7.

8. D'Hoore W, Bouckaert A, Tilquin C. Practical considerations on the use of the Charlson Comorbidity Index with administrative data bases. *J Clin Epidemiol.* 1996;49(12):1429-33. doi:10.1016/S0895-4356(96)00271-5

9. Ghali WA, Hall RE, Rosen AK, Ash AS, Moskowitz MA. Searching for an improved clinical comorbidity index for use with ICD-9-CM administrative data. *J Clin Epidemiol.* 1996;49(3):273-8. doi:10.1016/0895-4356(95)00564-1

10. Hosmer D, Lemeshow S. Applied logistic regression. 2.ed. New York: Wiley & Sons; 2000.

11. Kasper DL, Braunwald E, Hauser S, Longo D, Jameson JL, Fauci AS. Harrison Principles of Internal Medicine. 16.ed. New York: McGraw Hill; 2004.

12. McKee M, Coles J, James P. 'Failure to rescue' as a measure of quality of hospital care: the limitations of secondary diagnosis coding in English hospital data. *J Public Health.* 1999;21(4):453-8. doi:10.1093/pubmed/21.4.453

13. Needham DM, Scales DC, Laupacis A, Pronovost PJ. A systematic review of the Charlson comorbidity index using Canadian administrative databases: a perspective on risk adjustment in critical care research. *J Crit Care*. 2005;20(1):12-9. doi:10.1016/j.jcrc.2004.09.007

14. O´Connell RL, Lim LL. Utility of the Charlson comorbidity index computed from routinely collected hospital discharge diagnosis codes. *Methods Inf Med.* 2000;39(1):7-11.

15. Poses RM, Smith WR, McClish DK, Anthony M. Controlling for confounding by indication for treatment. Are administrative data equivalent to clinical data? *Med Care.* 1995;33(4 Supl):AS36-46.

16. Quan H, Sundararajan V, Halfon P, Fong A, Burnand B, Luthi JC, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care*. 2005;43(11):1130-9. doi:10.1097/01.mlr.0000182534.19832.83

17. Romano PS, Roos LL, Jollis JG. Adapting a clinical comorbidity index for use with ICD-9-CM administrative data: differing perspectives. *J Clin Epidemiol.* 1993;46(10):1075-9. doi:10.1016/0895-4356(93)90103-8

18. Romano PS, Leslie LR, Jollis JG. Further evidence concerning the use of a clinical comorbidity index with ICD-9-CM administrative data. *J Clin Epidemiol.* 1993;46(10):1085-90. doi:10.1016/0895-4356(93)90106-B

19. Schneeweiss S, Maclure M. Use of comorbidity scores for control of confounding in studies using administrative databases *Int J Epidemiol.* 2000; 29(5):891-8. doi:10.1093/ije/29.5.891

20. Schneeweiss S, Wang PS, Avorn J, Maclure M, Levin R, Glynn RJ. Consistency of performance ranking of comorbidity adjustment scores in Canadian and U.S. utilization data. *J Gen Intern Med.* 2004;19(5):444-50. doi:10.1111/j.1525-1497.2004.30109.x

21. Shaughnessy PW, Hittle DF. Overview of risk adjustment and outcome measures for home health agency OBQI reports: Highlights of current approaches and outline of planned Enhancements. Center for Health Services Research, University of Colorado Health Sciences Center; 2002. Available from: http://www.cms.hhs.gov/HomeHealthQualityInits/Downloads/HHQIRiskAdj.pdf

22. Sundararajan V, Henderson T, Perry C, Muggivan A, Quan H, Ghali WA. New ICD-10 version of the Charlson Comorbidity Index predicted in-hospital mortality. *J Clin Epidemiol.* 2004;57(1):1288-94. doi:10.1016/j.jclinepi.2004.03.012

23. World Health Organization. International Statistical Classification of Diseases and Health Related Problems ICD-10. Geneva; 2004.