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# A tool to support the clinical decision based on risk of death in hospital admissions

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**Abstract**

This article presents a computational tool that calculates the risk of death, based on the study of comorbidity. The data represent patients hospitalized in general hospitals of the region of Ribeirao Preto, Brazil. The risk of death was estimated by calculating the Charlson comorbidity index (CCI) and age-adjusted Charlson comorbidity index (ACCI). The CCI employs weights from 0 to 6 in selected comorbidities. The higher the score of the patient, the greater the chance of dying. For ACCI, in addition to comorbidities, more scores is incorporated according to the patient's age - for each decade above 50 years. For the demonstration of the tool, we obtained the distribution of cases studied by CCI and ACCI. The tool that assists in the manipulation of the CCI and ACCI calculations has allowed real-time analysis of hospitalizations, thus providing a good aid for health decision-making.



*Keywords:* computational tool; risk of death; Charlson comorbidity index (CCI); support the clinical decision.

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## 1. Introduction

Hospital indicators are tools used to evaluate hospital performance, involving its organization, resources and work methodology. The data collected in different areas of the hospital, when related to each other, are transformed into useful management tools for the assessment of care, quantity and type of re-sources involved, control of costs generated in the production of services and degree of resolution of same [1].

The use of indicators with methodology and scientific criteria, gives hospitals a gain in quality and efficiency in their actions [2]. The gain with the use of indicators in the management process can be even more effective, if the monitoring is carried out continuously, not only after the regular closing, but also in the day-to-day management, with daily evaluations.

The North American agency "Agency for Healthcare Research and Quality (AHRQ)" advocates some indicators of hospital quality as well defined and studied. The "Inpatient Quality Indicator" is a set of measures that provide a perspective on the quality of care in hospitals, using administrative data of establishments. These indicators include hospital mortality by some clinical conditions and surgical procedures, utilization rates and volume of some procedures.

Hospital mortality is a traditional indicator of hospital performance, and probably will be for a long time. It expresses a crucial dimension of the quality of care provided: the result. However, differences between hospitals can be derived from medical practice, the pro le of the treated cases or the interaction between these elements [3]. Thus, in comparative studies, patients with different health characteristics that imply different treatments cannot be analyzed as similar and a setting suitable for the characterization of such patients is very important [4]. The factors of risk of death of patients (severity) are the variables for adjusting hospital mortality rates in conducting these types of studies and together, the comparison of the time of permanence, costs or mortality implies determine to what extent the differences observed can be attributed to the type of case admitted or the differences in treatment [5]. Particularly, the intensity (number and severity) of coexisting diseases is an important predictor of complications and unfavorable results [6].

The Charlson comorbidity index (CCI) is a severity rating based on comorbidities. Typically, the methods of risk adjustment based on the presence of co-morbidity can be applied when data are available from administrative databases, because, despite not containing other clinical information, always provide diagnostic information. However, its usefulness depends of the completeness and accuracy of this information.

A set of relevant information can best describe a given scenario studied and from this, we can consider that engaging the information from the CCI to other hospital information, we can describe the distribution of the risk of death of patients, raise hypotheses about the care offered and assist in decision-making of the managers.

In addition, the exploration of comorbidities can, among other things: (i) correct confusion in clinical studies, (ii) identify changes in the presented effect, (iii) to study prediction of death, prognosis and/or natural history, and (iv) to allow the application of statistical methods to raise hypotheses [7].

The tool presented aims to use and improve technologies, in this case, the manipulation of the CCI for hospital data analysis providing hospital death prediction. The final product consists in organizing access to information, better management and handling of hospital data from web portal.

## 2. Background

### *2.1 The Charlson comorbidity index*

The CCI was defined in 1987 by Mary E. Charlson and colleagues to rate the severity of patients. This method employs selected clinical conditions registered as secondary diagnosis - comorbidities - in the calculation of the risk of dying, in other words, calculates the index of the patient's disease burden, regardless of the principal diagnosis. Face of this, we have according to the recommended weights for Charlson [8] a total weight that identifies the patient in relation to its severity before the care that must be provided to the hospital. The clinical conditions and weights that compose the index (Table 1; columns score and description) were selected because they presented a relative risk, derived from the survival analysis, greater than 1.2 in the set of 30 clinical conditions originally studied in a cohort study with 604 cases of breast cancer from New York Hospital [8].

Together the methodology recommended by Charlson in CCI, the authors also proposed the age-adjusted Charlson comorbidity index (ACCI) which incorporates a weighting in accordance with the patient age - for each decade over 50 years you must add more points in the previous score about the comorbidities [9].distribution of the risk of death of patients, raise hypotheses about the care offered and assist in decision-making of the managers.

So, the patient's CCI or ACCI final score will be allocated to a stratum with a variant score of zero to greater than 6, where the higher the allocation stratum, the greater the chance of death.

### *2.2 The web portal: ORAH.*

The Regional Health Care Observatory (ORAH portal), was created in 2009 and is an initiative of the XIII Regional Health Department - Ribeirao Preto, Sao Paulo State Health Secretary in partnership with the Ribeirao Preto Medical School - University of Sao Paulo, whose main objective is to ensure that health information, especially on hospital care, gains in quality with development for health care, management and research. For this, hospital admission data from the region are collected and qualified by Center of Hospital Data Processing (CPDH), of the Hospital of Clinics of the Medicine School in Ribeirao Preto, University of Sao Paulo, Brazil. The CPDH was created in 1969 with the purpose of collecting, processing and guaranteeing the quality of hospital admission information through internal protocols to verify and correct inconsistencies. In general, the CPDH has collaboration with 34 hospitals and processes approximately 170 thousand hospitalizations annually, of which 60% are funded by public assistance.

Currently, the ORAH portal has six computational tools developed specifically to support the arrangement of hospital information in order to aid in the decision making of physicians and health managers. These tools can be classified into two analytical computational categories, the first one that allows its users to perform sophisticated queries and analysis on their data, including simulations, hypothetical scenarios, and trend analysis; and the second, widely known as data mining, which allows, through an intense analysis of the relationship between stored data, the discovery of information that may be valuable to the aid of health business strategies [10].

The tool presented in this article is allocated in the Portal ORAH and manipulation of the data from the case study were from the portal.

## 3. Methods

The tool developed is based an anterior version tool in language Java [11] that provided the calculation of the Charlson Comorbidity Index and presented as a result a table containing general information, for each hospital, with the values of CCI and ACCI [12]. The version presented in the article had as primary objective the incorporation into a web portal content for which the access and manipulation of data could achieve managers of the area. For each hospital, is made the weighting according to the number and severity of secondary diagnoses, following the methodology recommended by Charlson to the comorbidities and age [4,8,9].

The dataset explored by the tool comes from ORAH Portal and is based on the sheet of Hospital Discharge, which contains information about the demographic profile of the patients; the diagnostics primary and secondary; the surgical procedures, therapeutics and diagnostics; the medical specialty of the case treated; the dates of admission and discharge; the type of discharge and the source of payment. The information, although they are available for each patient are anonymous, so that it is impossible to identify patients and it have universal coverage of all hospitalizations, whether public or private. An important feature of this database is that it allows the recording of information from up to four secondary diagnoses, which is an essential data for the development of the tool based on the weighting of comorbidity. A record represents a hospital discharge and not a patient and therefore we characterized the case of patient during hospitalization.

The computational tool that allows the calculation of the CCI and the ACCI was developed in Hypertext Preprocessor Language and technology resources Hypertext Markup Language and Cascading Style Sheets, due to suitability for web development and in order to follow the standards previously deployed in the ORAH portal [10]. There was first the need for conversion of the standard for encoding ICD 9 - originally used to encode the 17 clinical conditions the Charlson - for ICD 10 - standard used in the data presented by the Hospital Discharge Sheet [13]. In addition to allowing the automation of the calculation of the index, the tool also allows the use of data by queries

filters, such as: gender, cause of hospitalization (primary diagnosis) and type of service (public or private). The query filters allow you to exchange the input variables of the values dynamically and in real time and displays the results of a query in the form of tables and graphs, thus ensuring greater accuracy and detail of the results.

For the demonstration of the tool, a case study was applied with all hospitalizations in general hospitals belonging to the region of Ribeirão Preto in 2011.

## 4. Results and Discussion

The tool to calculate the Charlson comorbidity index is available in http://ciis.fmrp.usp.br/orah and in order to have access the user must request a password for the service. The Figure 1 shows the initial interface of the tool for calculating the Charlson Comorbidity Index and Adjusted Age-Adjusted Charlson Comorbidity Index. To the left are the query filters that allow a more detailed manipulation of data so that they are operated according to the user's interest and to the right the description of the tool and the space of display of the response.

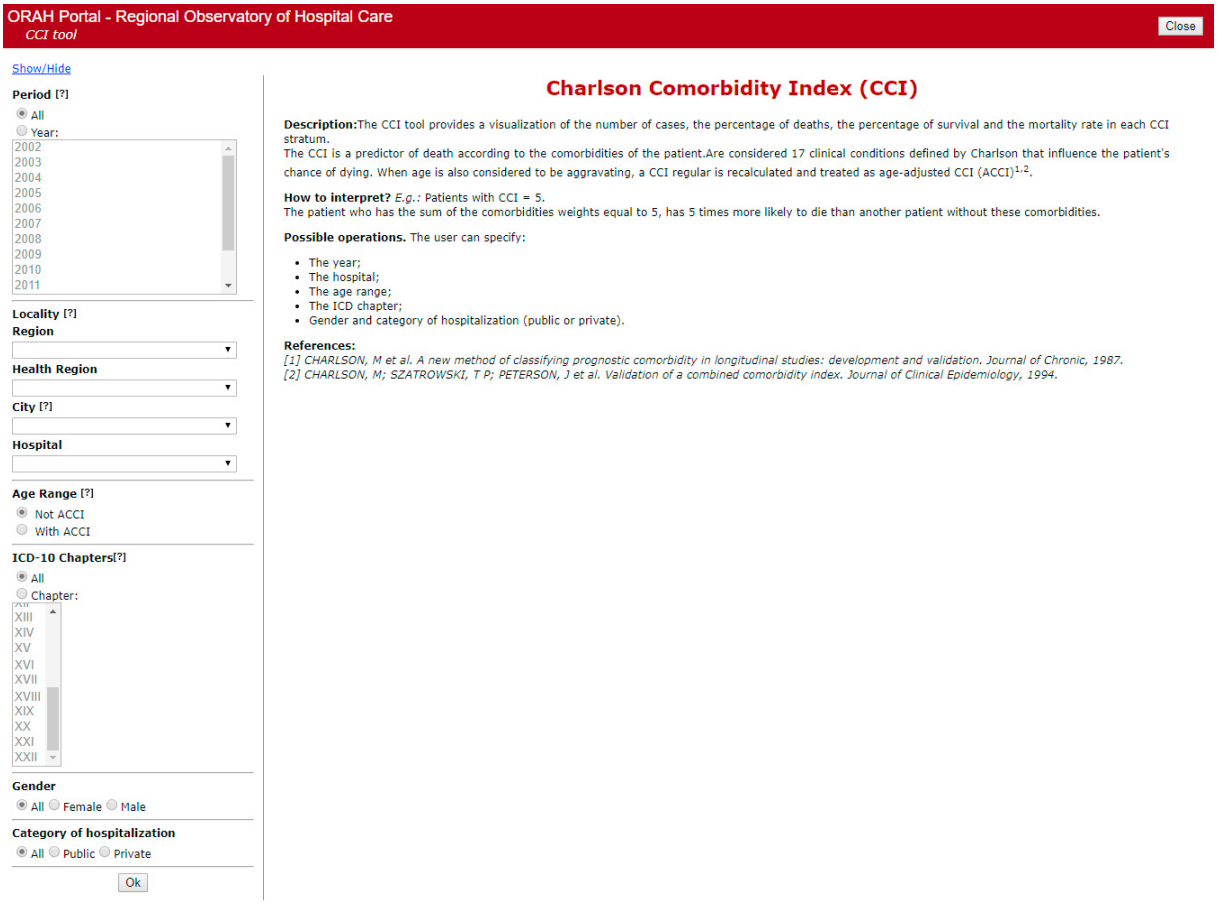


Fig. 1. Homepage CCI/ACCI tool - ORAH portal.

The Figure 2 is an example of output data from the tool. The answer provides a table with the total number of admissions, the number of hospitalizations whose output condition refers to deaths and the number of admissions whose output condition refers to the hospital discharge, in each CCI or ACCI stratum. We can also, in order to facilitate the analysis of the data, with the aid of the buttons provided below the table, to show each column as a graphic illustration (Figure 3).

| CCI | Cases | % of death | % of survival |
|---|---|---|---|
| 0 | 263447 | 3.18% | 96.82% |
| 1 | 13198 | 7.16% | 92.84% |
| 2 | 2453 | 7.79% | 92.21% |
| 3 | 887 | 20.74% | 79.26% |
| 4 | 387 | 12.14% | 87.86% |
| 5 | 304 | 37.5% | 62.5% |
| >= 6 | 221 | 12.67% | 87.33% |
| **Total** | 280897 | 3.52% | 96.48% |

Cases % of death % of survival

Fig. 2. CCI/ACCI tool. Example output data in table format.

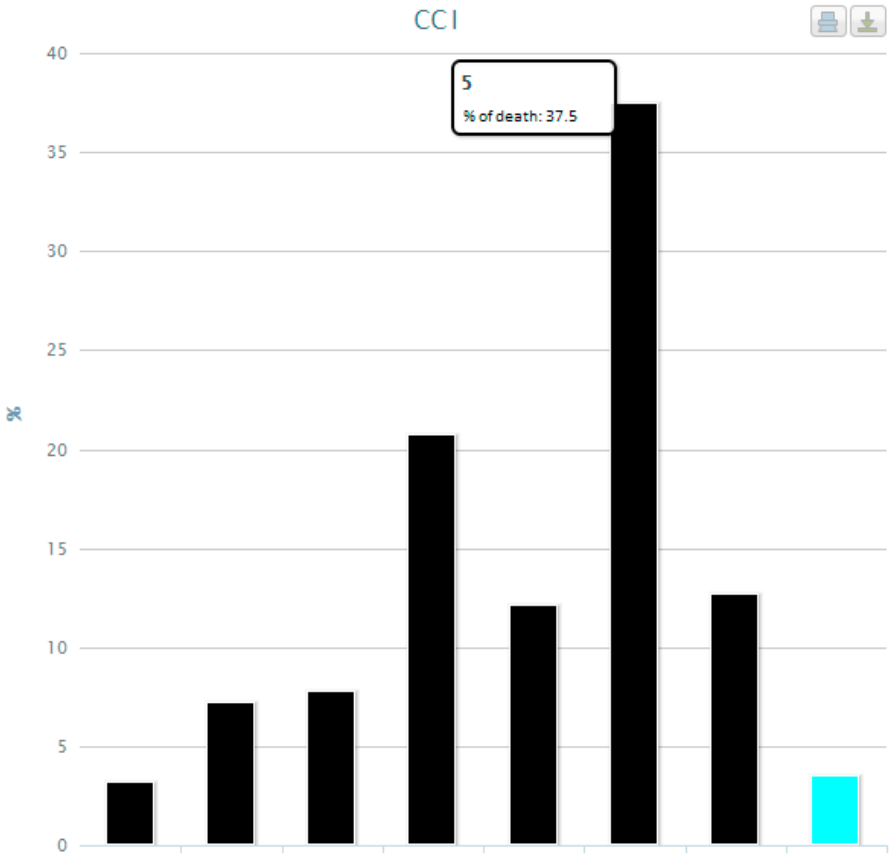


Fig. 3. CCI/ACCI tool. Example output data in chart format.

With the support of the tool presented, we were able to obtain the characterization of the distribution of death risk based on the CCI/ACCI of the case study. This characterization aims to support health decisions. The following analyzes are an example of how the manipulation of the information through the tool can aid the investigation of the hospital routine.

The Table 1 lists the 17 clinical conditions studied by Charlson, their scores according to the ICC and the number of hospitalizations for each one of the co-morbid conditions studied. 5,760 cases are part of the set of hospitalizations with clinical conditions selected by Charlson representing 5% of total hospitalizations of hospitals selected for the year 2011.

Table 1. Frequency of the clinical conditions presented by Charlson.

| Clinical Conditions | | Hospital Admission | | | |
|---|---|---|---|---|---|
| Score | Description | For comorbidity | | For stratum | |
| | | n | % | N | % |
| 1 | Acute myocardial infarction | 356 | 0.31 | 4659 | 4.01 |
| 1 | Congestive heart failure | 0 | 0 | | |
| 1 | Peripheral vascular disease | 190 | 0.16 | | |
| 1 | Cerebral vascular accident | 415 | 0.36 | | |
| 1 | Dementia | 10 | 0.01 | | |
| 1 | Pulmonary disease | 178 | 0.15 | | |
| 1 | Connective tissue disorder | 80 | 0.07 | | |
| 1 | Peptic ulcer | 0 | 0 | | |
| 1 | Liver disease | 316 | 0.27 | | |
| 1 | Diabetes | 3114 | 2.68 | | |
| 2 | Diabetes complications | 357 | 0.31 | 645 | 0.55 |
| 2 | Hemiplegia or paraplegia | 9 | 0.01 | | |
| 2 | Renal disease | 135 | 0.12 | | |
| 2 | Cancer | 144 | 0.12 | | |
| 3 | Metastatic cancer | 112 | 0.10 | 394 | 0.34 |
| 3 | Severe liver disease | 282 | 0.24 | | |
| 6 | HIV | 62 | 0.05 | 62 | 0.05 |

The Figure 4 explores the CCI and ACCI index. In Figure 4(a) it is showed the number of cases per CCI stratum. Disregarding the stratum 0 – without comorbidities listed to the patient - the strata 1 and 2 that represent the lower risk of death, have the highest number of cases. In Figure 4(b), we observed that although the strata with high values (greater than 3) from the CCI present the highest rates of deaths of the group, the curve of mortality is not growing and does not align risk distribution provided by Charlson whose highest scores of the CCI suggest greater death risk and consequently should result in higher death rates.

However, we do not want to investigate the why the behavior of the curve, which may be a dataset feature worked or else a reflection of the care provided to patients in this region.

We realize, then, that in this set, the hospitalizations classified in strata 4 and 5 represent the most serious cases.

Already in Figure 4(c) it is showed the number of cases distributed per stratum ACCI. The strata 1, 2 and 3 present the highest number of cases. According to 4(d), it can be observed that the ACCI curve of mortality is increasing and aligns with the risk distribution provided by Charlson, thus, the ACCI became more appropriate for studying the severity of these cases. In this set, the hospitalizations allocated in the strata 5 and 6 represent the most serious cases. The analyzes present in real time the situation of severity of the hospitalizations of the establishment selected.

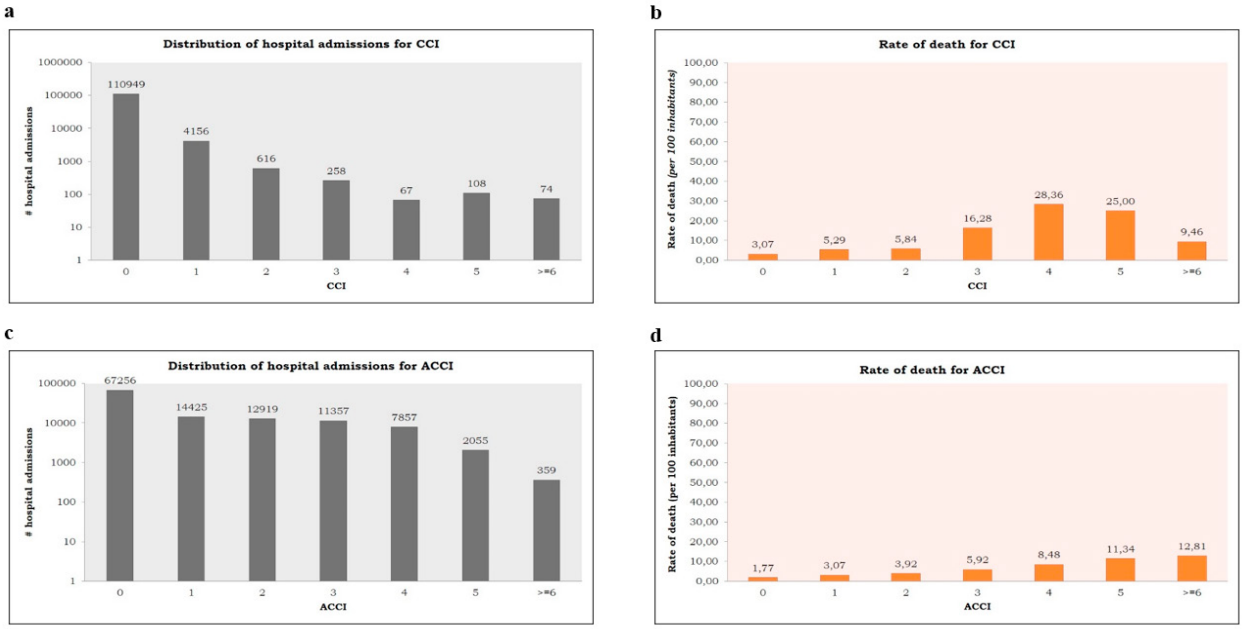


Fig. 4. (a) Hospital admission for CCI; (b) Rate of death for CCI; (c) Hospital admission for ACCI; (d) Rate of death for ACCI.

The findings are in agreement with the literature that presents, in recent works, the importance of exploring the CCI and ACCI in order to analyze the severity of the cases together with the mortality rate, with these indicators as relevant evaluators in the quality of health care services [14, 15].

However, the main difficulty in using CCI and ACCI is in relation to annotations of comorbidities in the health services. Unfortunately, this practice is not incorporated in Brazil, because in the Authorization for Hospital Admittance - standard document for the identification of hospitalization - only one field is reserved for annotation of comorbidities, which makes it difficult to explore studies in this area [16].

## 5. Conclusion

The tool available in a web portal, allows the handling in different strata and situations - according to gender, main diagnosis, type of care, and others - and provides users with information regarding the severity of the cases being attended by one hospital, what comorbidities among those listed by Charlson deserve more attention in care and the rate of death in relation to cases of low and high severity. In addition, we realize that the manipulation of the indicator by means of the tool is an aid to managers to analyze the care provided enabling the decision support and the survey of actions to improve the service.

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## References

[1] Schiesari, Laura Maria César, and Marcos Kisil. (2003) “A avaliação da qualidade nos hospitais brasileiros.” *Rev. Adm. Saúde*: 7-17.

[2] Gonçalves, Ernesto Lima. (2006) "Gestão hospitalar: administrando o hospital moderno." São Paulo: Saraiva.

[3] Iucif Jr, Nelson, and Juan S. Yazlle Rocha. (2004) “Study of inequalities in hospital mortality using the Charlson comorbidity index.” *Revista de Saúde Pública* **38 (6)**:780-786.

[4] Blumberg, Mark S. (1986) “Risk adjusting health care outcomes: a methodologic review.” *Medical Care Review* **43 (2)**:351-393.

[5] Martins, Mônica, Claudia Travassos, and José Carvalho de Noronha. (2001) “Brazilian Hospital Database System as risk adjustment in performance indicators.” *Revista de Saúde Pública* **35(2)**:185-192.

[6] Thomas, J. William. (2004) “Risk adjustment for measuring health care outcomes.” *International Journal for Quality in Health Care* **16 (2)**:181-182.

[7] de Groot, Vincent, et al. (2003) "How to measure comorbidity: a critical review of available methods." *Journal of Clinical Epidemiology* **56 (3)**: 221-229.

[8] Charlson, Mary E., et al. (1987) “A new method of classifying prognostic comorbidity in longitudinal studies: development and validation.” *Journal of Chronic Diseases* **40 (5)**:373-383.

[9] Charlson, Mary E., et al. (1994) “Validation of a combined comorbidity index.” *Journal of Clinical Epidemiology* **47 (11):**1245-1251.

[10] Carvalho, Isabelle, et al. (2013) "Ferramentas Computacionais para Análise de Dados no Auxílio à Gestão Hospitalar na Região de Ribeirão Preto." *XIII Workshop de Informática Médica*.

[11] Arnold, Ken, James Gosling, and David Holmes. (2005) “The Java programming language.” 4th edition. Addison Wesley Professional.

[12] Hitomi, Wagner Y., et al. (2012) “O índice de comorbidade de Charlson como ferramenta do observatório regional de atenção hospitalar.” *XIII Congresso Brasileiro de Informática em Saúde,* Curitiba: 19-23.

[13] Quan, Hie, et al. (2005) “Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data.” *Medical Care* **43 (11)**: 1130:1139.

[14] Charlson, Mary E., et al. (2014) “The Charlson comorbidity index can be used prospectively to identify patients who will incur high future costs.” *PloS one* **9 (12)**: e112479.

[15] Johnston, Marjorie C., et al. (2015) "Charlson index scores from administrative data and case-note review compared favourably in a renal disease cohort." *The European Journal of Public Health* **25 (3)**: 391-396.

[16] Martins, Monica. (2010) “Uso de medidas de comorbidades para predição de risco de óbito em pacientes brasileiros hospitalizados.” *Revista de Saúde Pública* **44 (3)**:448–456.