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

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Abstract

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.

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Contributions: Research idea and study design: IK, BLJ; data acquisition: IK, BLJ; data analysis/interpretation: IK, LLP, NEM, BLJ; statistical analysis: LLP; supervision or mentorship: BLJ. Each author contributed important intellectual content during manuscript drafting or revision and accepts accountability for the overall work by ensuring that questions pertaining to the accuracy or integrity of any portion of the work are appropriately investigated and resolved. BLJ takes responsibility that this study has been reported honestly, accurately, and transparently; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned have been explained.

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SUPPLEMENTARY MATERIAL

Figure S1: Flow diagram of derivation of analytical dataset.

Note: The supplementary material accompanying this article (<http://dx.doi.org/10.1053/j.ajkd.2014.08.024>) is available at www.ajkd.org

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.

Keywords

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 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 $\pm$ 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 macro¹⁷). 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 creatinine difference with hospital readmission, using the same adjustment variables. Results of regression analyses are displayed as odds ratio (OR) with 95% confidence interval (CI).

All analyses were conducted using SAS, version 9.3 (SAS Institute Inc). The Kaplan-Meier survival plot was created using the R system software.¹⁹ All *P* values were 2 sided and considered to be statistically significant at the 0.05 level.

RESULTS

Analytical Data Set

During the 7-year period, there were 97,472 hospitalizations representing 51,207 patients. By limiting the data set to the first hospitalization per patient, 46,265 hospitalizations were excluded. Of the remaining 51,207 eligible index hospitalizations, after applying the exclusion criteria, 22,001 patients were included in the primary cohort (Fig S1, available as online supplementary material). Compared with patients included in the primary cohort, patients in the excluded cohort were significantly younger ($P < 0.001$) and more likely to be women (likely reflecting admissions to the obstetrical service; $P < 0.001$), had fewer comorbid conditions according to the Charlson-Deyo comorbidity index ($P < 0.001$), and were less likely to be hospitalized for acute myocardial infarction ($P < 0.001$), heart failure ($P < 0.001$), pneumonia ($P < 0.001$), or COPD ($P < 0.001$). They also were less likely to undergo cardiac catheterization or CABG ($P < 0.001$), but more likely to undergo abdominal surgery ($P < 0.001$; Table S1).

After applying propensity score matching, 2,956 pairs of patients were selected for the secondary cohort.

Characteristics of Study Cohorts

Table 1 lists characteristics of the 2 study cohorts, stratified according to the presence or absence of hospital-acquired AKI. In the primary cohort, hospital-acquired AKI developed in 3,345 (15.2%) patients, most of whom had AKI stage 1 (99.6%). Compared with patients without AKI, patients with AKI were significantly older ($P < 0.001$) and more likely to be men ($P < 0.001$); had a higher prevalence of comorbid conditions, as evidenced by a higher Charlson-Deyo comorbidity index score ($P < 0.001$), and lower baseline eGFR ($P < 0.001$); were more likely to be hospitalized on the surgical service ($P < 0.001$) and had a higher prevalence of sepsis ($P < 0.001$); and also were more likely to have a primary diagnosis of acute myocardial infarction ($P < 0.001$), heart failure ($P < 0.001$), and pneumonia ($P < 0.001$).

In the secondary cohort, standardized differences for all characteristics of the 2 groups were less than 0.1, except for baseline serum creatinine level (standardized difference, 0.16) and baseline eGFR category of <30 mL/min/1.73 m² (standardized difference, 0.14), 2 covariates that originally were not included in the matching algorithm (Table 1).

Association of AKI With Hospital Readmission

As shown in Fig 1A, in the primary cohort, compared with patients without AKI, patients with AKI had a significantly higher 30-day hospital readmission rate (11% vs 15%; $P < 0.001$), which persisted at 60 (15% vs 20%; $P < 0.001$) and 90 days (18% vs 23%; $P < 0.001$). Similarly, as shown in Fig 2, after stratification by the primary diagnosis of the index hospitalization, compared with patients without AKI, 30-day readmission rates were significantly higher among patients with hospital-acquired AKI who had a primary diagnosis of heart failure (15% vs 18%; $P = 0.02$), acute myocardial infarction (8% vs 13%; $P = 0.003$), pneumonia (13% vs 18%; $P = 0.04$), and COPD (15% vs 19%; $P = 0.02$).

In the propensity score-matched secondary cohort, patients with AKI also experienced a higher readmission rate across all 3 time frames, but statistical significance was reached only at 30 days (13% vs 15%; $P = 0.05$; Fig 1B).

Furthermore, compared with patients without AKI, patients with AKI who were readmitted within 30 days were more likely to be rehospitalized for cardiovascular-related conditions, mainly heart failure ($P < 0.001$) and acute myocardial infarction ($P = 0.01$; Fig 3).

In the primary cohort, Kaplan-Meier analysis revealed that during the first 90 days following discharge from the index hospitalization, patients who experienced an episode of hospital-acquired AKI had cumulative higher odds of hospital readmission compared with patients who did not experience AKI (Fig 4; $P < 0.001$).

Table 2 lists results of the logistic and generalized estimating equation regression analyses examining the association of AKI with hospital readmission in the 2 cohorts. In the primary cohort, after full adjustment for all selected covariates, hospital-acquired AKI was associated with increased odds for hospital readmission at 30 (adjusted OR, 1.21; 95% CI, 1.08–1.3), 60 (adjusted OR, 1.15; 95% CI, 1.03–1.27), and 90 (adjusted OR, 1.13; 95% CI, 1.02–1.25) days. In the secondary cohort, after propensity score matching, hospital-acquired AKI remained associated independently with increased odds for hospital readmission at 30 days (adjusted OR, 1.16; 95% CI, 1.00–1.34), but was not significant at 60 (adjusted OR, 1.11; 95% CI, 0.98–1.27) or 90 (adjusted OR, 1.08; 95% CI, 0.96–1.23) days.

In both cohorts, there was no significant interaction between any of the 4 common causes of hospitalization (ie, acute myocardial infarction, heart failure, pneumonia, or COPD) and hospital-acquired AKI for the outcome of 30-day hospital readmission ($P = 0.9$, $P = 0.8$, $P = 0.9$, and $P = 0.9$, respectively).

Subgroup and Sensitivity Analyses

Figure 5 displays subgroup analyses examining the association of AKI with hospital readmission. AKI was associated with a higher adjusted OR for 30-day hospital

readmission in index hospitalizations involving patients younger than 65 years (P for interaction = 0.005). However, in the fully adjusted models, there was no significant interaction between hospital-acquired AKI and hospital service ($P = 0.2$), comorbid conditions as defined by the Charlson-Deyo comorbidity index ($P = 0.2$), and baseline eGFR ($P = 0.6$) for 30-day hospital readmission.

In a sensitivity multivariable analysis aimed at examining the continuous association of the peak- to-nadir serum creatinine difference with hospital readmission in the primary cohort, we found the peak- to-nadir serum creatinine difference to be associated independently with hospital readmission at 30 ($P = 0.01$), 60 ($P = 0.06$) and 90 days ($P = 0.04$).

DISCUSSION

The present analysis of more than 20,000 adults who survived hospitalization at an acute-care facility reveals that development of a mild episode of AKI (ie, AKI stage 1, in accordance with the KDIGO AKI classification and staging system) has important short-term consequences and is a determinant of hospital readmissions. In the entire cohort, AKI during the index hospitalization was associated independently with higher readmission rates at 30, 60, and 90 days. Hospital-acquired AKI was associated with an adjusted OR of 1.21, 1.15, and 1.13 for hospital readmission at 30, 60, and 90 days, respectively. These findings also were observed in the more selected propensity score-matched cohort, with OR of 1.16 for hospital readmission at 30 days, although effect estimates were attenuated at 60 and 90 days. These associations were stronger in younger patients. The analyses also revealed an association between AKI during the index hospitalization and greater odds of rehospitalization within 30 days for cardiovascular-related conditions, mainly heart failure and acute myocardial infarction. Our study suggests that AKI might be an unrecognized determinant of short-term hospital readmission and calls for the systematic study of transitions of care among hospitalized patients who experience an episode of AKI, with the ultimate goal of preventing or decreasing unplanned rehospitalizations. Furthermore, the link we observed between hospital-acquired AKI and rehospitalization for cardiovascular-related conditions is concerning in light of a recent population-based study linking episodes of recovered de novo dialysis-requiring AKI to a long-term risk of coronary events.²⁰

In 2012, as part of implementation of the Accountable Care Act, the Centers for Medicare & Medicaid Services established a Hospital Readmissions Reduction Program, which requires the US federal government to decrease payments to acute-care hospitals with excess readmissions.²¹ This program was driven in part by a report from the US federal government that had identified reductions in hospital admissions and readmissions as an opportunity for reducing health care expenditures.¹⁰ The Hospital Readmissions Reduction Program has focused on reducing hospitalizations for ambulatory care-sensitive conditions (eg, acute myocardial infarction, heart failure, COPD, and pneumonia).²² As a result, health care organizations across the United States have focused on improving transitions of care following hospitalizations for these conditions, with emphasis on medication reconciliation, timely in-office follow-up visits with primary care physicians and specialists, and provision of home services, with an overall goal of reducing hospital readmissions.

Although older age, lower socioeconomic status, and presence of comorbid conditions are well-recognized predictors of hospital readmissions, the development of AKI during hospitalization might be an unrecognized, albeit important, care-related determinant of hospital readmissions. According to the US Renal Data System 2013 annual data report,²³ which uses administrative billing data, among Medicare beneficiaries 66 years and older who experienced a hospitalization associated with a diagnosis code for AKI, the probability of a recurrent hospitalization with AKI in the ensuing 12 months was 34%. The 30-day hospital readmission rate was 25% among patients with AKI compared to 17% among patients without AKI. Furthermore, following an initial AKI-associated hospitalization, 75% of patients saw a primary physician within 3 months of discharge, whereas only 13% saw a nephrologist. The use of administrative billing data to identify episodes of AKI in the hospital setting is subject to secular trends in coding practices. In recent years, hospitals across the United States have deployed clinical documentation improvement programs aimed at improving the accuracy of physician diagnoses and, as a result, coding and billing practices. This likely has resulted in increased use of administrative codes for AKI even in the setting of less severe episodes of AKI. Our analysis, which relied on a creatinine-based definition of AKI rather than the use of administrative codes for AKI, is in accordance with the data reported in the US Renal Data System annual data report, especially considering that closer to 100% of patients in our data set experienced mild AKI (stage 1). The development of AKI has been linked to an increased risk of hospital readmission in patients with heart failure²⁴ and following cardiac surgery.²⁵

Our study has several strengths. We analyzed a large, diverse, and unselected hospitalized adult population with an array of comorbid conditions. Our main finding in both the entire and propensity score-matched cohorts, as well as across all 3 time-frames of the outcome of interest, if externally validated, is of substantial importance because AKI already has been linked to increased use of health care services and expenditures directed to the need for postacute care.²⁻⁴ This analysis calls for the study of transitions of care following episodes of hospital-acquired AKI, a period of critical importance, which needs to be studied prospectively to identify patients in need of interventions to prevent hospital readmissions and reduce health care expenditures.

There also are several important limitations to consider. The study was conducted at a single acute-care facility; therefore, the generalizability of the findings may be narrowed. The identification of individual comorbid conditions using administrative codes is relatively crude and does not account for severity of the condition in question. The inability to incorporate the severity of these comorbid conditions might have led to some unmeasured confounding in the multivariable analyses of the entire cohort. However, we addressed this limitation, in part, by using the Charlson-Deyo comorbidity index, which is a well-validated instrument that summarizes the global burden of illness associated with each hospitalization and that we have used previously for other analyses.^{13,26} Furthermore, in the more restricted cohort, propensity score matching for a total of 16 covariates was used to reduce potential confounding and selection biases. Ascertainment of our primary outcome also has some drawbacks. There might have been outcome misclassification due to ascertainment bias of potential hospital readmissions to other acute-care facilities. However, the inability to capture these events would have biased our results toward the null hypothesis. By including

survivors of index hospitalizations, we studied primarily patients with mild forms of AKI (99.6% experiencing AKI stage 1) and excluded patients with AKI of higher stages of severity, which tend to be associated with higher in-hospital mortality. Furthermore, our definition of AKI may have underestimated AKI of higher stages of severity because it did not take into account the true baseline serum creatinine level, which may have been lower than the nadir value observed during the first 3 days of hospitalization, thus resulting in smaller peak-to-nadir serum creatinine differences. Alternatively, our hospital, which is not a trauma center, may witness milder stages of AKI, further limiting our observations. We also were unable to differentiate between scheduled and unscheduled hospital readmissions. There was lack of information for socio-economic status, which might have affected transitions of care services and hospital readmission risk. Other residual known and unknown confounders that were not accounted for in our analyses also might have affected our estimates.

In conclusion, this study provides support to the hypothesis that mild forms of hospital-acquired AKI portend increased odds of hospital readmissions within 30 days. Whether the relationship between hospital-acquired AKI and hospital readmission is causal or associative, AKI is a compelling risk factor for this unwarranted and costly outcome. If our findings are externally validated, the identification of mild episodes of hospital-acquired AKI should compel physicians to exercise heightened vigilance with a focus on timely follow-up of such patients in the ambulatory setting. In the meantime, studies of transitions of care are urgently needed to inform regarding how to incorporate strategies to prevent hospital readmissions among survivors of episodes of AKI and help reduce total health care expenditures.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

The 30-, 60-, and 90-day hospital readmission rates among patients with and without acute kidney injury (AKI) during the index hospitalization in the (A) primary (unmatched) cohort and (B) secondary (propensity score-matched) cohort. *P < 0.001; **P = 0.05 versus no AKI.

Figure 2.

The 30-day hospital readmission rate among patients with and without acute kidney injury (AKI) according to the primary diagnosis of the index hospitalization. The analysis pertains to the primary (unmatched) cohort. *P = 0.03; **P = 0.003; †P = 0.004; ‡P = 0.02 versus no AKI. Abbreviation: COPD, chronic obstructive pulmonary disease

Figure 3.

Distribution of 30-day rehospitalization primary diagnoses among patients with and without acute kidney injury (AKI) during the index hospitalization. The analysis pertains to the primary (unmatched) cohort. * $P < 0.001$; ** $P = 0.01$ versus no AKI. Abbreviation: COPD, chronic obstructive pulmonary disease.

Figure 4. Kaplan-Meier survival plot for time to hospital readmission among patients with (solid line) and without (dashed line) acute kidney injury (AKI) during the index hospitalization. The analysis pertains to the primary (unmatched) cohort and is censored at 90 days from time of hospital discharge. $P < 0.001$ by log-rank test

Hospital Service

Medical (n=17,013)

Surgical (n=3,030)

Other (n=1,229)

Age, years

<65 years (n=9,186)

≥65 years (n=12,086)

Charlson-Deyo comorbidity index

0-1 (n=15,241)

2-3 (n=4,729)

≥3 (n=1,302)

Baseline eGFR, mL/min/1.73 m²

≥60 (n=16,590)

30-59 (n=3,854)

<30 (n=828)

Figure 5.

Adjusted relationships between hospital-acquired acute kidney injury and 30-day hospital readmission in selected subgroups. The analysis pertains to the primary (unmatched) cohort. Abbreviations: CI, confidence interval; eGFR, estimated glomerular filtration rate.

Table 1.

Characteristics of Primary and Secondary Cohorts

	Primary (Unmatched) Cohort			Secondary (Propensity Score2Matched) Cohort		
	No AKI (n = 18,656)	AKI ^a (n = 3,345)	P	No AKI (n = 2,956)	AKI ^a (n = 2,956)	Standardized Difference
Age (y)	63.3 ± 19.1	70.1 ± 15.8	<0.001	69.6 ± 15.6	69.8 ± 15.9	0.01
Male sex	8,659 (46.4)	1,679 (50.2)	<0.001	1,478 (50.0)	1,477 (50.0)	-0.001
Race			0.02			
White	15,465 (82.9)	2,744 (82.0)		2,513 (85.0)	2,532 (85.7)	0.02
Black	872 (4.7)	148 (4.4)		141 (4.8)	138 (4.7)	-0.005
Other	1,735 (9.3)	313 (9.4)		302 (10.2)	286 (9.7)	-0.02
Missing	584 (3.1)	140 (4.2)		-	-	
Baseline serum creatinine (mg/dL)	0.9 ± 0.41	1.31 ± 1.22	<0.001	1.1 ± 0.7	1.3 ± 1.2	0.16
Baseline eGFR (mL/min/1.73 m ²)	84.3 ± 25.9	67.5 ± 31.5	<0.001	69.8 ± 27.1	69.3 ± 31.4	-0.02
Baseline eGFR category			<0.001			
60 mL/min/1.73 m ²	14,756 (81.7)	1,834 (57.2)		1,848 (62.5)	1,769 (59.8)	-0.06
30–59 mL/min/1.73 m ²	2,899 (16.1)	955 (29.8)		882 (29.8)	838 (28.4)	-0.03
<30 mL/min/1.73 m ²	412 (2.3)	416 (13.0)		226 (7.7)	348 (11.8)	0.14
Hospital service			<0.001			
Medical	14,955 (80.2)	2,669 (79.8)		2,356 (79.7)	2,361 (79.9)	0.004
Surgical	2,519 (13.5)	567 (17.0)		485 (16.4)	493 (16.7)	0.007
Other	1,182 (6.3)	109 (3.3)		115 (3.9)	102 (3.5)	-0.02
Charlson-Deyo comorbidity index			<0.001			
0	8,342 (44.7)	814 (24.3)		746 (25.2)	774 (26.2)	0.02
1	5,599 (30.0)	990 (29.6)		916 (31.0)	915 (31.0)	-0.0007
2	2,704 (14.5)	787 (23.5)		703 (23.8)	671 (22.7)	-0.03
3	2,011 (10.8)	754 (22.5)		591 (20.0)	596 (20.2)	0.004
Primary hospital diagnosis ^b						
Acute myocardial infarction	1,647 (8.8)	639 (19.1)	<0.001	527 (17.8)	502 (17.0)	-0.02
Heart failure	1,750 (9.4)	777 (23.2)	<0.001	668 (22.6)	617 (20.9)	-0.04
COPD	2,033 (10.9)	388 (11.6)	0.2	363 (12.3)	346 (11.7)	-0.02

	Primary (Unmatched) Cohort		Secondary (Propensity Score2Matched) Cohort			
	No AKI (n = 18,656)	AKI ^a (n = 3,345)	P	No AKI (n = 2,956)	AKI ^a (n = 2,956)	Standardized Difference
Pneumonia	1,202 (6.4)	276 (8.3)	<0.001	226 (7.7)	238 (8.1)	0.02
Acute hospital-related factors						
Heart failure	2,152 (11.5)	1,051 (31.4)	<0.001	857 (29.0)	814 (27.5)	-0.03
Sepsis	233 (1.3)	113 (3.4)	<0.001	73 (2.5)	81 (2.7)	0.02
Cardiac catheterization or CABG	2,873 (15.4)	1,078 (32.2)	<0.001	907 (30.7)	883 (29.9)	-0.02
Abdominal surgery	820 (4.4)	153 (4.6)	0.6	119 (4.0)	128 (4.3)	0.02
AOSD	720 (3.9)	309 (9.2)	<0.001	198 (6.7)	227 (7.7)	0.04
Hospital length of stay (d)	4.78 ± 3.82	8.19 ± 6.52	<0.001	7.39 ± 6.26	7.44 ± 5.44	0.01

Note: Values for categorical variables are given as frequency (percentage); values for continuous variables, as mean ± standard deviation. Conversion factor for serum creatinine in mg/dL to $\mu\text{mol/L}$, $\times 88.4$. Abbreviations: AKI, acute kidney injury; AOSD, acute organ system dysfunction; CABG, coronary artery bypass grafting; COPD, chronic obstructive pulmonary disease; eGFR, estimated glomerular filtration rate.

^a According to KDIGO (Kidney Disease: Improving Global Outcomes) AKI definition and staging system.

^b Ascertained from subcomponents of Charlson-Deyo comorbidity index, except pneumonia, for which *International Classification of Diseases, Ninth Revision, Clinical Modification* codes specific for pneumonia were used.

Unadjusted and Adjusted Relationship Between Development of AKI During Index Hospitalization and Hospital Readmission

Table 2.

Outcome	Unadjusted OR (95% CI)	P	Adjusted OR (95% CI)	P
Primary cohort				
30-d hospital readmission	1.43 (1.29–1.58)	<0.001	1.21 (1.08–1.36)	0.001
60-d hospital readmission	1.37 (1.25–1.50)	<0.001	1.15 (1.03–1.27)	0.01
90-d hospital readmission	1.35 (1.23–1.48)	<0.001	1.13 (1.02–1.25)	0.02
Secondary cohort				
30-d hospital readmission	1.16 (1.00–1.34)	0.05	–	–
60-d hospital readmission	1.11 (0.98–1.27)	0.1	–	–
90-d hospital readmission	1.08 (0.96–1.23)	0.2	–	–

Note: For the primary (unmatched) cohort, multivariable logistic regression analyses were performed. For the secondary (propensity score-matched) cohort, generalized estimating equation repeated-measures regression analyses were performed to account for matched-pairs design.

Abbreviations: AKI, acute kidney injury; CI, confidence interval; OR, odds ratio.