The Charlson Comorbidity Index in Registry-based Research

Which Version to Use?

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Summary

Background: Comorbidities may have an important impact on survival, and comorbidity scores are often implemented in studies assessing prognosis. The Charlson Comorbidity index is most widely used, yet several adaptations have been published, all using slightly different conversions of the International Classification of Diseases (ICD) coding.

Objective: To evaluate which coding should be used to assess and quantify comorbidity for the Charlson Comorbidity Index for registry-based research, in particular if older ICD versions will be used.

Methods: A systematic literature search was used to identify adaptations and modifications of the ICD-coding of the Charlson Comorbidity Index for general purpose in adults, published in English. Back-translation to ICD version 8 and version 9 was conducted by means of the ICD-code converter of Statistics Sweden.

Results: In total, 16 studies were identified reporting ICD-adaptations of the Charlson Comorbidity Index. The Royal College of Surgeons in the United Kingdom combined 5 versions into an adapted and updated version which appeared appropriate for research purposes. Their ICD-10 codes were back-translated into ICD-9 and ICD-8 according to their proposed adaptations, and verified with previous versions of the Charlson Comorbidity Index.

Conclusion: Many versions of the Charlson Comorbidity Index are used in parallel, so clear reporting of the version, exact ICD-coding and weighting is necessary to obtain transparency and reproducibility in research. Yet, the version of the Royal College of Surgeons is up-to-date and easy-to-use, and therefore an acceptable co-morbidity score to be used in registry-based research especially for surgical patients.

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1. Introduction

The problem of confounding effects of comorbidities on survival was recognised in the early 1970s, and is also referred to as susceptibility bias [1]. If certain comorbidities, e.g. diabetes mellitus or obesity, are known and important confounders, their effect should be analysed individually. Yet, often a more general assessment of comorbidity status is required, preferably as a single numeric score which could easily and reliably be added to the statistical model [2]. There are several comorbidity scoring systems developed and in use, of which the Charlson Index is among the oldest and the most widely used [3, 4]. This scoring system is based on a selected number of chronic, mainly non-communicable diseases an individual has. These were selected based on a cohort of only 559 medical patients admitted in 1984 to a hospital in New York, the United States, aiming to include "comorbid conditions which singly or in combination might alter the risk of short-term mortality" [3]. Since the original Charlson scoring was based on the review of medical records, International Classification of Diseases (ICD) coding was not reported; nor was it in the age-modified version (adding additional weight for age) [5]. Especially for research using registry data, exact coding information is however needed to improve transparency and reproducibility; and the first translations of these diseases into ICD-codes (9th edition) were published in the early 1990s [6, 7]. Since administrative registries may have used different ICD versions over time, exact coding is necessary for different

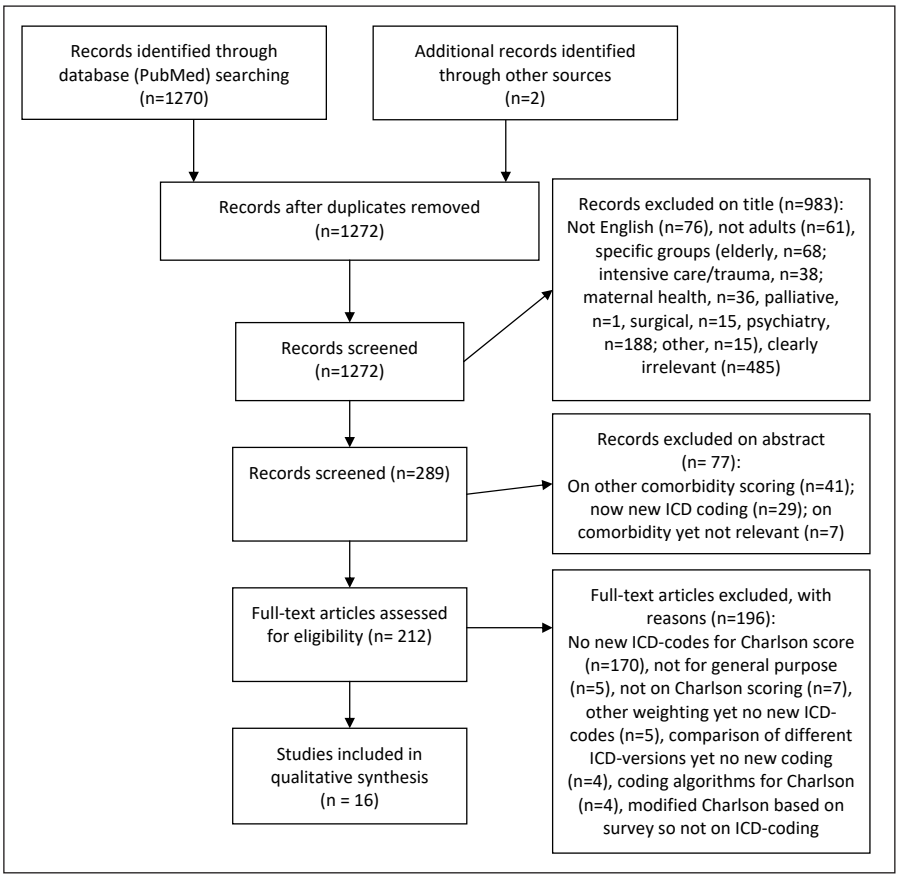

Figure 1 Flow chart describing the systematic literature search. ICD = International Classification of Diseases.

versions of the ICD coding (8–10th edition) to improve the ascertainment of the burden of chronic diseases over a longer period of time [8]. What complicates the use of the Charlson Comorbidity Index, are the different updates and adaptations used in research, in particular the different ICD-codes used to define the included diseases. Currently, many versions are used, and several studies using the Charlson Index do not specify which version, ICD-codes or weighting have been used. Therefore, reproducibility is often problematic, and the validity of the comorbidity variable insufficiently clear. Especially if comorbidity is assessed as a main exposure, the results may even be unreliable. The aim of this report was to evaluate which version of the Charlson Comorbidity Index ICD-coding should be used for general purpose in registry-based prognostic research in adults, in particular when comorbidity is ascertained based on different (older) ICD-versions.

2. Methods

2.1 Systematic Literature Search and Translations

A systematic literature search was performed to identify all articles published in English describing adaptations or modifications of the ICD-codes of the Charlson Comorbidity Index for general purpose in adults. Studies which merely modified the weights of the included comorbidities were excluded. The search was conducted in PubMed (▶Figure 1), using the following search string (last updated 25th March 2016): ("International Classification of Diseases"[Mesh] OR "ICD"[Tiab] OR "coding"[Tiab] OR "codes"[Tiab] OR "Charlson"[Title] OR "scores"[Title] OR "scoring"[Title]) AND ("Charlson"[Tiab] OR "morbidity"[Title] OR "comorbidity"[Title]). The ICD-code converter of Statistics Sweden was used to back-translate codes from ICD-version 10 to earlier ICD-versions [9].

2.2 ICD-Coding in Administrative Databases

The ICD-codes are the global health information standard for mortality and morbidity statistics, and are presently translated into 43 languages and used in all member states of the World Health Organisation. The ICD-coding has existed since 1893, and has been regularly updated since to reflect advances in healthcare and medical science over time [10], introducing new disease categories, and more specific disease information. Yet, there are several versions adapted for different countries and updates occurring between two official ICD versions, also showing important differences concerning comorbidities [11]. In Sweden, the 7th, 8th, 9th and 10th editions were introduced in 1955, 1968, 1987 and 1997, respectively. Since the Swedish Patient Registry was established in 1964 and has gradually expanded, with nationwide coverage since 1987, the ICD 8th, 9th and 10th versions of the ICD-coding in particular have been used, depending on the year of hospitalisation [12]. Since comorbidities are not always recorded as part of the discharge diagnosis for each hospitalisation, exact coding for the 3 last versions is needed to optimise the coverage of chronic comorbidities to catch comorbidities listed for previous hospitalisations.

2.3 The Original Charlson Comorbidity Index

The original Charlson Index was developed based on a cohort of 559 medical patients, and validated in a cohort of women with primary breast cancer [3]. This weighted index grouped 19 clinically relevant comorbidities, i.e. those resulting in a ≥20% increase in 1-year mortality, in 4 categories according to their assigned weight: 1 point was given to patients with an ICD-code for myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, connective tissue disease, peptic ulcer disease, mild liver disease, or diabetes; 2 points were given for hemiplegia, moderate or severe renal disease, diabetes with end organ damage, any malignant tumour, leukaemia or lymphoma; 3 points were given for mod-

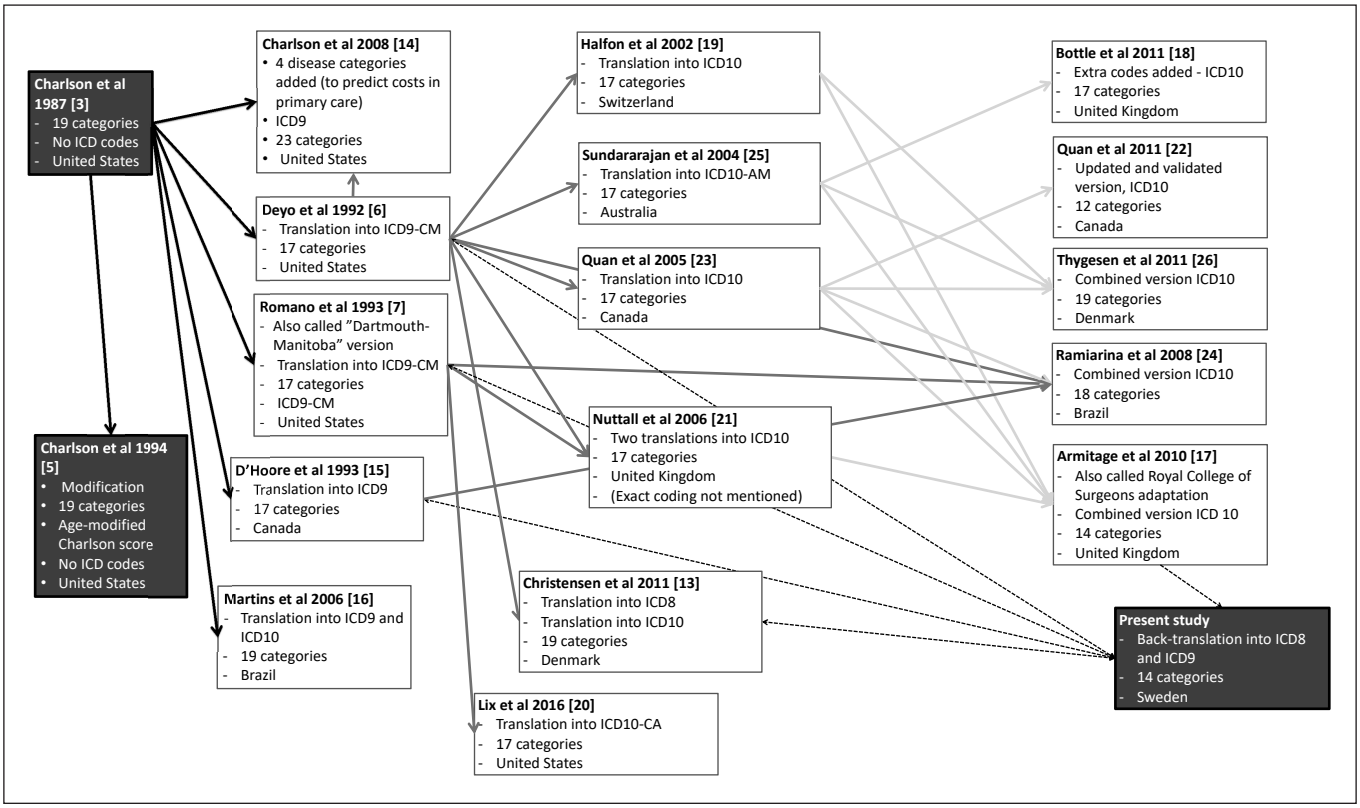

Figure 2 Schematic overview of the different adaptations and translations of the Charlson Comorbidity Index identified with the systematic literature search, and their relation, based on the International Classification of Diseases (ICD) 8th, 9th and 10th versions. ICD-CM = clinical modification; ICD-AM = Australian modification; ICD-CA = Canadian modification.

erate or severe liver disease; and 6 points were given following a diagnosis of metastatic solid malignant tumours or acquired immunodeficiency syndrome (AIDS). The sum of these 19 comorbidities equals the total Charlson Comorbidity Index.

3. Results

The search identified 16 studies presenting modified or adapted ICD-coding for the Charlson Comorbidity Index; 1 using ICD-8 coding [13], 5 using ICD-9 coding [6, 7, 14–16], and 12 using ICD-10 coding [13, 17–26]. The complex relation between the different versions is presented in ▶ Figures 2–3, with the 5 different versions of ICD-9 coding based directly on the original Charlson's index; and the ICD-10 versions based on 1–4 of these ICD-9 versions.

Both of the two best-known adaptations of the Charlson Comorbidity Index into ICD-9 codes reduced the number of comorbidities from 19 to 17, grouping lymphoma, leukaemia and any malignant tumour together as "any malignancy" [6, 7]. In general, the first version interpreted the Charlson categories more strictly [6], while the "Dartmouth-Manitoba" codes (i.e. developed in 2 universities in the United States and Canada) also included entities which were conceptually comparable – although not all codes of the first version were included [7]. One problem with the original index was that some included diagnoses that could be complications during the particular hospitalisation episode (e.g. myocardial infarction, acute stroke) instead of pre-existing comorbidities [17, 27]. Without medical records it cannot be discerned if these are complications or comorbid conditions; and these codes should therefore be excluded if the outcome of the current hospital episode is being evaluated [3, 7]. At least three other ICD-9 conversions have been published [14–16]. Yet, in particular the 2 above mentioned versions have been used and converted into ICD-10. Consequently, there are also several different ICD-10 Charlson Comorbidity scoring versions in use, using different ICD coding for each comorbidity [13, 17–26].

Recently, the Royal College of Surgeons summarised, re-evaluated and updated 5 different versions [19, 21, 23, 25] into a modified Charlson Index [17]. This version reduced the number of comorbidity categories from 17 into 14, removing the category of peptic ulcer disease (since it is not considered a chronic disease anymore), and grouping diseases together despite the severity level (which may be difficult to assess based on registry-based data). For example, diabetes mellitus codes with or without complications were grouped into one category. This version also eliminated procedure codes (because of variation between countries and coding systems), paediatric diagnostic codes (since the Charlson Index is designed for adults), and very rare entities. The codes were also simplified to reduce coding errors and improve generalisability; aiming towards an internationally-applicable and user-friendly tool to assess

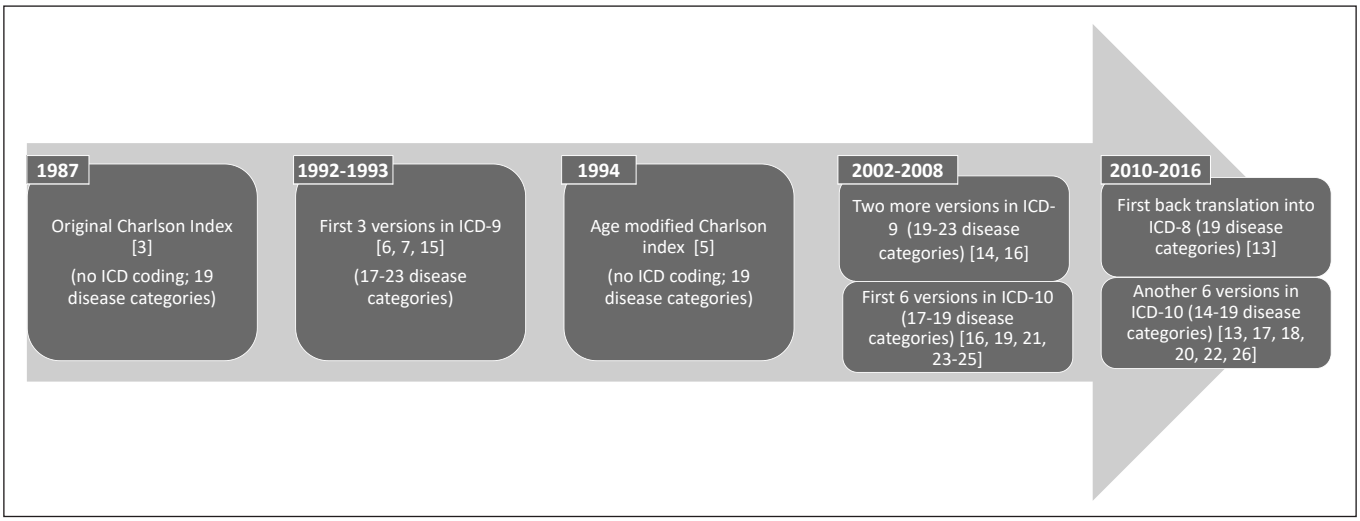

Figure 3 Time-line of time of publication of the different adaptations and translations of the Charlson Comorbidity Index identified with the systematic literature search, based on the different versions of the International Classification of Diseases (ICD).

comorbidity. This version also recommended to drop the weighting of comorbidities, and instead categorised the number of comorbidities into 0, 1, 2 or ≥3. The final ICD-10 codes suggested by the Royal College of Surgeons were back-translated into ICD-9 and ICD-8 versions, following the above mentioned rules of eligibility [17], and double checked with three ICD-9 versions [6, 15, 27], and one previously published ICD-8 version [13]. This resulted in the codes presented in ▶Table 1.

4. Discussion

Transparency and generalisability are crucial in epidemiological research, especially when administrative databases are used for research purposes. Even if comorbidities

Table 1 International Classification of Diseases (ICD) coding based on the Royal College of Surgeons' adaptation of the Charlson Comorbidity Index, back-translated from ICD-10 into ICD-9 and ICD-8.

	Comorbidity	ICD-10 (Armitage et al 2010)[17]	ICD-9 (back-translated)	ICD-8 (back-translated)
1	Myocardial infarction	I22-I23, I252	410, 412	410, 412
2	Congestive heart failure	I11, I13, I255, I42–43, I50, I517	402, 425, 428, 429	4270, 428
3	Peripheral vascular disease	I70–73, I770-I771, K551, K558–559, R02, Z958–959	440–447, 785E, V43D	440–445
4	Cerebrovascular disease	G45–46, I60–69	362C, 430–438	430–438
5	Dementia	A810, F00–03, F051, G30–31	290, 294	2900–2901
6	Chronic pulmonary disease	I26–27, J40-J47, J60–67, J684, J701, J703	416–416, 490–496, 500–505, 506D	490–493, 515–518
7	Rheumatic disease	M05–06, M09, M120, M315, M32-M36	710–714, 725	710–712, 734
8	Liver disease	B18, I85, I864, I982, K70–71, K721, K729, K76, R162, Z944	070, 456A-456C, 571–573	070, 4560, 571, 573
9	Diabetes mellitus	E10–14	250	250
10	Hemiplegia/paraplegia	G114, G81–83	342–344	344
11	Renal disease	I12–13, N01, N03, N05, N07, N08, N171, N172, N18, N19, N25, Z49, Z940, Z992	403–404, 580–586, 588, V420, V451	403–404, 580–583, 792
12	Malignancy	C00–26, C30–34, C37–41, C43, C45–58, C60–76, C80–85, C88, C90–97	140–172, 174–195, 200–208,	140–172, 174–194, 200–207
13	Metastatic tumours	C77–79	196–199	196–199
14	AIDS/HIV	B20–24	279K	-

AIDS, Acquired Immunodeficiency Syndrome; HIV, Human Immunodeficiency Virus.

are used as a confounder and not as main exposure, a consistent, transparent and easy-to-use scoring system should be used, based on clear and generally accepted definitions. Yet, it is clear that different versions of the Charlson comorbidity index are currently used in research, often without stating the exact coding or time-period used. Although disease specific versions of comorbidity scoring are gaining popularity, a general comorbidity score remains of use for example to compare different patient groups and pathologies in health-economic evaluations [28].

In (research) practice, we believe it is best to use as much information available as possible if measuring chronic comorbidities based on hospitalisation or out-patient records. Therefore, we recommend using older time-periods as well, even if the information is coded in older ICD-versions and therefore requires more work. This increases the validity of the comorbidity scoring, since if a patient had diabetes mellitus in 1965, the patient will still have it later in live (even if not recorded for later hospitalisation episodes). For power reasons, comorbidity is often scored in 2–3 categories (none, 1, more than 1) which is usually sufficient when incorporating comorbidity as a confounder – with an easy-to-use scoring system or a "one size fits all" approach. Yet, when assessing comorbidities as a main exposure, a more detailed assessment (more risk categories, specific comorbidities singled out) may be preferred. Yet in both scenarios, it has to be clearly specified which version of the scoring system is used and which time period is used to collect this information.

With this article we do not claim that the Charlson comorbidity index is the best scoring of comorbidity to be used in registry-based research, yet it is without doubt the most widely implemented. The original score has been developed based on a small cohort of medical patients and was validated in breast cancer patients [3]. Many of the validation and adaptation studies since have also been based on rather small and specific patient populations (e.g. only including surgical patients). There are other scoring systems such as the Elixhauser score, or diagnostic scores based on drug intake, of which some have been proven superior to the Charlson score [29, 30]. Yet, the Charlson score is still the most commonly used. To have transparency in research, stating that the Charlson score has been used is clearly insufficient because of the many versions. Evidently, the treatment and prognosis of several of the included comorbidities has changed dramatically over the last 30 years, not in the least considering the treatment of the human immunodeficiency virus (HIV), making the original 1987 version inappropriate to score comorbidity today.

Although especially developed for surgical patients, the version of the Charlson Index of the Royal College of Surgeons combines 5 different ICD-10 versions into 1 version, updates the Charlson scoring for contemporary use and simplifies the scoring to enable international use and improve user-friendliness. Therefore, this ICD-10 based version appears to be recommendable because of its' simplicity and recency, and has now been back-translated into ICD-9 and ICD-8 coding for use in Swedish administrative databases to quantify and assess comorbidity in earlier time-periods (and consequently improve ascertainment of comorbidity). If several ICD versions are available categorising the same information, the most recent version should be used [23].

It is however important to consider the limitations of the Charlson Comorbidity Index, which does not cover all diseases relevant in outcome research, in particular psychological/psychiatric morbidities and rare diseases. Another important limitation is that many versions of the Charlson score are based on incorrectly assigned weights, including the original score of Charlson et al [31, 32]. In short, an additive scale such as the Charlson Index should be based on additive weights (regression coefficients) and not on risk ratios (multiplicative scale), which may over- or underestimate the risk of each comorbidity [31]. There have been attempts to re-analyse the weighting of the comorbidity, which show that some diseases should have a higher weight (incl. dementia), and others a lower weight (incl. rheumatological disease, and peptic ulcers – which are removed from the Royal College of Surgeons version) [33]. Using an equal-weight system as in the version of the Royal College of Surgeons (categorising comorbidities into 0, 1, 2 or ≥3 comorbidities) makes the score easy-to-use since all comorbidities are considered equally important. Yet, the effect of diseases such as metastatic cancer, AIDS and moderate liver disease will be underestimated – especially if individuals will be categorised into the group with 1 comorbidity. Therefore, this version of the Charlson index may be not ideal to investigate the impact of comorbidity on the outcome in all populations, especially if comorbidity is the main exposure of interest. Therefore, it remains important to consider alternative scorings, depending on the study question, available data and study population [4].

To conclude, many versions of the Charlson Index are currently in use, defining comorbidities based on different ICD coding. When assessing comorbidity in epidemiological studies based on administrative data, it is essential to report which version of a comorbidity scoring is used, including a clear description of used ICD version and comorbidity codes.

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