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Original Article

Performance of Charlson and Elixhauser Comorbidity Index to Predict in-Hospital Mortality in Patients with Stroke in Sumadija and Western Serbia

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Abstract

Background: Comorbidities are major predictors of in-hospital mortality in stroke patients. The Charlson comorbidity index (CCI) and the Elikhauser comorbidity index (ECI) are scoring systems for classifying comorbidities. We aimed to compare the performance of the CCI and ECI to predict in-hospital mortality in stroke patients.

Methods: We included patients hospitalized for stroke in the Clinical Center of Kragujevac, Serbia for the last 7 years. Hospitalizations caused by stroke, were identified by the International Classification of Diseases-10 (ICD-10) codes I60.0 - I69.9. All patients were divided into two cohorts: Alive cohort (n=3297) and Mortality cohort (n=978).

Results: There were significant associations between higher CCIS and increased risk of in-hospital mortality (HR = 1.07, 95% CI = 1.01–1.12) and between higher ECIS and increased risk of in-hospital mortality (HR = 1.04, 95% CI = 0.99–1.09). Almost 2/3 patients (66.9%) had comorbidities included in the CCI score and 1/3 patients (30.2%) had comorbidities included in the ECI score. The statistically significant higher CCI score (t = -3.88, df = 1017.96, P <0.01) and ECI score (t = -6.7, df = 1447.32, P <0.01) was in the mortality cohort.
Area Under the Curve for ECI score was 0.606 and for CCI score was 0.549.

Conclusion: Both, the CCI and the ECI can be used as scoring systems for classifying comorbidities in the administrative databases, but the model's ECI Score had a better discriminative performance of in-hospital mortality in the stroke patients than the CCI Score model.

Keywords: Stroke; In-hospital mortality; Charlson comorbidity index; Elixhauser comorbidity index

Introduction

Stroke is one of the leading causes of mortality and morbidity in the population aged ≥65 years. According to the WHO, Stroke and Ischaemic heart disease in 2019 caused over 2.5 million deaths. Stroke accounts for about 5% of all disability-adjusted life-years (DALY). In the last 25 years, the risk of stroke increased from 22.8% to 24.9% (1,2).

In 2019 in Serbia, stroke was the second leading cause of DALY for males and the leading cause for females with 136,090 DALY for the total population. The analysis of 10 leading causes of death in Serbia in the period from 2009-2019 showed that stroke is in the second place, right after Ischaemic heart disease, but its share in total deaths decreased by 10% in 2019 when compared to 2010 (3).

Apart from affecting the quality of life of patients and the usage of health resources, comorbidities are major predictors of mortality. Hypertension, diabetes mellitus, coronary, and congestive heart failure and chronic pulmonary disease are the most common comorbidities in stroke (4).

The Charlson Comorbidity Index (CCI) is a scoring system to classify comorbidities in an administrative database. The modified version of the CCI contains 17 conditions which are coded according to the International Classification of Diseases, X revision (ICD-10). Each comorbidity is scored almost 1, 2, or 6 and higher CCI scores are an increased risk of one-year mortality in stroke patients. CCI, in addition to the ability to predict mortality, can be used to measure disease burden, which is especially important in diseases of great public health importance, such as stroke (5,6).

One year after the implementation of the Charlson Comorbidity Index, researcher Elixhauser and colleagues introduced a new model for estimating the comorbidity index, The Elixhauser Comorbidity Index (ECI). The ECI is suitable for studying data from administrative databases, such as the hospitalization database, and it includes 31 comorbidities (7,8).

The main objective of the present study was to compare the performance of the Charlson and Elixhauser comorbidity index to predict in-hospital mortality in patients with stroke.

Methods

Study design and population

The Clinical Center of Kragujevac is one of the 4 regional clinical centers in the Republic of Serbia, in which the population of Sumadija and Western Serbia is treated - about 2 million people and in which there are more than 50,000 hospitalizations annually. The databases on hospitalization reports, which the Clinical Center of Kragujevac submits to the Institute of Public Health in Kragujevac, are part of the Integrated Health Information System of the Republic of Serbia. This was a retrospective cohort study, which included all hospitalizations at the Clinical Center of Kragujevac between 2014, and 2020, in which stroke was listed as a discharge diagnosis.

The dataset included patient characteristics such as sex, age, primary and secondary diagnoses based on International Classification of Diseases-10 (ICD-10) codes and hospital discharge information including in-hospital mortality. All data were collected from the hospital base of the Institute of the Public health Kragujevac. Hospitalizations caused by cerebrovascular diseases, including stroke, were identified by the ICD-10 codes I60.0- I69.9. Incomplete reports and reports in which patients are under 18 years of age have not been analyzed. If a patient had more than one admission during this period, the last hospitalization was analyzed. After filtering and coding the base, a sample of 4275 hospitalizations was obtained. All patients divided in two cohorts: Alive cohort (n=3297) and Mortality cohort (n=978).

Ethical approval

The study protocol complied with the Declaration of Helsinki and was approved by the Ethics Committee of Institute of Public Health Kragujevac, No: 01-6591.

Classification of comorbidities scores

Comorbidities were coded as three-score numbers according to ICD-10 diagnoses codes. We calculated the Charlson and Elixhauser index (7). CCIS has 17 disease categories and ECIS has 31 categories. Two researchers independently screened comorbidity categories for CCI and ECI.

Statistical Analysis

The prevalence of comorbidities was calculated and the outcome was measured by in-hospital mortality. Patient characteristics were described and group differences were tested by using independent *t*-tests and Chi-squared tests. Cox proportional hazards regression was used to identify the risk factors associated with death in the whole sample. C-statistics was used to analyze the predictive ability of ECI and CCI score in in-hospital death in the stroke and compared with tests of equality for Receiver Operating Characteristic (ROC) curves.

SAS statistical software for Windows, Version 9.3 (SAS Institute, Cary, NC, USA) and SPSS statistical software for Windows, Version 19 (Chicago, IL, USA) were used (IBM, Armonk, NY, USA). A *P*-value of ≤ 0.05 was considered significant.

Results

During the period 01. 01. 2014-31. 12. 2020, 4275 patients with stroke were treated at the Clinical Center of Kragujevac, and 978 patients (22.9%) died in the hospital.

As shown in Table 1, the mean age of hospital stroke patients was 70.12 ± 12.45 yr, males were represented with 51.3%. Almost 2/3 of them live on the territory of the City of Kragujevac. Patients with stroke are most often treated at the Clinic of Neurology.

Table 1: Demographic characteristics and the hazard ratio of mortality

Variables	*N (mean)*	*% (sd)*	*HR*	*95%CI*	*P*
Age(yr)	70.12	12.45	1.04	1.03-1.04	<0.01
Sex					
Men	2191	51.3	1.00		>0.05
Women	2084	48.7	1.04	0.92-1.18	
Region					
Kragujevac	2746	64.2		1.00	
Sumadia district without Kragujevac	1013	23.7	0.65	0.53-0.79	<0.01
Western Serbia	516	12.1	0.94	0.76-1.17	>0.05
Admission department					
Neurology	2835	66.3		1.00	
Neurosurgery and vascular surgery	346	8.1	1.33	1.15-1.54	<0.01
Emergency Center and other	1094	25.6	0.14	0.07-0.26	<0.01
Discharge department					
Neurology	2956	69.1		1.00	
Neurosurgery and vascular surgery	416	9.7	1.25	1.07-1.45	<0.05
Emergency Center and other	903	21.1	0.12	0.07-0.23	<0.01
Charlson Comorbidity Index Score	2.28	1.33	1.07	1.01-1.12	<0.05
Elixhauser Comorbidity Index Score	3.17	4.54	1.04	0.99-1.09	0.05

There were significant associations between higher CCIS and increased risk of mortality (HR = 1.07, 95% CI = 1.01–1.12) and between higher ECIS and increased risk of mortality (HR = 1.04, 95% CI = 0.99–1.09). By comparing the Alive cohort and In-hospital mortality cohort, we can

observe that the patient who died were on average 7 years older than the ones who survived (t=-15.64, df=1801.52, P<0.01), but the share of genders was similar in both groups (χ^2=0.32, df=1, P>0.05). Patients from both cohorts (Alive cohort and In-hospital mortality cohort) were mostly from Kragujevac (χ^2=0.32, df=1, P<0.05), admitted at the Clinic for Neurology (χ^2=86.76, df=2, P<0.01) and discharged from the Clinic for Neurology (χ^2=107.49, df=2, P<0.01). Patients who survived spent on average 2 days longer in the hospital as compared to deceased hospitalized stroke patients (11.88 ± 10.3, vs 10 ± 15.32, t= -11.782, P<0.01). A statistically significant difference could be observed in the average values of CCI score in the examined groups (t = -3.88, df = 1017.96, P<0.01). The mean Charlson Comorbidity Index score in the Alive cohort was 2.23 ± 1.31, and in the In-hospital mortality cohort 2.47 ± 1.38. The mean value of The Elixhauser Comorbidity Index in Alive cohort was 2.9 ± 4.36 and in the In-hospital mortality cohort 4.08 ± 4.99, which was a statistically significant higher score (t = -6.7, df =1447.32, P<0.01) (Table 2).

Table 2: General characteristics of the study population

Variables	***Alive cohort***		***Mortality cohort***		***P***
	n (mean)	% (sd)	n (mean)	% (sd)	
Age(yr)	68.64	12.47	75.07	10.91	<0.01
Sex					
Men	1698	51.5	493	50.4	>0.05
Women	1599	48.5	485	49.6	
Region					
Kragujevac	2156	64.2	590	60.3	<0.05
Sumadia district without Kragujevac	747	23.7	266	27.2	
Western Serbia	394	12.1	122	12.5	
Admission department					
Neurology	2122	64.4	713	72.9	<0.01
Neurosurgery and vascular surgery	336	10.2	10	1	
Emergency Center and other	839	25.4	255	26.1	
Discharge department					
Neurology	2207	66.9	749	76.6	<0.01
Neurosurgery and vascular surgery	405	12.3	11	1.1	
Emergency Center and other	685	20.8	218	22.3	
Length of Stay	11.88	10.3	10	15.32	<0.01
Charlson Comorbidity Index Score	2.23	1.31	2.47	1.38	<0.01
Elixhauser Comorbidity Index Score	2.9	4.36	4.08	4.99	<0.01

Out of the 4,275 hospitalized patients from the stroke, 2,864 (66.9%) had comorbidities included in the CCI score. The most common comorbidities from the CCI comorbidity list were: Previous cerebrovascular disease and hemiplegia, diabetes mellitus without end-organ damage and congestive heart failure. As for the patients who died, the most common CCI listed morbidities were congestive heart failure, renal disease, mild liver disease and metastatic solid tumor (Table 3).

Table 3: Distribution of Charlson Comorbidities and Mortality (n = 4275)

Charlson Comorbidities	*Comorbidity*		*Mortality**	
	n	%	n	%
Myocardial infarction	90	2.1	22	24.4
Congestive heart failure	424	9.9	157	37
Peripheral vascular disease	116	2.7	13	11.2
Cerebrovascular disease	1599	37.4	326	20.4
Dementia	106	2.5	12	11.3
Chronic pulmonary disease	187	4.4	48	25.7
Rheumatic disease	10	0.2	3	30
Peptic ulcer disease	30	0.7	1	3.3
Mild liver disease	12	0.3	4	33.3
Diabetes mellitus without end-organ damage	561	13.1	99	17.6
Diabetes mellitus with end-organ damage	240	5.6	50	20.8
Hemiplegia	815	19.1	219	26.9
Renal disease	140	3.3	47	33.6
Any malignancy, including lymphoma and leukemia, except malignant neoplasm of skin	81	1.9	22	27.2
Moderate liver disease	1	0.02	1	100
Metastatic solid tumor	16	0.4	5	31.3
HIV/AIDS	/	/	/	/

*Died in relation to the total number of patients with this comorbidity

Comorbidities included in the ECI score had 1292 patients (30.2%). The most common comorbidities from the ECI score listed morbidities were hypertension uncomplicated, paralysis, diabetes, complicated and cardiac arrhythmias. Among the deceased patients, the most common ESIC-listed morbidities were lymphoma, coagulopathy, fluid and electrolyte disorders and congestive heart failure (Table 4).

A comparison of the predictive power of the CCI and the ECI score for in-hospital deceased patients shows that the discrimination of the model's ECI score was better than the CCI score model. Area Under the Curve for ECI score was 0.606 and for CCI score was 0.549 (Fig. 1).

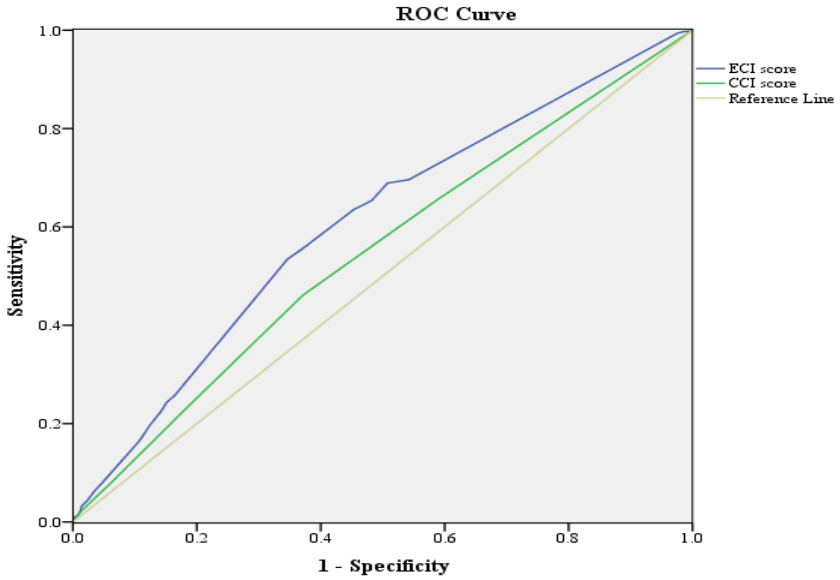

Fig. 1: Receiver operating characteristic (ROC) curves of CCI and ECI score

Table 4: Distribution of Elixhauser Comorbidities (n = 4275)

Elixhauser Comorbidities	*Comorbidity*		*Mortality**	
	n	**%**	**n**	**%**
Congestive heart failure	380	8.9	140	36.8
Cardiac arrhythmias	551	12.9	148	26.9
Valvular disease	69	1.6	15	21.7
Pulmonary circulation disorders	45	1.1	8	17.8
Peripheral vascular disorders	86	2	7	8.1
Hypertension, uncomplicated	1842	43.1	321	17.4
Hypertension, complicated	14	0.3	3	21.4
Paralysis	727	17	195	26.8
Neurodegenerative disorders	233	5.5	53	22.7
Chronic pulmonary disease	164	3.8	52	31.7
Diabetes, uncomplicated	85	2	13	15.3
Diabetes, complicated	668	15.6	129	19.3
Hypothyroidism	35	0.8	5	14.3
Renal failure	106	2.5	33	31.1
Liver disease	13	0.3	4	30.8
Peptic ulcer disease excluding bleeding	19	0.4	1	5.3
AIDS/HIV	/	/	/	/
Lymphoma	10	0.4	4	40.0
Metastatic cancer	16	1.6	5	31.3
Solid tumor without metastasis	68	0.2	20	29.4
Rheumatoid arthritis/collagen vascular diseases	10	0.5	1	10
Coagulopathy	20	0.1	8	40
Obesity	6	0.02	0	0
Weight loss	1	2.1	0	0
Fluid and electrolyte disorders	88	0.4	34	38.6
Blood loss anemia	19	1.1	4	21.1
Deficiency anemia	46	0.3	9	19.6
Alcohol abuse	11	0.2	2	18.2
Drug abuse	9	1.9	1	11.1
Psychoses	65	1.7	2	3.1
Depression	89	3.3	10	11.2

* Died in relation to the total number of patients with this comorbidity

Discussion

The burden of comorbidities with in-hospital stroke patients is high. The Charlson comorbidity index and the Elixhauser Comorbidity Index are the most commonly used indexes to calculate comorbidity scores in hospital databases. Despite the opinion of Quan et al (9) that the original Charlson comorbidity index could be modified with an increase in the number of available data in large administrative databases, such as the hospitalization base, the performance of the proposed CCI model is not significantly better than the original CCI model. The only advantage of using a modified CCI score model is the fact that it encodes 10 instead of 17 comorbidities, which can be significant in situations where we do not already have coded data (9).

In our research, 66.9% of the patients with the stroke have had comorbidities (one or more) which is in accordance with the prevalence of comorbidity in stroke statistics which ranges from 60% to 89%. The analysis of the frequency of comorbidities in the United States among the population who suffered stroke shows that, similarly to the results of this research, the most fre-

quent comorbidities are hypertension, diabetes, and heart disease (10). When it comes to Turkey, the most frequent health disorders associated with stroke were: vascular diseases, psychiatric problems, and endocrine and metabolic disorders (11). In our research, 28.5% of the patients have had two or more comorbidities while in rural areas, such as Kentucky, almost 80% of people who suffered a stroke have experienced three or more comorbidities (12).

The importance of the comorbidities is reflected in the effects of the therapy given to the patients, the duration and the outcome of the hospitalization, hospital readmission, functional recovery, and the treatment expenses.

Neglecting the importance of the comorbidities is a common occurrence even among the researchers. In accordance with that, the research conducted in Germany (of the systematic reviews type), has shown that only 11.4% of the studies which were analyzing the efficiency of the new treatments among the patients who suffered from an ischemic stroke included comorbidities (13). The duration of the hospitalization has been influenced both by the degree of damage caused by the stroke and by the type and number of comorbidities. Many types of research throughout Europe, Asia and Australia showed that the higher CCI and ECI score is associated with the longer duration of stay (5,14).

In order to decrease the rate of readmission and stroke mortality, it is necessary to direct attention towards both the risk factors and comorbidities. According to the allegations made by the Centers for Disease Control and Prevention, every fourth patient who has suffered a stroke is very likely to experience another one. The connection between the rate of readmission and the death risk among the patients with the transient ischemic attack has been shown in the research conducted at the Mayo Clinic, United States (5). Elderly patients who have suffered a stroke and who have multiple comorbidities and high Charlson comorbidity index and the Elixhauser comorbidity index were associated with the increased likelihood of in-hospital death. In our study, the in-hospital mortality rate among the patients who suffered a stroke was 22.9%, and the deceased patients had a significantly higher CCI and ECI index. The rate of mortality caused by acute stroke was between 3% and 18% in Taiwan, 12.5% in Ethiopia, while in the United States every fourth patient died of the stroke (15,16).

Stroke accompanied by comorbidities is the leading cause of long-term disability. The patients who have suffered a stroke require comprehensive care and specialized techniques of care and rehabilitation for a longer period of time. Total cost amounts to the sum of costs of health care services, medicines necessary for the treatment of stroke and comorbidities as well as productivity losses which imply absence from work and premature death. According to the research conducted in 32 European countries, 1.7% of funds have been spent on stroke in 2017, and the total cost has amounted to 60 billion euros. In the United States, the estimated stroke-related costs have amounted to 40 trillion euros per year. The research conducted in Canada has shown that, with the increase in the number of comorbidities among the patients who have lived through a stroke, there is an increase in need and consumption which is conditioned not by the stroke but by the comorbidities (17-19).

Limitations

The study has some limitations. This retrospective study analyzed data on patients hospitalized at a Clinical Center in Serbia. The results of our research should be compared with the results of the same research which would include patients from other 3 clinical centers, in this way patients from all over the country would be part of the analysis, from all geographical areas, and including them would provide more reliable data. Also, it should be taken into account the fact that errors in the classification and coding of diseases might occur.

Conclusion

Both the CCIS or ECIS were used, but we found that the model's Elixhauser comorbidity Index

Score had a better discriminative performance of in-hospital mortality in the stroke patients than the Charlson Comorbidity Index Score model.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflicts of interest

The authors declare that no conflict of interest.

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