Article

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Charlson index scores from administrative data and case-note review compared favourably in a renal disease cohort

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Abstract

Background:

The Charlson index is a widely used measure of comorbidity. The objective was to compare Charlson index scores calculated using administrative data to those calculated using case-note review in relation to all-cause mortality and initiation of renal replacement therapy in a Scottish chronic kidney disease cohort (GLOMMS-1).

Methods:

Modified Charlson index scores were calculated using both data sources in the GLOMMS-1 cohort. Agreement between scores was assessed using the weighted Kappa. The association with outcomes was assessed using Poisson regression and the performance of each was compared using net reclassification improvement.

Results:

Of 3,382 individuals, median age 78.5 years, 56% female, there was moderate agreement between scores derived from the two data sources (weighted kappa 0.41). Both scores were associated with mortality independent of a number of confounding factors. Administrative data Charlson scores were more strongly associated with death than case-note review scores using net reclassification improvement. Neither score was associated with commencing renal replacement therapy.

Conclusion:

Despite only moderate agreement, modified Charlson index scores from both data sources were associated with mortality. Neither was associated with commencing renal replacement therapy. Administrative data compared favourably and may be superior to case-note review when used in the Charlson index to predict mortality.

Key words: Administrative data, Case-mix, Chronic Disease, Comorbidity

Introduction

Comorbidity, the burden of disease co-existing with a particular disease of interest, is having an increasing impact ~~upon our health services~~ as our population ages and the prevalence of chronic disease increases.[1,2] It affects the course and outcome of disease ~~or illness~~, is costly to health and social care services and is an important confounding factor as well as being predictive of outcomes.[1,3-7] Consequently, accurately adjusting for its impact is an important aspect of health services research as well as providing information for the assessment for case-mix and supporting individual patient care planning including prognosis.[8]

The Charlson comorbidity index is a widely used measure of comorbidity developed over 20 years ago to predict one-year mortality in a cohort of medical inpatients.[9] Since then it has been used in many populations with a variety of outcomes.[4,10-17] An overall score is calculated from a list of conditions, each of which has been allocated a weight of between one and six based upon its adjusted relative risk of one-year mortality.[9]

The Charlson index was originally developed using case-note review (CNR) data, often considered the gold-standard method of assessing comorbidity.[4] However, it is resource intensive and consequently the index has been adapted for use with routine administrative datasets.[18,19] Despite this, there remains uncertainty about the appropriateness of its application to administrative data. Previous studies comparing the methodological approaches have produced conflicting results, which may be related to the heterogeneous populations studied and also to their relatively small sample sizes.[5,13,20-25] The majority of studies have assessed populations of less than 1,000[5,21,23-25] and the largest study was 1,989 cardiovascular patients in Canada.[20]

The Grampian Laboratory Outcomes Mortality and Morbidity Study (GLOMMS-1) cohort is a sample of over 3,000 individuals with impaired renal function and provides a valuable opportunity to compare ~~case-note review~~CNR and administrative data Charlson scores in a large population. The aim of this study was to compare Charlson scores calculated using administrative data to those calculated using ~~case-note review~~CNR data and explore the impact of these methods on the association with all-cause mortality and initiation of renal replacement therapy (RRT).

Method

Setting and study population

In 2003, a study was set up to explore outcomes in adults aged over 15 years with abnormal renal function (serum creatinine ≥150µmol/l for males and ≥130µmol/l for females) resident in the National Health Service (NHS) Grampian administrative region in the North-East of Scotland. NHS Grampian is one of 14 regional Health Boards in Scotland and provides medical services to a defined population (n= 433, 109 aged over 15 in 2003).

Chronic Kidney Disease (CKD) is commonly classified in five stages based upon evidence of kidney damage and the glomerular filtration rate. Increasing stage indicates increasing severity.[26] The GLOMMS-1 cohort, used in this study, included only those who met the definition of CKD based upon an estimated glomerular filtration rate of less than 60ml/min/1.73m^2 for 90 days. The long term outcomes are described elsewhere.[27] Patients not meeting the definition of CKD and those on RRT at index date (the date of the first qualifying raised creatinine measurement during the period 1st January to 30th June 2003) were excluded.

The GLOMMS-1 cohort contained 3,426 individuals aged over 15 with stage three to five CKD ~~sourced from 433,109 individuals aged over 15 within the~~living in NHS Grampian ~~administrative region~~ in 2003. After excluding 12 patients who died on the index date, and 32 patients who could not be linked to their administrative data, the study population available for analysis from baseline was 3,382. The cohort was followed-up for six years. Of the survivors, only 51 had no contact with NHS Grampian within one year of the end of the study.

Available variables

Data on baseline comorbid conditions, smoking status and postcodes (allowing identification of the Scottish Index of Multiple Deprivation status of individuals) were extracted by ~~case-note review~~CNR in 2003. The presence of protein in the urine is a sign of kidney injury. Baseline proteinuria status was based upon the ~~single~~ ~~most recent~~latest measurement of protein in the urine from 1999 to index date.[26]

~~The GLOMMS-1 cohort was linked to NHS Grampian hospital episode data through deterministic matching using the Community Health Index number (a unique patient identifier used throughout the Scottish healthcare system). Scottish hospital administrative data are held centrally by the Information Services Division, and coded using the World Health Organization's International Classification of Disease version 10 (ICD-10) tool. General acute inpatient and day case episodes are held in the form of Scottish Morbidity Record (SMR) 01 administrative data.~~

The GLOMMS-1 cohort was linked to three datasets through deterministic matching using the Community Health Index number (a unique patient identifier used throughout the Scottish healthcare system) in order to ascertain ~~administrative data~~ comorbidity information, RRT status and mortality status. These datasets were the local renal management system, the NHS Grampian-held National Records of Scotland data and the NHS Grampian-held Scottish Morbidity Record (SMR) 01 administrative data. The National Records of Scotland provide mortality data. SMR01 is an episode-based patient record relating to all hospital general acute inpatient and day case stays. Diagnoses are recorded on

discharge using the World Health Organization's International Classification of Disease version 10 (ICD-10) tool.

~~The SMR01 administrative data included conditions coded as a primary diagnosis or as an additional diagnosis on discharge.~~

Charlson comorbidity index

~~Case-note review~~CNR and data linkage were carried out for the purpose of another study and not with the primary intention of calculating the Charlson index. Therefore due to limitations in the data available a modified Charlson index was used (Table 1). Scores were calculated from both ~~case-note review~~CNR and administrative data. For pragmatic reasons, a five-year restriction on the look-back period of administrative data was applied (based upon findings of a previous study)[28] whilst there was no restriction for the ~~case-note review~~CNR. As renal disease was the condition of interest in this cohort it was not included as is the widely adopted convention when calculating the Charlson index.[5,29-32]

Statistical Analysis

The primary outcome of interest was all-cause mortality at six years. Secondary outcomes ~~of interest~~ were all-cause mortality at one and five years and the initiation of RRT.

The baseline characteristics were summarised. Agreement between Charlson categories derived from the two data sources was assessed by the weighted Kappa with sub-group

analysis by gender, age group and CKD stage. The individual patient differences between Charlson scores from the two data sources were calculated.

Poisson regression modelling was used to assess the association between Charlson scores and each outcome as the data did not meet the assumptions of proportional hazards for Cox regression. Models were unadjusted, partially adjusted (for age, sex, CKD stage at index and baseline proteinuria status) and fully adjusted (for these factors plus deprivation and smoking status). A Charlson score of 0 was the reference group. Results were presented as incidence rate ratios (IRRs) with 95% confidence intervals (CIs) for each Charlson index category.

Net reclassification improvement (NRI) compared the data sources for predicting all-cause mortality and initiation of RRT. Significance was set at the 5% level. Tables were produced which cross-tabulated the two data sources on the basis of low, medium and high risk categories of Charlson score (scores of 0, 1 to 3 and 4 and over respectively). The Tables were produced separately for those with and without an event (e.g. those who died and those who did not die). NRI compares how the two data sources classify individuals (on the basis that a good model will class individuals who suffer an event as high risk and those who do not suffer the event as low risk). The reclassification of risk by one data source compared to another (e.g. lower risk class in those who do not suffer an event) is quantified to allow assessment as to which data source is superior at classifying risk of the outcome.[33]

~~NRI compares two models using reclassification tables with different risk categories. In this study the models were the two different data sources and the risk categories were Charlson . Tables are produced separately for those with and without an event and the NRI process~~

~~then quantifies the correct movement within risk categories (which should be upwards for those with events and downwards for those with non-events). For both events and non-events, the proportion where reclassification worsened using one model compared to the other is subtracted from the proportion where reclassification improved using the same comparison. The total NRI is derived from the difference between these two figures and gives an indication as to which model is superior at classifying the individuals according to the risk of the outcome.~~[33]

All analyses were performed using Stata version 12.1 and Excel. Ethical approval for GLOMMS-1 and the comparison of comorbidity data sources has been given by the University of Aberdeen Research Ethics Committee and the NHS Grampian Caldicott Guardian.

Results

Baseline data are available in supplementary Tables 1 to 3. The median age was 78.5 years, 55.9% were female and 66.8% had stage three CKD. The highest Charlson score from both data sources was eight. Both sources classified most individuals as having Charlson scores of 2 or less. The majority of patients (72.9%) had administrative data scores within plus or minus one point of their ~~case-note review~~CNR data scores. ~~Case-note review~~CNR scores were generally higher than administrative data scores.

There was moderate agreement between the two data sources for the whole cohort (weighted Kappa 0.41) (supplementary Table 4). Agreement decreased in the older age groups from 0.58 in 15-54 year olds to ~~0.37 in 75-84 year olds and~~ 0.38 in the 85 years and over group. Additional analysis (supplementary Table 5) showed the same pattern when smaller age categories were used. Agreement for CKD stage five was higher than for stages three and four (0.58 compared to 0.41 and 0.40 respectively). Additional analysis (supplementary Table 6) demonstrated that more of those with CKD stage five were older (76 out of the 90 individuals were aged 55 or over).

By one year 22.1% had died and by six years 61.2% had died and 5.0% had started RRT (Table 2). Survival curves for six-year mortality by Charlson index scores derived from each data source showed a consistent pattern of lower survival with higher Charlson scores from both data sources (Figure 1).

Poisson regression results are reported in Table 2 (partially adjusted models are available in supplementary Table 7 and five-year mortality is available in supplementary Table 8). In the unadjusted model for six-year mortality, the IRRs from ~~case-note review~~CNR data increased

from 1.76 (~~95% CI~~ 1.52-2.04) for a Charlson score of 1 to 3.51 (2.89-4.26) for a score of 5 and over. The IRRs from administrative data in the same model increased from 1.67 (1.48-1.88) for a score of 1 to 3.94 (3.20-4.87) for a score of 5 and over. This pattern of higher IRRs with higher Charlson scores was also observed for one-year mortality and five-year mortality and this trend was unchanged within the partially and fully adjusted models ~~for all mortality outcomes~~. The IRRs generated from the two data sources were of similar magnitude to each other in all models.

The IRRs for initiating RRT were less than one for Charlson scores above 0. In the unadjusted model, these IRRs were statistically significantly reduced for all ~~case-note review~~CNR Charlson index subgroups and for some administrative data subgroups. Adjusted models demonstrated no statistically significant association with RRT (Table 2).

NRI is reported in Table 3 (five-year mortality available in supplementary Table ~~8~~9). For all mortality outcomes, the administrative data models were significantly better at classifying the risk of death than the CNR models. For six-year mortality for example, the use of administrative data yielded an overall NRI of 0.053 (95% CI 0.024-0.082). This was statistically significant with a positive z score (2.4), $p<0.05$. For RRT the administrative data model was marginally better at classifying RRT risk than the CNR model, but this was not statistically significant ($z= 1.0$, $p=0.3$).

Discussion

Interpretation of findings

There was moderate agreement between the data sources. Administrative data scores were generally lower than ~~case-note review~~CNR scores, consistent with the findings of a number of other studies.[4,5,20] ~~and a systematic review.~~ Previous work using the GLOMMS-1 cohort by Soo et al examined agreement between individual comorbidities, finding at least moderate agreement for most and that the prevalence of all comorbidities was higher based on CNR compared with administrative data.[34] Our findings may relate to the restriction of the administrative data look-back period to five years, whilst there was no restriction on the look-back period for ~~case-note review~~CNR. ~~This is a limitation but is an approach similar to that taken by others.~~

Agreement was better for younger age groups and those with more severe CKD, however these groups contained small numbers. ~~Age did not appear to affect the association as more of those with stage five CKD at the index date were older.~~ Soo et al found the prevalence of the majority of Charlson comorbidity conditions to be higher in those aged over 75.[34] Better agreement in younger individuals may therefore reflect that coders had less conditions to code for on hospital discharge and so are more likely to capture all relevant conditions.

The association of the Charlson index with mortality is unsurprising given ~~that~~ the Charlson index was originally developed to predict mortality~~.~~[9] and ~~The Charlson index~~ has also been found to predict mortality in a number of renal studies.[14-17] However, ~~it is surprising that administrative data classified the risk of death better than case-note review data, particularly given the restriction in look-back period for administrative data. T~~to the best of

our knowledge, no previous studies have reported administrative data to be superior to ~~case-note review~~CNR when calculating the Charlson index. Previous studies ~~of other disease conditions and in other countries~~ have found either little difference ~~between the two data sources for predicting mortality outcomes~~,[5,13,22,35] or that ~~Charlson scores derived from case-note review~~CNR scores were superior to ~~those derived from~~ administrative data scores.[21,32] However~~,~~, we cannot be certain of the impact of our use of a modified version of the Charlson. Additionally, ~~it~~ it should be highlighted that the IRRs generated during Poisson regression from the two data sources were of similar magnitude. Therefore in this context the results from NRI should not be over-interpreted.

One explanation for our finding that administrative data are at least comparable to ~~case-note review~~CNR data, ~~if not superior,~~ could be that health conditions which lead to admission are more favourably identified by administrative data. These active conditions may be more severe and more likely to lead to death. ~~Case-note review data may detect more conditions but, as the Charlson index does not assess disease severity, these may be conditions at a level not severe enough to impact upon mortality. As described below, the issue could also be due to the manner in which case-note review data were collected with the potential for measurement bias due to two different individuals recording the data.~~

The unadjusted (but not the adjusted) results suggested that ~~having any~~ comorbidity decreased the likelihood of receiving RRT. However, an explanation for this is that those with a high burden of comorbid disease may not survive to initiate RRT or may choose a more conservative management course. A reason why the adjusted results were not significant is that the models were adjusted for CKD stage and proteinuria, both of which are

associated with the instigation of RRT.[27] In addition the number of individuals receiving RRT was small and confidence intervals wide.

Strengths and limitations

Our study has a number of important strengths. The Charlson is a commonly used comorbidity index which~~, despite having been developed in a different population,~~ has been extensively used in many different populations including renal populations.[14-17] As well as being the largest study of its kind in a chronic disease population, only one previous study has compared Charlson scores derived from the two data sources using a renal population and this was a small population (n=134) of dialysis patients with the outcome of mortality.[25]

CKD is a chronic condition with high associated comorbidity and mortality, which thus places a substantial burden on both individuals and the healthcare system.[26] Our findings in relation to patients with CKD may well therefore apply to other chronic conditions. As the cohort was identified from electronic laboratory records, there was a low risk of participation bias. ~~The large study allowed for the identification of statistically significant differences and potentially wider generalizability.~~ A number of important potential confounding factors were included within the regression models. ~~The partially adjusted model showed the impact of factors previously shown to be important predictors of outcome in CKD,[27] whilst the fully adjusted model included factors which may be of wider interest to practitioners and researchers. Despite this however, there was little difference between the partially and fully adjusted models.~~

Our study used NRI to assess model performance. This has an advantage compared to the previously widely used approach of area under the receiver operating-characteristic curve. This latter approach requires very strong associations of the variable of interest with the outcome in order to produce a statistically significant area under the curve. This is not an issue for NRI.[33] NRI is a relatively new technique which has been widely used since it was proposed. However, there is still debate regarding its use and care needs to be taken when describing and interpreting NRI.[36] We have described our methodology and also presented component parts of the NRI as proportions and percentages to aid interpretation.

Our study has some important limitations. As the ~~case-note review~~CNR data for the GLOMMS-1 study were not originally collected ~~for the primary purpose of calculating~~for the Charlson index ~~scores~~, some Charlson conditions were not available ~~for inclusion~~ and we ~~therefore~~ calculated a modified Charlson index score. Furthermore, the ICD-10 codes used within the administrative data did not identically match the recommended ICD-10 codes detailed in ICD-10 adaptations of the Charlson index.[37] Some of the higher scoring Charlson conditions were not included ("Metastatic solid tumour" and "Acquired Immunodeficiency Syndrome (AIDS)". However, it is not likely that this has altered our findings significantly. These conditions have a fairly low prevalence in previous renal studies, even when Human Immunodeficiency Virus (HIV) is used instead of AIDS (between 0.5% and 1.6% for "metastatic solid tumour" and between 0.0% and 0.4% for "AIDS/HIV").[15,38] In addition the prevalence of HIV amongst the Grampian population is very low (501 HIV reports in NHS Grampian between 1990 and 2011).[39] Nonetheless, whilst our findings provide important

support for the use of administrative data in comorbidity scores, it is important to be aware we have used a modification of the Charlson comorbidity score.

Despite this limitation, as ~~T~~the same index was used for both data sources, ~~so while the strength of association with outcomes might be affected (although the results suggest it worked well)~~it would not affect the aim of the study which was to compare the data sources.

Original Charlson weights do not necessarily adequately represent the risk of the outcomes in this study, however, as described earlier, the original Charlson weights have been used widely since it was created and have been shown to be applicable in many different populations and for a range of outcomes.[4,10-17]

The ~~case-note review~~CNR data were not double data extracted, although a third individual did check a sample of both data extractions. ~~As described earlier, t~~There was a restriction on the look-back period for the administrative data but not for the ~~case-note review~~CNR data. However, although this could be seen as disadvantaging administrative data, it still performed well despite this indicating the restricted look-back period ~~(carried out for pragmatic reasons)~~ was reasonable.

The administrative data request timescale was based upon a study which found that shorter look-back periods (of around one year) were sufficient for modelling post-hospitalisation mortality but that looking back five years improved modelling for readmission outcomes.[28] However, future research could clarify the optimal look-back timescale for hospital administrative data, particularly for non-mortality outcomes which are generally less commonly studied.

Conclusion

The use of administrative data within patient care is becoming more prominent with the development of electronic patient records. Comorbidity measurement can be used to inform tools which can identify patients at high risk of hospital readmissions and mortality. This can enable the targeting of care which can reduce costs and burden to the individual and the health care system. Accurate comorbidity adjustment is also important with the increasing emphasis upon comparing the outcomes of hospitals and units using league tables.[40] Another use is in research, for example to adjust for the confounding effect of comorbidity.

This study demonstrated that, whilst agreement between modified Charlson index scores derived from ~~case-note review~~CNR and routine hospital administrative data may only be fair to moderate, administrative data are at least comparable if not superior when used to predict mortality outcomes. The modified Charlson index was not associated with the risk of commencing RRT. This research indicates the feasibility of using routinely collected data with a commonly used comorbidity index and is therefore an important contribution to comorbidity research.

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Conflicts of interest

All authors report no conflicts of interest

Key points

- Administrative data compared favourably and may be superior to case-note review when used in a modified Charlson comorbidity index to predict mortality in those with chronic kidney disease.
- Neither data source was associated with commencing renal replacement therapy.
- Accurately assessing comorbidity is a key public health consideration due to increasing emphasis upon adjusting for comorbidity when comparing healthcare institutions and upon identifying and managing high risk individuals.
- This work concludes it is reasonable to use administrative data rather than carrying out the more resource intensive process of case-note review when assessing comorbidity.

Table 1: Comparison of original Charlson index to modified Charlson index used in this study

Original Charlson comorbidity index		**Modified Charlson comorbidity index** [a]	
Comorbid condition	**Weight**	**Comorbid condition**	**Weight**
Myocardial infarct	1	Ischemic heart disease [b]	1
Congestive heart failure	1	Congestive heart failure	1
Peripheral vascular disease	1	Peripheral vascular disease	1
Cerebrovascular disease	1	Cerebrovascular disease	1
Dementia	1	Dementia	1
Chronic pulmonary disease	1	Chronic obstructive pulmonary disease [c]	1
Mild liver disease	1	Chronic Liver Disease [d]	1
Connective tissue disease	1	Connective tissue disease	1
Diabetes with end-organ damage	2	Diabetes	2
Any tumour	2	Non-haematological malignancy	2
Leukaemia	2	Haematological malignancy [e]	2
Lymphoma	2		
Diabetes without chronic complication	1	Not scored	
Moderate/severe renal disease	2	Not scored	
Moderate/severe liver disease	3	Not scored	
Ulcer disease	1	Not available	
Hemiplegia	2	Not available	
Metastatic solid tumour	6	Not available	
AIDS	6	Not available	

Abbreviations: AIDS, Acquired immunodeficiency syndrome

[a] Most of the case-note review data were sourced from events occurring prior to the index date, as per convention when calculating Charlson index scores. The exception was ischemic heart disease. Therefore the administrative data were made comparable to this.

[b] It was not possible to separate out myocardial infarction from other forms of ischemic heart disease in the case-note review. The administrative data were made comparable

[c] Only chronic obstructive pulmonary disease was available from case-note review. The administrative data were made comparable

[d] Only one option for liver disease was available from the case-note review. A cautious approach was taken and it was assigned a score of 1.

[e] Leukaemia and lymphoma are not available individually from the case-note review and instead all forms of haematological malignancy were combined. The administrative data were made comparable.

Table 2: Outcomes by Charlson index score and unadjusted and fully adjusted models for each outcome

		Numbers				Unadjusted		Fully adjusted [b]	
		CNR data		SMR01		CNR data	SMR data	CNR data	SMR data
	CCI Score	No event n (%)	Event n (%)	No event n (%)	Event n (%)	IRR (95% CI)	IRR (95% CI)	IRR (95% CI)	IRR (95% CI)
Six year mortality	**0**	430 (57.5)	318 (42.5)	695 (52.3)	635 (47.7)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
	1	286 (38.9)	449 (61.1)	240 (35.2)	442 (64.8)	1.76 (1.53-2.04)	1.67 (1.48-1.88)	1.43 (1.24-1.65)	1.47 (1.30-1.66)
	2	306 (35.6)	554 (64.4)	220 (32.1)	466 (67.9)	1.94 (1.70-2.23)	1.85 (1.64-2.08)	1.84 (1.60-2.12)	1.73 (1.53-1.95)
	3	177 (31.9)	378 (68.1)	109 (29.0)	267 (71.0)	2.20 (1.89-2.55)	2.02 (1.75-2.33)	2.13 (1.83-2.48)	1.93 (1.66-2.23)
	4	82 (26.8)	224 (73.2)	36 (18.4)	160 (81.6)	2.56 (2.16-3.03)	2.83 (2.38-3.36)	2.48 (2.08-2.96)	2.77 (2.31-3.31)
	5+	30 (16.9	148 (83.1)	11 (9.8)	101 (90.)2	3.51 (2.89-4.26)	3.94 (3.20-4.87)	2.86 (2.34-3.50)	3.72 (2.99-4.63)
	Total	1311 (38.8)	2071 (61.2)	1311 (38.8)	2071 (61.2)				
One year mortality	**0**	673 (90.0)	75 (10.0)	1175 (88.3)	155 (11.7)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
	1	582 (79.2)	153 (20.8)	522 (76.5)	160 (23.5)	2.25 (1.71-2.97)	2.16 (1.73-2.70)	1.94 (1.46-2.57)	1.86 (1.49-2.33)
	2	653 (75.9)	207 (24.1)	504 (73.5)	182 (26.5)	2.58 (1.98-3.36)	2.53 (2.04-3.13)	2.55 (1.94-3.34)	2.42 (1.95-3.01)
	3	404 (72.8)	151 (27.2)	259 (68.9)	117 (31.1)	2.97 (2.25-3.91)	3.03 (2.38-3.85)	3.12 (2.34-4.15)	3.16 (2.47-4.04)
	4	217 (70.9)	89 (29.1)	116 (59.2)	80 (40.8)	3.31 (2.43-4.50)	4.13 (3.15-5.41)	3.58 (2.60-4.93)	4.51 (3.41-5.96)
	5+	106 (59.6)	72 (40.4)	59 (52.7)	53 (47.3)	4.87 (3.52-6.73)	4.99 (3.65-6.81)	4.66 (3.32-6.53)	5.01 (3.62-6.95)
	Total	2635 (77.9)	747 (22.1)	2635 (77.9)	747 (22.1)				

Commencing RRT	**0**	682 (91.2)	66 (8.8)	1238 (93.1)	92 (6.9)	1.00 (reference)	1.00 (reference)	1.00 (reference)	1.00 (reference)
	1	713 (97.0)	22 (3.0)	662 (97.1)	20 (2.9)	0.34 (0.21-0.56)	0.43 (0.27-0.70)	0.92 (0.54-1.58)	0.63 (0.39-1.05)
	2	820 (95.3)	40 4.7)	654 (95.3)	32 (4.7)	0.54 (0.36-0.80)	0.69 (0.46-1.03)	0.89 (0.58-1.35)	0.76 (0.50-1.15)
	3	532 (95.9	23 (4.1	362 (96.3	14 (3.7	0.48 (0.30-0.77)	0.55 (0.31-0.97)	0.92 (0.54-1.55)	0.80 (0.45-1.44)
	4	292 (95.4)	14 (4.6)	191 (97.4)	5 (2.6)	0.53 (0.30-0.95)	0.38 (0.16-0.94)	1.11 (0.59-2.08)	0.45 (0.18-1.13)
	5+	173 (97.2)	5 (2.8)	105 (93.8)	7 (6.3)	0.33 (0.13-0.82)	0.95 (0.44-2.05)	0.74 (0.28-1.94)	0.94 (0.42-2.08)
	Total	3212 (95.0)	170 (5.0)	3212 (95.0)	170 (5.0)				

Abbreviations: CCI, Charlson comorbidity index; CNR, Case-note review; SMR01, Scottish Morbidity Record 01; IRR, incidence rate ratio; CI, Confidence Interval

a. Partially adjusted for age, sex, CKD stage at index and baseline proteinuria status

b. Fully adjusted for age, sex, CKD stage at index, baseline proteinuria status, the Scottish Index of Multiple Deprivation and smoking status

Table 3: Net reclassification improvement for each outcome by Charlson index score risk categories [a]

	6 year mortality				1 year mortality				RRT			
	SMR01 score				SMR01 score				SMR01 score			
CNR Score	0	1 to 3	4+	Total	0	1 to 3	4+	Total	0	1 to 3	4+	Total
Died					**Died**				**Yes**			
0	**215**	101	2		**36**	37	2		**58**	8	0	
1 to 3	377	**900**	104		105	**355**	51		29	**52**	4	
4+	43	174	**155**		14	67	**80**		5	6	**8**	
Total				2071				747				170
Total proportion where classification improved using SMR				207/2071 (10.0%)				90/747 (12.0%)				12/170 (7.1%)
Total proportion where classification worsened using SMR				594/2071 (28.7%)				186/747 (24.9%)				40/170 (23.5%)
Net gain in reclassification proportion for event				-0.187 (18.7%)				-0.129 (12.9%)				-0.164 (16.4%)
Alive					**Alive**				**No**			
0	**368**	62	0		**547**	126	0		**525**	155	2	
1 to 3	311	**440**	18		583	**985**	71		659	**1288**	118	
4+	16	67	**29**		45	174	**104**		54	235	**176**	
Total				1311				2635				3212
Total proportion where classification improved using SMR				394/1311 (30.1%)				802/2635 (30.4%)				948/3212 (29.5%)
Total proportion where classification worsened using SMR				80/1311 (6.1%)				197/2635 (7.5%)				275/3212 (8.6%)
Net gain in reclassification proportion for no event				0.24 (24.0%)				0.229 (22.9%)				0.209 (20.9%)

Total net reclassification improvement (95% CI)	0.053 (0.024,0.082)	0.102 (0.072,0.130)	0.045 (-0.020,0.095)
Z -Total	2.4	4	1
2-tailed P *	0.01	<0.0001	0.31

[a] Correct reclassifications are shaded in light grey and incorrect reclassifications are shaded in dark grey.

Abbreviations: CNR, Case-note review; SMR01, Scottish Morbidity Record 01.

* P-value <0.05.

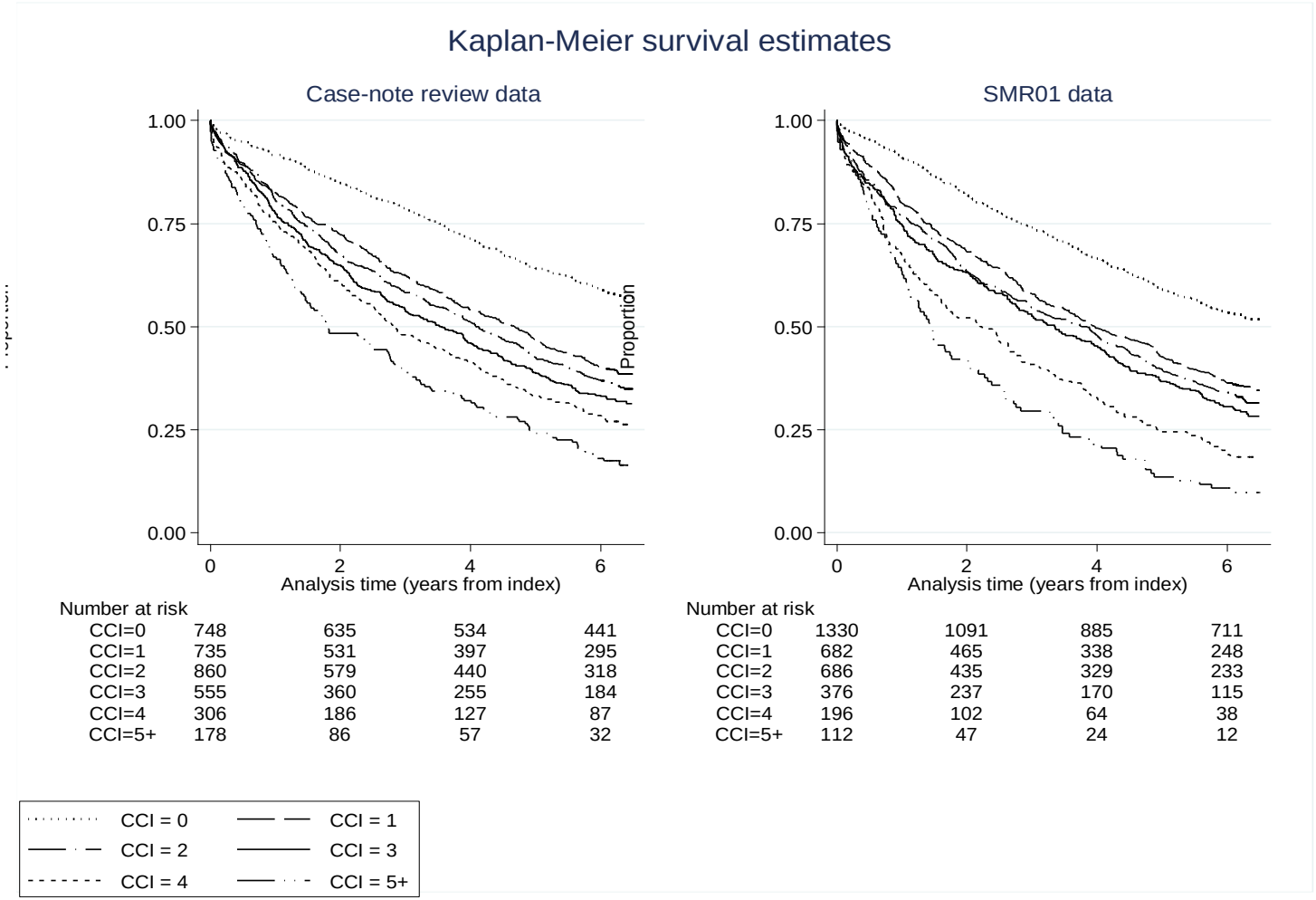

Figure 1: Kaplan Meier survival estimates for 6 year mortality by Charlson comorbidity index scores derived from case-note review and administrative data

Abbreviations: CCI, Charlson comorbidity index; SMR01, Scottish Morbidity Record 01.

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