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Original Investigation

Hospital-Acquired Acute Kidney Injury and Hospital Readmission: A Cohort Study

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Background: Hospital-acquired acute kidney injury (AKI) is associated with increased mortality and resource consumption. Little is known about the association of AKI with short-term hospital readmissions.

Study Design: Retrospective cohort study.

Setting & Participants: We investigated whether adult survivors of hospital-acquired AKI were at increased odds for early hospital readmission.

Predictor: The peak-to-nadir serum creatinine difference during the index hospitalization was used to define AKI according to the KDIGO (Kidney Disease: Improving Global Outcomes) classification and staging system.

Measurements: Multivariable logistic regression analyses examined the association of AKI with 30-, 60-, and 90-day hospital readmission, adjusting for age, sex, race, Charlson-Deyo comorbidity index score, acute hospital-related factors, common causes of hospitalization, and baseline estimated glomerular filtration rate.

Results: 3,345 (15%) of 22,001 included patients experienced AKI during the index hospitalization. Compared to the non-AKI group, the AKI group had a significantly higher 30-day hospital readmission rate (11% vs 15%; $P < 0.001$), which persisted at 60 and 90 days. The AKI group also was more likely to be readmitted to the hospital within 30 days for cardiovascular-related conditions, mainly heart failure ($P < 0.001$) and acute myocardial infarction ($P = 0.01$). AKI associated independently with higher odds of 30-day hospital readmission (OR, 1.21; 95% CI, 1.08-1.36), which persisted at 60 (OR, 1.15; 95% CI, 1.03-1.27) and 90 days (adjusted OR, 1.13; 95% CI, 1.02-1.25). Results were attenuated in a propensity score–matched cohort of 5,912 patients.

Limitations: Single-center study of mild forms of AKI; ascertainment bias and outcome misclassification due to the use of administrative codes.

Conclusions: Our results suggest that survivors of hospital-acquired AKI experience higher odds of early hospital readmission. Transitions of care services may be warranted for such patients to prevent readmissions and reduce health care costs.

INDEX WORDS: Acute kidney injury (AKI); acute renal failure (ARF); hospital-acquired; readmission; re-hospitalization; care transition.

Acute kidney injury (AKI) commonly is seen in the hospital setting and has important public health implications.[1] Mild to severe forms of AKI are associated with substantial morbidity, including increased short-term risk for in-hospital mortality and high resource consumption, mainly prolonged hospital length of stay, prolonged mechanical ventilation, and heightened need for postacute care.[2-5] Patients with severe forms of AKI requiring short-term dialysis particularly are at increased risk for the long-term development or acceleration of pre-existing chronic kidney disease, resulting in end-stage kidney failure and long-term dialysis therapy.[6] As a result, investigation of care transitions following episodes of hospital-acquired AKI is urgently required to help identify patients who are susceptible to these intermediate and long-term adverse outcomes and in greater need of interventions.[7,8]

In the United States, the federal government has deemed reductions in hospital readmissions as an opportunity for decreasing health care spending. In a landmark study, almost 20% of Medicare beneficiaries who had been discharged from a hospital were readmitted within 30 days,[9] accounting for an estimated $15 billion of health care–related spending.[10] Although older age, lower socioeconomic status, and the presence of comorbid conditions are important

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patient-related determinants of hospital readmissions, it is not known whether episodes of AKI associate with a higher likelihood of hospital readmission. To address this gap in knowledge, this study investigates whether hospital-acquired AKI in adults is associated with increased risk of hospital readmission during the first 90 days following discharge.

METHODS

Study Design and Data Source

We conducted a single-center retrospective cohort study of hospitalized adults using a data set that contained fully deidentified health records of patients discharged from a tertiary acute-care facility (St. Elizabeth's Medical Center, Boston, MA) over a 7-year period (October 1, 2000, through September 30, 2007). Discharge abstracts provided information for patient's age, sex, race, hospital service type (medical, surgical, and other), up to 15 *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnosis codes, procedural codes, hospital length of stay, hospital discharge status (alive or dead), and discharge disposition for those who survived (ie, discharged to home, a short- or long-term care facility, hospice, or against medical advice). Each discharge abstract was linked to the hospital's electronic laboratory database. Institutional review board approval (protocol no. HW138) was obtained.

Derivation of Study Cohorts

Two study cohorts were created for the purpose of our analyses: an unmatched cohort composed of patients with and without hospital-acquired AKI (primary cohort) and a propensity score–matched cohort at a ratio of 1:1 between patients with and without hospital-acquired AKI (secondary cohort, see Statistical Analysis section).

The source population consisted of all adults (aged ≥18 years) hospitalized for the first time during the study period at our acute-care facility (index hospitalization) and discharged alive. We excluded patients admitted to the addiction medicine service or those with missing service assignment, patients who died during the index hospitalization, patients who were discharged against medical advice or to hospice, and patients for whom we were unable to ascertain survival status at discharge. We also excluded patients with chronic kidney failure, using a previously published method,[11] and patients who did not have serum creatinine measured after the nadir value (see the following section). To avoid lead-time bias, we also excluded hospitalizations with a discharge date after July 28, 2007, which corresponded to 90 days prior to the end date of the follow-up period in our data set.

Prediction and Outcome Variables

Our primary predictor variable was the development of hospital-acquired AKI during the index hospitalization based on the KDIGO (Kidney Disease: Improving Global Outcomes) AKI classification and staging system,[12] using peak-to-nadir serum creatinine difference.[13] In brief, nadir serum creatinine was defined as the lowest value recorded in the first 3 days of the index hospitalization.[13] Peak serum creatinine was defined as the highest value recorded in up to the first 8 hospital days following the nadir value. The peak-to-nadir serum creatinine difference then was calculated to define AKI using an absolute 0.3-mg/dL or relative ≥50% increase in serum creatinine level or dialysis requirement.

Our main outcome variable was all-cause hospital readmission at 30, 60, and 90 days following discharge from the index hospitalization. While there is no consensus about what time frame should be used to define a hospital readmission, commonly used time frames have ranged from 7 up to 90 days following discharge from an initial hospitalization. We also examined cause-specific hospital readmissions.

Description of Covariates

The baseline covariates were age, sex, race, baseline estimated glomerular filtration rate (eGFR) derived from the nadir serum creatinine recorded during the index hospitalization using the CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration) creatinine equation,[14] Charlson-Deyo comorbidity index score,[15] and hospital discharge service (medical, surgical, or other). Additional covariates of interest recorded during the index hospitalization were sepsis, heart failure, cardiac catheterization, coronary artery bypass grafting (CABG), abdominal surgery, 4 common causes of hospitalization (acute myocardial infarction, heart failure, pneumonia, and chronic obstructive pulmonary disease [COPD], each included if listed among the first 3 diagnosis codes), and presence of acute organ system dysfunction other than the kidney, using a previously described method.[3,16]

Statistical Analysis

Continuous variables were described as mean ± standard deviation, and categorical variables, as count and percentage. Propensity score matching was used to reduce potential confounding and selection biases introduced by analyses based on the development of hospital-acquired AKI, a nonrandom event. The propensity score for each patient was calculated by modeling the probability of developing hospital-acquired AKI using multivariable logistic regression with the following set of covariates: age, sex, race, Charlson-Deyo comorbidity index score, hospital service, sepsis, heart failure, CABG, abdominal surgery, acute organ system dysfunction, baseline eGFR, hospital length of stay, and the 4 mentioned common causes of hospitalization. The calculated propensity scores were used to match patients who developed AKI in a 1:1 ratio with patients who did not develop AKI with a caliper width of less than 0.05 using the Greedy matching algorithm (gmatch SAS macro[17]). Matching was performed without replacement. Standardized differences were calculated to assess balance between groups.[18]

For analysis of the primary cohort, comparisons of characteristics between patients with and without AKI were conducted using χ^2 test for binary variables and *t* test for normally distributed continuous variables. A Kaplan-Meier survival curve was constructed for time to hospital readmission following discharge stratified according to the presence or absence of AKI. Log-rank test was used to test survival time differences between the 2 groups. Comparisons of hospital readmission rates between patients with and without AKI were conducted using McNemar test.

Multivariable logistic (for the primary cohort) and generalized estimating equation repeated-measures (to account for the matched-pairs design in the secondary cohort) regression analyses were performed to examine the association between the development of AKI during the index hospitalization and hospital readmission within 30, 60, and 90 days following discharge. The covariates used for analyses of the primary cohort were age, sex, race, baseline eGFR, Charlson-Deyo comorbidity index score, hospital service, length of stay, sepsis, heart failure, cardiac catheterization, CABG, abdominal surgery, acute organ system dysfunction, and the 4 common primary diagnoses. We tested for interactions between hospital-acquired AKI and hospital service, age, Charlson-Deyo comorbidity index score, baseline eGFR, or 1 of the 4 common causes of hospitalization, for the outcome of 30-day hospital readmission. Subgroup analyses were conducted to explore the robustness of the findings, including analyses by hospital service, age, Charlson-Deyo comorbidity index score, and baseline eGFR. A sensitivity analysis also was performed to examine the continuous association of the peak-to-nadir serum