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Original Investigation

Association Between Kidney Function, Rehabilitation Outcome, and Survival in Older Patients Discharged From Inpatient Rehabilitation

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Background: Chronic kidney disease (CKD) is common in older people, but it is unclear if it affects survival and rehabilitation outcomes independent of comorbid conditions and physical function in this population.

Study Design: Cohort analysis of prospective, routinely collected, linked clinical data sets.

Setting & Participants: Patients discharged from a single inpatient geriatric rehabilitation center over a 12-year period.

Predictors: Admission estimated glomerular filtration rate (eGFR) category as a predictor of improvement in the 20-point Barthel score (activities of daily living measure) during rehabilitation; discharge eGFR category and Barthel score as predictors of survival postdischarge.

Outcomes: Survival postdischarge was modeled using Cox regression analyses, unadjusted and adjusted for age, sex, morbidities (ischemic heart disease, chronic obstructive pulmonary disease, stroke, diabetes, and heart failure), Barthel score and eGFR category on discharge, and serum calcium, hemoglobin, and albumin levels. The effect of admission eGFR category on change in Barthel score during admission was modeled using analysis of covariance, adjusted for admission, Barthel score, and comorbid conditions.

Results: 3,012 patients were included; mean age, 84 years. 2,394 patients died during a mean follow-up of 8.3 years. Compared with patients with eGFR of 60 to 89 mL/min/1.73 m^2, adjusted HRs for death were 1.26 (95% CI, 1.13-1.40), 1.45 (95% CI, 1.29-1.63), and 1.68 (95% CI, 1.42-1.99) for eGFR categories of 45 to 59, 30 to 44, and <30 mL/min/1.73 m^2, respectively. The relationship between discharge Barthel score and survival was similar within each discharge eGFR category (HRs of 0.95, 0.93, 0.92, 0.95, and 0.90 per Barthel score point within eGFR categories of ≥ 90, 60-89, 45-59, 30-44, and <30 mL/min/1.73 m^2; *P* for interaction = 0.2). Similar improvements in Barthel score between admission and discharge were seen for each admission eGFR category.

Limitations: Single-center study using routinely collected clinical data.

Conclusions: eGFR category and Barthel score are independent risk markers for survival in older rehabilitation patients, but advanced CKD does not preclude successful rehabilitation.

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INDEX WORDS: Chronic kidney disease (CKD); reduced renal function; older adults; oldest old; geriatric; Barthel score; activities of daily living (ADLs); mortality; physical function; functional impairment; frailty; rehabilitation.

Chronic kidney disease (CKD) increases in prevalence with advancing age. Between 31% and 45% of people older than 70 years have CKD stage 3a (estimated glomerular filtration rate [eGFR] of 45-59 mL/min/1.73 m^2) or worse.[1,2] This decreased kidney function is associated with increased all-cause and cardiovascular mortality even in people older than 75 years.[3] Although impaired physical function appears to be a risk marker for mortality in younger patients with CKD,[4] it is less clear in older patients whether decreased kidney function and impaired physical function are independent risk markers for mortality or whether low GFR merely reflects frailty or impaired physical function, themselves both powerful markers for mortality in older people.[5] Clarifying this issue is important, first in deciding whether labeling very old patients as having CKD serves a useful purpose, and second in considering whether intervening to ameliorate declines in kidney function in the oldest old is likely to translate into clinically relevant benefits. This is of particular importance given that chronic kidney failure is a comparatively less common mode of death in older patients with CKD.[3]

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Poor physical function and decreased exercise capacity have been found to exist in patients with CKD, and recent studies suggest that patients with CKD are more likely both to be frail[4] and to undergo more rapid decline in physical function.[6] This close relationship between CKD and physical function suggests that incorporating measures of physical function into analyses of outcome for older patients with CKD thus is important. It also raises the question of how the presence of CKD affects the ability of older people to rehabilitate following illness.

We therefore undertook an analysis to examine the effect of CKD on mortality in very old patients, accounting for the effect of physical function. We also aimed to examine the effect of CKD stage on the ability of older people to successfully rehabilitate after illness.

METHODS

Study Population

The study cohort was derived from a group of older patients who underwent inpatient rehabilitation over a 12-year period (January 1999 through December 2011) in the Dundee Medicine for the Elderly service; details of the service and a subset of the cohort have been published previously.[7] Patients were transferred to the rehabilitation unit after recovery from acute illness including stroke, fractures, and general medical or general surgical illness. Data for routinely collected rehabilitation outcomes for the cohort include the 20-point Barthel score (a measure of activities of daily living [ADLs])[8] at admission and discharge. These data were linked to data held by the University of Dundee Health Informatics Centre (HIC) on a range of other routinely collected health care measures.[9] Information for biochemistry and hematology results, hospitalization data, and diagnoses (Scottish Morbidity Record [SMR] 01) coded using *International Classification of Diseases, Tenth Revision* (*ICD-10*) codes were accessible in the linked data set. Dates of death, derived from the Scottish Government Records Office, which records all deaths registered within Scotland, were also held by HIC in the linked data set. For this analysis, data from the first admission to the rehabilitation service were used. Analyses of improvement in rehabilitation were confined to those who had an admission and discharge Barthel score recorded; survival analyses were confined to those alive at discharge from rehabilitation who had a discharge Barthel score recorded. A flow chart depicting the derivation of the analysis cohort is given in Fig 1. Data Protection Office (Caldicott Guardian) approval was obtained prior to data linkage and analysis, but the need for institutional review board approval was waived in view of the routinely collected nature of the data.

Exposure and Outcome Measures and Covariates

Time to death was calculated as the time between the date of discharge from rehabilitation facility to the date of death as recorded in Scottish General Records Office death records. The Barthel score was recorded as part of routine care by the multidisciplinary rehabilitation team. As a measure of basic ADLs, the Barthel score records what a person is capable of doing across 10 activities: walking, transfers, feeding, bathing, grooming, dressing, bowel function, bladder function, toilet use, and stair use[8] (score range, 0-20; 20 = highest level of independence). It is widely used as a measure of basic ADLs in older people, and previous work in this cohort has shown that a 1-point difference between admission and discharge on the Barthel score relates to a 5% to 10% difference in mortality.[7]

All biochemical indexes were taken from routinely collected clinical data, held by HIC. All analyses were performed in a single laboratory (Biochemical Medicine, NHS Tayside). The measurement taken closest to the date of admission to rehabilitation was used in analyses of the effect of eGFR category on change in Barthel score during rehabilitation. For postdischarge survival analyses, the measurement taken closest to the date of discharge from rehabilitation was used. Creatinine was measured using a compensated rate-blanked method on a Roche multichannel analyzer; the methodology was traceable to isotope-dilution mass spectrometry. In February 2007, a new algorithm for creatinine calculation was introduced locally to align results with UK National External Quality Assessment Service (UK NEQAS) results. Results in our database prior to this point were corrected in our analyses using the equation: Creatinine = (old creatinine $\times$ 1.1358) $-$ 26. eGFR was derived from creatinine measures using the CKD-EPI (CKD Epidemiology Collaboration) creatinine equation.[10] Kidney function was then categorized on the basis of KDIGO (Kidney Disease: Improving Global Outcomes) GFR categories in CKD[11] ($\geq$90, 60-89, 45-59, 30-44, 15-29, and $<$15 mL/min/1.73 m^2). Data for proteinuria were not available and hence were not included in analyses. Only a small proportion of patients had phosphate or bicarbonate measurements performed because these analytes were not part of standard biochemistry panels; these analytes therefore are not included in the analyses. Specific morbidities (ischemic heart disease, stroke, heart failure, or chronic obstructive pulmonary disease) were coded from *ICD-10* codes on the basis of previous hospitalizations for myocardial infarction, stroke, and heart failure. Diabetes status (present or absent) was taken from linked data from the Scottish Care Information–Diabetes Collaboration database,[12] also held by HIC. Cancer diagnosis in the 5 years prior to rehabilitation admission was taken from the Scottish Cancer Registry (SMR06) records, held by HIC.

Data Analysis

Descriptive statistics were generated for each category of eGFR; values in each category were compared to the reference group (eGFR $\geq$ 90 mL/min/1.73 m^2) using analysis of variance (ANOVA) for continuous variables and either Pearson χ^2 or Fisher exact test for categorical variables. Two main analyses were undertaken. The first compared kidney function category with the improvement in Barthel score from admission to discharge. The group with eGFRs of 60 to 89 mL/min/1.73 m^2 was used as reference, and each category of kidney function was compared

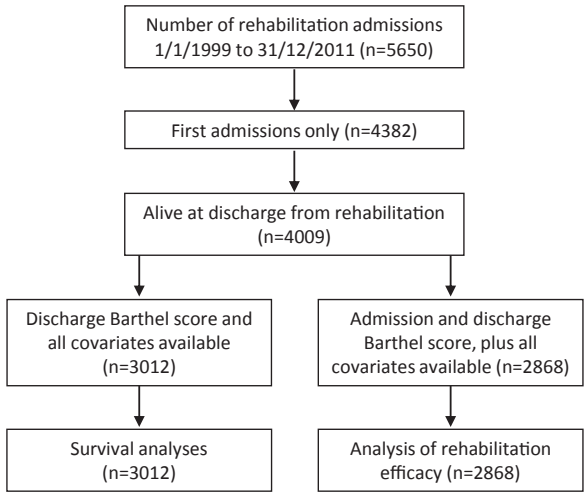

Figure 1. Flow chart shows selection of cohort for analysis.