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Prediction of Mortality in Patients Undergoing Maintenance Hemodialysis by Charlson Comorbidity Index Using ICD-10 Database

Je-Wook Chae[a] Chang Seok Song[a] Hyang Kim[a] Kyu-Beck Lee[a]
Byeong-Sung Seo[b] Dong-Il Kim[b]

[a]Division of Nephrology, and [b]Department of Occupational Medicine, Kangbuk Samsung Hospital, School of Medicine Sungkyunkwan University, Seoul, Korea

Key Words
Comorbidity · ICD-10 · Mortality · Hemodialysis

Abstract
Background/Aims: Many patients with end-stage renal disease have additional comorbidities that are important to clinical study and impact the patient's outcome. The Charlson Comorbidity Index (CCI) is a popular tool and a strong predictor of outcome in end-stage renal disease patients. We obtained comorbidity data from the hospital discharge database using the International Classification of Disease, 10th revision (ICD-10) and analyzed the mortality rate in incident patients undergoing maintenance hemodialysis (HD). ***Methods:*** We evaluated the medical records of a total of 456 patients on HD (58 ± 14 years of age, 56% males). We calculated CCI scores at the start of HD with information from the hospital discharge summary according to the ICD-10 code. We then analyzed patient mortality according to these CCI scores. ***Results:*** The percentages of patients that had diabetes with end-organ damage (51.1%), congestive heart failure (9.9%), coronary artery disease (8.1%) and stroke (6.8%) were identified. CCI scores were 5.09 ± 2.01 (range 2–11). Four comorbidity groups were established by quartile ranking of the CCI scores: low, moderate, high and very high. The mortality rates were: 0.83, 7.70, 14.09 and 18.69 deaths/100 patient-years, respectively (p = 0.001). Compared with the low comorbidity group, the hazard ratios for mortality were 9.22 (95% CI 3.29–25.84) for the moderate group, 16.77 (95% CI 5.97–47.11) for the high group, and 22.37 (95% CI 8.08–61.93) for the very high group. ***Conclusions:*** The CCI scores using the ICD-10 database information were significant predictors of mortality in incident patients undergoing maintenance HD.

Introduction

Although there have been many improvements in the management of patients on dialysis, the mortality rates of end-stage renal disease (ESRD) is still high [1, 2]. In addition to renal disease, the presence of comorbid conditions can explain the high mortality of patients on dialysis. Recently, in addition to the more advanced age at the start of maintenance dialysis, diabetes mellitus and cardiovascular diseases have been on the increase in the ESRD population [1, 2]. In ESRD, a comorbid illness may sometimes have a greater effect on the indi-

J.-W.C. and C.S.S. contributed equally to this paper.

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Kyu-Beck Lee, MD
Division of Nephrology, Kangbuk Samsung Hospital
108 Pyung-dong, Jongno-gu, Seoul 110-746 (Korea)
Tel. +82 2 2001 2449, Fax +82 2 2001 1596
E-Mail kyubeck.lee@samsung.com

Table 1. CCI scoring system using ICD-10 data

Score[1]	Comorbid conditions	ICD-10 code
1	Coronary artery disease	I20–I25
	Congestive heart failure	I11, I50
	Peripheral vascular disease	I73, I74, I77
	Cerebrovascular disease	G45, G46, I60–I69
	Dementia	F00–F03, G30
	Chronic pulmonary disease	J40–J47, J60–J66
	Connective tissue disorder	M05–M08, M30–M36
	Peptic ulcer disease	K25–K28
	Mild liver disease	B18, K70, K73, K75
	Diabetes without complications	E10–E14 (0.9)
2	Diabetes with end-organ damage	E10–E14 (0.0–0.8)
	Hemiplegia	G81–G82
	Moderate or severe renal disease	all patients
	Tumor without metastases (<5 years) leukemia, lymphoma, multiple myeloma	C00–C76, C81–C96
3	Moderate or severe liver disease (cirrhosis)	K72, K74, I85
6	Metastatic solid tumor	C77–C80
	AIDS	B20–B24

[1] Age factor: for each decade ≥50 years of age, 1 point was added to the comorbidity score.

vidual patient's outcome than renal disease. Comorbidity is not only a major confounder in clinical studies, but also a predictor of the patient's natural course and outcomes. Therefore, the assessment of comorbidity is essential to patient's outcomes and clinical studies [3–5]. However, there are many controversies in the methods currently used to quantify comorbidity in patients on dialysis.

The Charlson Comorbidity Index (CCI) was developed to predict the 1-year outcome of patient mortality using comorbidity data obtained from the hospital chart review [6–8]. The CCI has been a useful tool for clinician to measure the comorbid status and has commonly been used for the risk adjustment in clinical researches in many chronic diseases. The CCI has also been reported to predict clinical outcomes of ESRD patients [9–11]. Medical record reviews are usually used to calculate the CCI score, but this method is time-consuming and must be performed by trained clinicians. The International Classification of Diseases, 10th revision (ICD-10), which classifies diseases systematically by the World Health Organization, has been used to collect statistical data on diseases, injuries, and causes of death worldwide. We hypothesized that the ICD-10 database would provide a simple method to diagnose and characterize comorbidities associated with ESRD. We obtained comorbidity data from the hospital discharge database using ICD-10 and analyzed the mortality rates by using CCI scores.

Materials and Methods

Study Population

We initially reviewed data for 822 patients on hemodialysis (HD) who started their treatment at Kangbuk Samsung Hospital between 1998 and 2007. Out of the 822 patients, we excluded: 201 patients with acute kidney injury who had required HD, 55 patients who died within 3 months after they started HD, 79 patients who were treated with HD temporarily before maintenance peritoneal dialysis, 22 patients who had been treated with peritoneal dialysis before HD, and 9 patients who transferred to kidney transplantation. Therefore, a total of 456 patients undergoing maintenance HD were included in this study.

Methods

Information on comorbid illnesses were obtained from the ICD-10-based hospital discharge database at the start of HD. In our medical system, the duty resident doctor summarizes the inpatient's history, laboratory finding and special studies when the patient is discharged from the hospital, and records the patient's diagnosis and disease record according to the ICD-10. All of the admission medical records are reviewed and revised by qualified medical record administrators. This information is sent to the National Health Service, and used for billing and administrative purposes. In this study, we converted these ICD-10 data to CCI scores using the ICD-10 cording algorithm that was modified from other studies [12, 13] (table 1). The comorbidity criteria were considered from CHOICE [14], HEMO [15], and the DOPPS study [16]. Comorbid conditions were based on the original 19 Charlson comorbidities at the start of HD. New comorbidities that developed after the start of HD were not included. The CCI was scored at the start of HD using the definitions of Charlson et al. [17].

We divided the patients into four CCI groups by quartile ranking: low, moderate, high, and very high. We obtained mortality data from our hospital charts, telephone contacts and the Korea National Statistical Office. Patients were observed until death or the end of the study (December 2007). PASW Statistics 17.0 was used for statistical analyses. Kaplan-Meier survival analyses were used to generate the survival curve. Mortality was compared among comorbidity groups by log-rank sum test. We used the Cox regression model and showed the hazard ratio.

Results

We enrolled the 456 patients on HD in this study. The mean age was 58 ± 14 years and diabetes was the leading cause of ESRD. The main features of the study population

are shown in table 2. Diabetes with complications (51.1%) was the most common comorbidity. Congestive heart failure (9.9%), coronary artery disease (8.1%), cerebrovascular accidents (6.8%) and mild liver diseases (5.9%) were common comorbidities. Other comorbidities made up less than 5% in our study (table 3).

Four comorbidity groups were established by quartile ranking: low (2, 3), moderate (4, 5), high (6) and very high (7–11) comorbid. The mortality rates for each comorbidity quartile were 0.83, 7.70, 14.09 and 18.69 deaths/100 patient-years, respectively (table 4). Compared with the low comorbidity group, the hazard ratios for mortality were 9.22 (95% CI 3.29–25.84) for the moderate group, 16.77 (95% CI 5.97–47.11) for the high group, and 22.37 (95% CI 8.08–61.93) for the very high group. For each score, as the CCI score increased, the mortality also increased (fig. 1). Figure 2 shows the Kaplan-Meier survival curves according to the CCI quartile. CCI using the ICD-10 database predicted mortality. We re-examined the CCI scores excluding age and diabetes, because age factor and diabetes had a great impact on the CCI score. The results were very similar to the unadjusted scores (fig. 1, 2; tables 4, 5).

Table 2. Patient characteristics of 456 incident patients on HD

Age, years	58 ± 14 (range 19–91)
Male:female (male %)	257:199 (56%)
Diabetes, %	250 (55%)
CCI	5.09 ± 2.01 (range 2–11)
Time on HD	
Months	41 ± 3 (range 3–119)
Years	3.4 ± 2.5 (range 0.3–9.9)
Mortality rate	8.68/100 patient-years

Table 3. CCI and prevalence of comorbidities among 456 incident patients on HD using ICD-10 data

Score	Comorbidity variable	Patients (%) with condition
1	Coronary artery disease	37 (8.1)
	Congestive heart failure	45 (9.9)
	Peripheral vascular disease	7 (1.5)
	Cerebral vascular accident	31 (6.8)
	Dementia	1 (0.2)
	Pulmonary disease	10 (2.2)
	Connective tissue disorder	2 (0.4)
	Peptic ulcer	13 (2.9)
	Mild liver disease (hepatitis)	27 (5.9)
	Diabetes without complications	17 (3.7)
2	Diabetes with complications	233 (51.1)
	Paraplegia	1 (0.2)
	Renal disease	456 (100)
	Any tumor, leukemia, lymphoma	20 (4.4)
3	Severe liver disease (cirrhosis)	6 (1.3)
6	Metastatic cancer	2 (0.4)
	AIDS	0

Discussion

Comorbidities may influence treatment decisions, medical costs, data analysis and patients' outcomes. There are several inherent difficulties in measuring the impact of comorbid illness. First, the comorbidity criteria used by diverse researchers are not uniform. Second, the full examination of comorbidity is time-consuming and relevant studies are often expensive. Third, comorbidity data are generally abstracted from patient history, but taking a history is difficult especially in elderly patient. Therefore, some medical records are insufficient or inaccurate. Nevertheless, it is essential to measure comorbidity in patient's care and clinical studies in ESRD patients.

Although the Khan index [4], Davies index [18], and Index of Coexistent Diseases (ICED) [14, 15] have been used to evaluate comorbidity in ESRD, the CCI score is the most extensively studied comorbidity index in many chronic diseases including ESRD [6–8]. Traditionally, medical record review is thought to provide detailed and accurate documentation of comorbidities, but such a review takes a long time and requires trained clinicians to calculate the CCI scores. The ICD-10 classifies diseases systematically and was inaugurated in WHO Member States in 1994. The ICD is the international standard diagnostic classification for general epidemiological health management purposes and clinical use. In many studies, applications of the CCI are frequently based on coding of comorbidities according to the ICD-9. In this study, we designed a simple method to generate CCI scores using ICD-10 data. This method was quicker and simpler than traditional methods. Recently, ICD-10 data has been adapted in patients with myocardial infarction [19] and other diseases [20]. Although clinicians worry about the accuracy of information, new attempts to measure comorbidity by a patient's self-report are under study [21, 22].

In our study, diabetes with complications (51.1%), congestive heart failure (9.9%), coronary artery disease (8.1%), cerebrovascular accident (6.8%) and mild liver

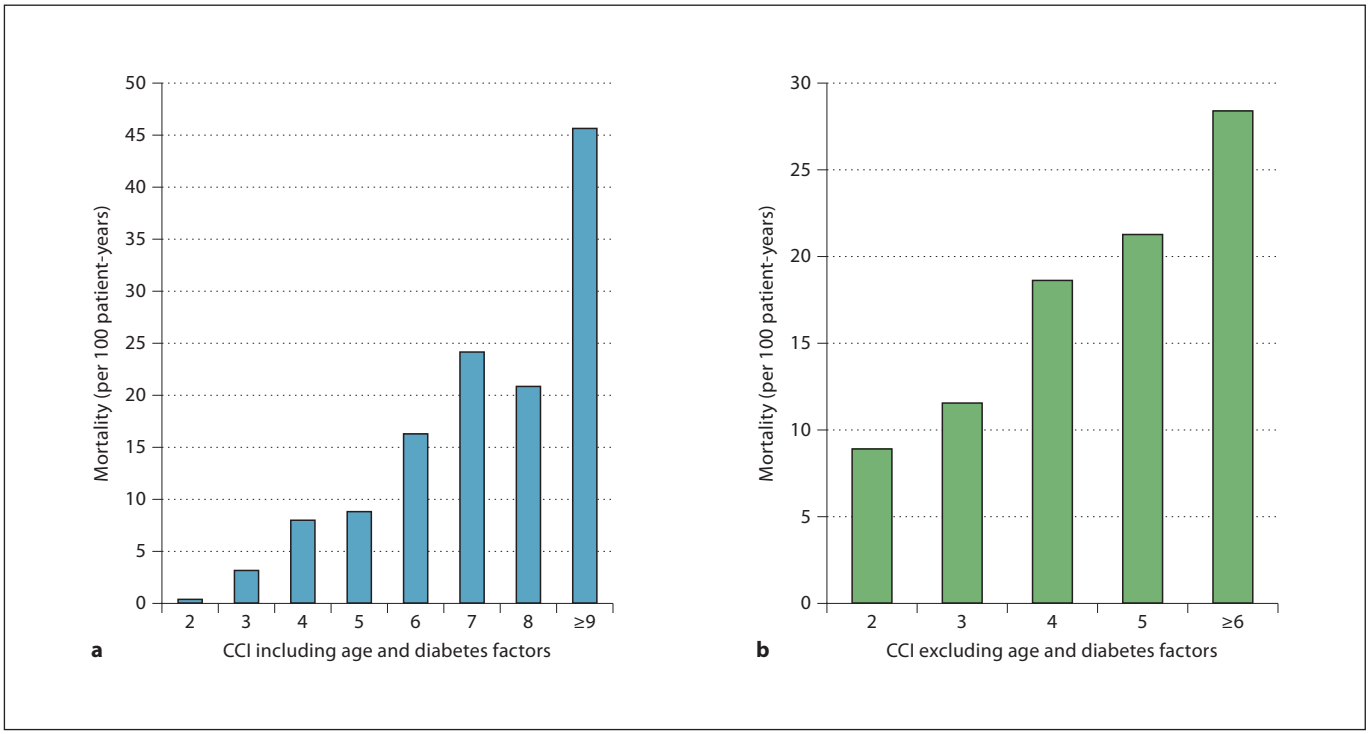

Fig. 1. Mortality in 456 incident patients on HD by each CCI including (**a**) and excluding (**b**) age and diabetes factors.

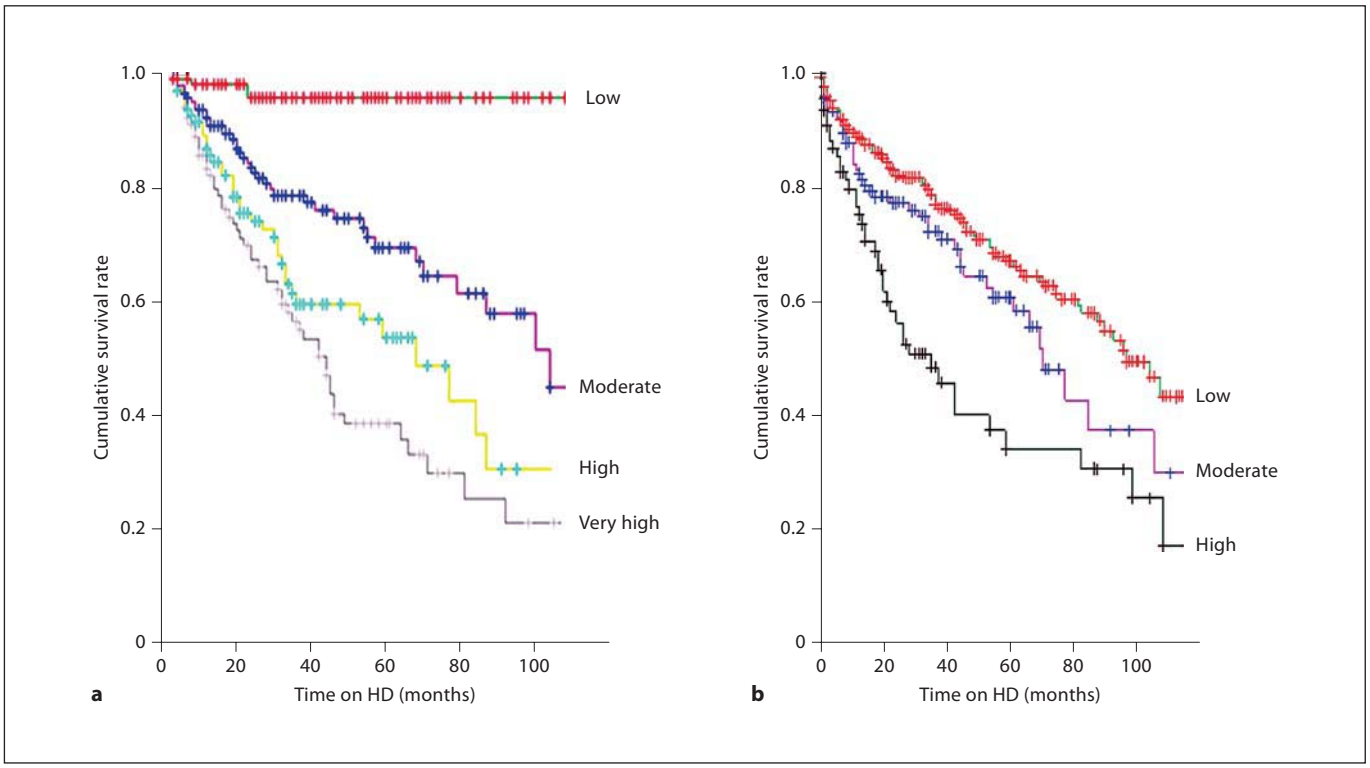

Fig. 2. Kaplan-Meier survival curves according to CCI groups including (**a**) and excluding (**b**) age and diabetes factors.

Table 4. Outcomes by scores on the CCI scoring system using ICD-10 including and excluding age and diabetes factors

CCI including age and diabetes factors	Low (2, 3)	Moderate (4, 5)	High (6)	Very high (7–11)
No	106	147	96	107
Follow-up, dialysis-years	483.5	506.2	269.8	283.6
Age, years	42 ± 10	56 ± 10	66 ± 7	70 ± 8
Diabetes, %	1 (1%)	89 (61%)	70 (73%)	90 (84%)
Mortality per 100 patient-years	0.83*	7.70*	14.09*	18.69*
CCI excluding age and diabetes factors	**Low (2)**	**Moderate (3)**	**High (4–8)**	
No	299	101	56	
Follow-up, dialysis-years	1,013.8	358.2	171.1	
Age, years	57 ± 15	59 ± 15	66 ± 10	
Diabetes, %	165 (53%)	57 (56%)	28 (50%)	
Mortality per 100 patient-years	7.21**	10.32**	15.03**	

log-rank sum test: * p = 0.001 and ** p = 0.009.

Table 5. Relationship between the CCI and mortality based on the Cox proportional hazards model

CCI group (score)	Not at risk	Events	Hazard ratio	95% CI	p
CCI including age and diabetes factors					
Low (2)	106	4 (3.8%)	1.00	ref.	
Moderate (4, 5)	147	39 (26.5%)	9.22	3.29–25.84	<0.0001
High (6)	96	38 (39.6%)	16.77	5.97–47.11	<0.0001
Very high (7–11)	107	53 (49.5%)	22.37	8.08–61.93	<0.0001
CCI excluding age and diabetes factors					
Low (2)	299	73 (24.4%)	1.00	ref.	
Moderate (3)	101	37 (36.6%)	1.39	1.01–2.05	<0.045
High (4–8)	56	24 (42.9%)	1.98	1.25–3.14	<0.004

diseases (5.9%) were common comorbidities. The frequency of diabetes with complications was higher than observed in other studies, while other comorbidities were lower [14–16]. These differences may be explained by geographical and biological variation. DOPPS documented variability in comorbid conditions and mortality across Europe, Japan and the USA [16]. Another explanation is that we evaluated admission charts at incipient dialysis and mainly examined the symptomatic disease. Therefore, asymptomatic comorbidities may have been underestimated. Needham et al. [23] reported that in comparison to chart review, ICD data generally underestimated the incidence of individual comorbidities, especially for asymptomatic diseases. In the CHOICE study [14], comorbid conditions were significantly underreported on Form 2728 (medical evidence report form), but diagnoses were not falsely attributed to ESRD patients. These studies suggest that comorbidities obtained from ICD codes or medical forms are probably underestimated, but reflect diagnosis patterns among ESRD patients correctly.

Our results demonstrate that CCI using the ICD-10 database accurately predicted mortality. Age and diabetes were major contributors to the CCI score in our study. We also calculated modified CCI scores by excluding age, diabetes or both. However, even after modifying these factors, the higher mortality rates were associated with higher CCI scores. We believe that calculation of CCI scores using ICD-10 database information is a simple and

effective method for predicting mortality in incident patients undergoing maintenance HD. It should be possible to calculate CCI scores automatically using computerized coding algorithms, and such information would be useful to clinicians.

There are limitations to this study. First, we retrospectively collected data in a single center during a 10-year period. Second, there were instances of obscurity in diagnosis criteria and the examination method. Third, while calculating CCI scores, other important prognostic factors in ESRD such as depression, psychological problems, and bone diseases were not included. Future studies should survey a greater number of comorbid diseases and formulate a standard method to measure comorbidity in ESRD. Large multicenter, even nation-wide, studies of comorbidity in patients with ESRD are therefore also warranted. In conclusion, the CCI scores calculating using information obtained from a hospital discharged abstract database following the ICD-10 were successfully used to predict the mortality.

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