Racial and Ethnic Disparities in Pregnancy-Related Acute Kidney Injury

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Abstract

Background: Pregnancy-related AKI (PR-AKI) is increasing in the United States. PR-AKI is associated with adverse maternal outcomes. Disparities in racial/ethnic differences in PR-AKI by race have not been studied.

Methods: This was a retrospective cohort study using the National Inpatient Sample (NIS) from 2005 to 2015. We identified patients who were admitted for a pregnancy-related diagnosis using the Neomat variable provided by the NIS database that indicates the presence of a maternal or neonatal diagnosis code or procedure code. PR-AKI was identified using ICD codes. Survey logistic regression was used for multivariable analysis adjusting for age, medical comorbidities, socioeconomic factors, and hospital/admission factors.

Results: From 48,316,430 maternal hospitalizations, 34,001 (0.07%) were complicated by PR-AKI. Hospitalizations for PR-AKI increased from 3.5/10,000 hospitalizations in 2005 to 11.8/10,000 hospitalizations in 2015 with the largest increase seen in patients aged ≥35 and black patients. PR-AKI was associated with higher odds of miscarriage (adjusted odds ratio [aOR], 1.64; 95% CI, 1.34 to 2.07) and mortality (aOR, 1.53; 95% CI, 1.25 to 1.88). After adjustment for age, medical comorbidities, and socioeconomic factors, blacks were more likely than whites to develop PR-AKI (aOR, 1.17; 95% CI, 1.04 to 1.33). On subgroup analyses in hospitalizations of patients with PR-AKI, blacks and Hispanics were more likely to have preeclampsia/eclampsia compared with whites (aOR, 1.29; 95% CI, 1.01 to 1.65; and aOR, 1.69; 95% CI, 1.23 to 2.31, respectively). Increased odds of mortality in PR-AKI compared with whites were only seen in black patients (aOR, 1.61; 95% CI, 1.02 to 2.55).

Conclusions: The incidence of PR-AKI has increased and the largest increase was seen in older patients and black patients. PR-AKI is associated with miscarriages, adverse discharge from hospital, and mortality. Black and Hispanic patients with PR-AKI were more likely to have adverse outcomes than white patients. Further research is needed to identify factors contributing to these discrepancies.
Table 1. Baseline characteristics of women with and without pregnancy-associated AKI

| Characteristics                                      | No PR-AKI                              | PR-AKI        | P Value |
|------------------------------------------------------|----------------------------------------|---------------|---------|
| **Patient demographics**                             |                                        |               | <0.001  |
| Racial/ethnic groups, N (%)                          |                                        |               |         |
| White                                                | 21,215,744 (43.91)                     | 11,209 (32.97) |         |
| Black                                                | 6,020,227 (12.46)                      | 9852 (28.98)   |         |
| Hispanic                                             | 9,271,923 (19.19)                      | 5294 (15.57)   |         |
| Other and/or missing                                  | 11,803,704 (24.43)                     | 7645 (22.48)   |         |
| Mean age, yr                                         | 27.74 (±6.11)                          | 28.87 (±6.89)  | <0.001  |
| Age                                                  |                                        |               |         |
| 12–19 yr                                             | 4,410,105 (9.13)                       | 2866 (8.43)    |         |
| 20–34 yr                                             | 36,700,000 (76.03)                     | 23,569 (69.32) |         |
| 35–50 yr                                             | 7,172,850 (14.85)                      | 7565 (22.25)   |         |
| **All Patient Refined–Diagnosis**                    |                                        |               | <0.001  |
| Related Group risk mortality score                   |                                        |               |         |
| 1                                                     | 47,600,000 (98.51)                     | 2820 (8.29)    |         |
| 2                                                     | 5,54,993 (1.15)                        | 9460 (27.82)   |         |
| 3                                                     | 1,10,085 (0.23)                        | 10,579 (31.12) |         |
| 4                                                     | 42,608 (0.09)                          | 11,127 (32.72) |         |
| **Comorbidities**                                    |                                        |               | <0.001  |
| Diabetes mellitus                                     | 67,825 (0.14)                          | 1758 (5.17)    |         |
| Hypertension                                          | 1,098,332 (2.25)                       | 8400 (24.7)    |         |
| Anemia                                                | 3,654,218 (7.56)                       | 8257 (24.29)   |         |
| Chronic pulmonary disease                             | 1,761,327 (3.65)                       | 2221 (6.53)    | <0.001  |
| Congestive heart failure                              | 51,072 (0.11)                          | 2770 (8.15)    | <0.001  |
| Hypothyroidism                                        | 1,038,187 (2.15)                       | 1209 (3.56)    | <0.001  |
| Electrolyte imbalance                                 | 5,84,265 (1.21)                        | 16,534 (48.63) | <0.001  |
| Chronic liver disease                                 | 75,199 (0.16)                          | 703 (2.07)     | <0.001  |
| Obesity                                               | 2,025,522 (4.19)                       | 3712 (10.92)   | <0.001  |
| CKD                                                   | 19,980 (0.04)                          | 4287 (12.61)   | <0.001  |
| Acquired immune deficiency syndrome                   | 13,443 (0.03)                          | 107 (0.32)     | <0.001  |
| Metastatic cancer                                     | 3606 (0.01)                            | 106 (0.31)     | <0.001  |
| Rheumatoid arthritis                                  | 1,25,684 (0.26)                        | 1192 (3.51)    | <0.001  |
| Psychoses                                             | 4,61,282 (0.95)                        | 924 (2.72)     | <0.001  |
| Alcohol abuse                                         | 81,426 (0.17)                          | 309 (0.91)     | <0.001  |
| Drug abuse                                            | 8,52,324 (1.76)                        | 1974 (5.81)    | <0.001  |
| **Zip code median income**                            |                                        |               | <0.001  |
| 76–100th percentile                                   | 10,500,000 (21.73)                     | 5227 (15.37)   |         |
| 51–75th percentile                                    | 11,600,000 (24.01)                     | 7149 (21.03)   |         |
| 26–50th percentile                                    | 1,200,000 (24.76)                      | 8415 (24.75)   |         |
| 0–25th percentile                                     | 13,300,000 (27.59)                     | 12,635 (37.16) |         |
| **Payment type**                                      |                                        |               | <0.001  |
| Medicare                                              | 3,62,963 (1)                           | 1555 (5)       |         |
| Medicaid                                              | 20,997,454 (44)                        | 17,255 (51)    |         |
| Private insurance                                     | 23,800,000 (49.25)                     | 12,508 (36.79) |         |
| Self-pay/no charge/others                             | 3,081,177 (6.38)                       | 2653 (7.8)     |         |
| **Admission type**                                    |                                        |               | <0.001  |
| Nonelective (emergency/urgent)                        | 25,500,000 (52.77)                     | 26,971 (79.33) |         |
| Elective                                              | 22,600,000 (46.8)                      | 6890 (20.27)   |         |
| **Hospital characteristics**                          |                                        |               | <0.001  |
| Hospital bed size                                     |                                        |               |         |
| Large                                                 | 29,500,000 (61.04)                     | 23,689 (69.67) |         |
| Medium                                                | 12,800,000 (26.54)                     | 7463 (21.95)   |         |
| Small                                                 | 5,749,200 (11.9)                       | 2534 (7.45)    |         |
| **Hospital region**                                   |                                        |               | <0.001  |
| Northeast                                             | 7,942,042 (16.44)                      | 5053 (14.86)   |         |
| Midwest or North Central                              | 10,300,000 (21.37)                     | 8007 (23.55)   |         |
| South                                                 | 18,400,000 (38.08)                     | 14,096 (41.46) |         |
| West                                                  | 11,700,000 (24.11)                     | 6845 (20.13)   |         |
| **Hospital teaching status**                          |                                        |               | <0.001  |
| Urban teaching                                        | 24,100,000 (49.88)                     | 23,923 (70.36) |         |
| Urban nonteaching                                     | 18,700,000 (38.78)                     | 8524 (25.07)   |         |
| Rural                                                 | 5,226,358 (10.82)                      | 1239 (3.64)    |         |
| **Discharge**                                         |                                        |               | <0.001  |
| Home                                                  | 46,900,000 (97.13)                     | 25,837 (75.99) |         |
| Against medical advice                                | 1,33,524 (0.28)                        | 665 (1.96)     |         |
| Long-/short-term facility/home                        | 1,235,959 (2.56)                       | 6161 (18.12)   |         |
women with PR-AKI recover and very few require RRT. However, AKI is suspected to be an important risk factor for the future development of CKD and ESKD, which places these young women at risk for significant long-term morbidity (10).

Prior studies have found that non-Hispanic black women in the United States are at a three to four times higher risk of pregnancy-related mortality than white women, for reasons that are poorly understood and undoubtedly complex (4). Although racial/ethnic disparities in kidney disease have been identified, to date, racial differences in PR-AKI by race have not been studied (11–13). We hypothesized that black and Hispanic women will have a higher incidence of PR-AKI when adjusted for common risk factors such as age, medical comorbidities, and socioeconomic factors.

### Materials and Methods

#### Data Source

We extracted our study cohort from the National Inpatient Sample (NIS) database provided by the Agency for Healthcare Research and Quality (AHRQ) (14). The NIS is the largest publicly available all-payer inpatient healthcare database in the United States. The NIS contains all-payer discharge data from inpatient hospitalizations from 20% of all hospitals in 44 participating states. The NIS uses data from roughly 1000 hospitals each year to create a sample representing >95% of the United States population. Each individual hospitalization in this database is de-identified and maintained as a unique entry with one primary discharge diagnosis, <24 secondary diagnoses, and <15 procedural codes during that hospitalization. Weights provided by the NIS were used to generate national estimates. Because we used publically available, de-identified data, the study was considered to be institutional-review-board exempt at the Icahn School of Medicine at Mount Sinai.

#### Study Population and Design

Pregnancy-related hospitalizations from the year 2005 to 2015 were identified using the data element Neomat. This indicator was created in the NIS database to identify maternal and/or neonatal diagnosis records on the basis of the ICD-9 and the ICD Tenth Revision, Clinical Modifications (ICD-10-CM) diagnosis and procedure codes for pregnancy and delivery (15). This method of identifying pregnancy-related hospitalization has been used previously in other pregnancy-related articles (16,17). We excluded hospitalizations with age <12 years and >50 years (Supplemental Figure 1). Diagnosis of AKI among these hospitalizations was identified using ICD-9 and -10-CM diagnosis codes in any diagnosis fields. A list of ICD codes used for cohort and outcome identification is included in Supplemental Table 1. Ultimately, our population under consideration was divided into two groups for comparison: pregnancy hospitalizations with AKI, and pregnancy hospitalizations without AKI.

#### Definition of Variables

We examined baseline characteristics of the study population for the potential of confounding. Patient-level characteristics included age, race/ethnicity, median household income according to zip code by quartile, primary payer (Medicare/Medicaid, private insurance, self-pay, or no charge), and admission type. Hospital-level characteristics such as hospital bed size (small, medium, and large), region (Northeast, Midwest or North Central, South, and West), and teaching status were identified. Race/ethnicity was grouped into white, black, Hispanic, and other/missing. Length of stay was calculated only for survivors. We used publically available, de-identified data, the study was considered to be institutional-review-board exempt at the Icahn School of Medicine at Mount Sinai.

#### Definition of Outcomes

The outcomes were in-hospital mortality, adverse discharge, and pregnancy-related complications of miscarriage, preterm labor, and preeclampsia/eclampsia. ICD-9/-10-CM diagnosis codes were used to identify pregnancy-related complications. Adverse discharge was defined as discharge to skilled nursing facility, intermediate care center, medical facility, or long-term care hospital (21–23).

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**Table 1. (Continued)**

| Characteristics                      | No PR-AKI | PR-AKI | P Value |
|--------------------------------------|-----------|--------|---------|
| Length of stay, d                    | 2.66±2.61 | 9.54±11.92 | <0.001  |
| Total charges                        | 13,471±14,715 | 91,465±70,215 | <0.001  |
| Maternal outcomes                    |           |        |         |
| Miscarriage                          | 1,66,299 (0.34) | 906 (2.66) | <0.001  |
| Preterm labor                        | 4,016,887 (8.31) | 4599 (13.53) | <0.001  |
| Preeclampsia/eclampsia               | 2,061,083 (4.27) | 9639 (28.35) | <0.001  |
| Maternal death during hospitalization| 4457 (0.01) | 1323 (3.89) | <0.001  |

Values are presented as number of patients and percentage. PR-AKI, pregnancy-related AKI.
Statistical Analyses
NIS represents a 20% stratified random sample of United States hospitals. So, analyses were performed using hospital-level discharge weights provided by the NIS to obtain national estimates. We compared the baseline characteristics of pregnancy-related hospitalizations with and without AKI. To estimate differences, we used the chi-squared test for categoric variables, t test for normally distributed continuous variables, and Wilcoxon rank-sum test for non-normally distributed continuous variables. We calculated trends of pregnancy hospitalizations with AKI from 2005 to 2015. A P value of <0.05 was considered significant for all analyses. For trend analysis, the chi-squared test of trend for proportions was used with the Cochrane Armitage test via the "trend" command in SAS. Survey logistic regression was used to estimate the effect of AKI on outcomes of mortality, adverse discharge, and pregnancy-related complications of miscarriage, preterm labor, and preeclampsia/eclampsia. Adjusted odds ratios (aOR) for the above-mentioned outcomes were calculated after adjusting with age, APR-DRG risk score, diabetes mellitus (DM; both type 1 and type 2), hypertension (HTN), anemia, chronic pulmonary disease, congestive heart failure, hypothyroidism, electrolyte imbalance, chronic liver disease, obesity, CKD, AIDS, metastatic cancer, rheumatoid arthritis, psychoses, alcohol abuse, drug abuse, median household income, primary payer (Medicare, Medicaid, private insurance, self-pay, or no charge), admission type, and hospital-level characteristics of hospital bed size (small, medium, and large), region (Northeast, Midwest or North Central, South, and West), and teaching status. The variables we adjusted for were based off of prior literature and to account for systemic factors and social determinants that may potentially affect outcome (24–28). Given the complex interplay between preeclampsia/eclampsia, PR-AKI, and race/ethnicity; we performed sensitivity analysis adjusting for preeclampsia/eclampsia for the outcomes of miscarriage, preterm labor, adverse discharge, and maternal mortality. We performed subgroup analysis by race/ethnicity to determine differences in adverse outcomes by race/ethnicity. SAS version 9.4 (SAS Institute Inc., Cary, NC) was used for all analyses.

Results
Of 48,316,430 maternal hospitalizations, 34,001 (0.07%) had an ICD code associated with AKI. The baseline characteristics of patients are seen in Table 1. Patients with hospitalizations complicated by PR-AKI were more likely to be black (29% versus 13%), older (mean age 29.6 years versus 28.6 years), and had significantly more comorbidities than patients without AKI. Comorbidities included CKD (12% versus 0.04%), DM (8% versus 1%), HTN (25% versus 2%), anemia (24% versus 8%), electrolyte imbalances
Hospitalizations complicated by PR-AKI had a higher proportion of patients in the lowest quartile of income than hospitalizations without PR-AKI (37% versus 28%), and more patients that had Medicare/Medicaid insurance (55% versus 44%). In patients with PR-AKI, 79% of admissions were rated as an emergency or urgent compared with 53% in those hospitalized without PR-AKI. Patients with hospitalizations with PR-AKI were more likely to be in a large hospital (70% versus 61%) and were more likely to be in an urban teaching hospital (70% versus 50%). Patients with hospitalizations with PR-AKI had significantly higher rates of adverse discharge (18% versus 3%). The length of stay for patients with PR-AKI was longer, with a mean length of stay of 9.5 ± 11.9 days compared with 2.7 ± 2.6 days.

Mortality was significantly higher in patients with hospitalizations with PR-AKI, 4% compared with 0.01% of patients without PR-AKI.

Hospitalizations for PR-AKI increased by more than three times from 3.5/10,000 hospitalizations in 2005 to 11.8/10,000 hospitalizations in 2015 (Figure 1A). Patients aged ≥35 and black patients had the largest increase and the highest incidence of pregnancy hospitalizations complicated by PR-AKI (Figure 1, B and C). Black patients had the highest proportion of PR-AKI and the largest increase across all age groups (Figure 2).

Even after adjustment for patient and hospital factors, black patients were more likely than white patients to develop PR-AKI (aOR, 1.17; 95% CI, 1.04 to 1.33). The additional adjustment of preeclampsia/eclampsia decreased the odds ratio (aOR, 1.16; 95% CI, 1.0 to 1.3) but there remained a significant association. Hospitalizations of patients with CKD (aOR, 9.97; 95% CI, 7.99 to 12.44), electrolyte imbalances (aOR, 3.2; 95% CI, 2.9 to 3.6), and HTN (aOR, 1.77; 95% CI, 1.55 to 2.02) had the highest aOR for PR-AKI (Table 2). Although other studies found an association between AKI and hemorrhage, we did not find an association in our adjusted model (aOR, 1.0; 95% CI, 0.9 to 1.1).

After adjustment for socioeconomic factors, age, comorbidities, and hospital characteristics (as detailed in the Materials and Methods section), PR-AKI remained significantly associated with higher odds of miscarriage (aOR, 1.64; 95% CI, 1.3 to 2.07) and mortality (aOR, 1.53; 95% CI, 1.25 to 1.88) but was no longer significant for preterm labor, preeclampsia/eclampsia, or adverse discharge (Table 3). Additional adjustment for preeclampsia/eclampsia for the other maternal outcomes did not substantially change the odd ratios (Supplemental Table 2).

On subgroup analyses of outcomes by racial/ethnic groups between hospitalizations with and without PR-AKI, in white patients after adjustment, PR-AKI was associated with increased odds of mortality (aOR, 1.62; 95% CI, 1.09 to 2.41) and miscarriage (aOR, 1.61; 95% CI, 1.06 to 2.44). For black patients after adjustment, PRI-AKI was associated with miscarriage (aOR, 2.3; 95% CI, 1.5 to 3.5). In Hispanic women after adjustment, PR-AKI was only associated with mortality (aOR, 1.94; 95% CI, 1.01 to 3.5). Finally, in women of other or
| Characteristic                                      | Odds Ratio (95% CI) | Unadjusted | Adjusted* |
|----------------------------------------------------|---------------------|------------|-----------|
| **Patient demographics**                           |                     |            |           |
| Racial/ethnic groups                               |                     |            |           |
| White (reference)                                  |                     |            |           |
| Black                                              | 3.10 (2.87 to 3.34)  | 1.17 (1.04 to 1.33) |
| Hispanic                                           | 1.08 (0.99 to 1.18)  | 0.92 (0.79 to 1.07) |
| Other and/or missing                               | 1.22 (1.09 to 1.35)  | 1.03 (0.88 to 1.2)  |
| Age                                                |                     |            |           |
| 12–19 yr (reference)                               | 0.99 (0.9 to 1.08)   | 0.85 (0.72 to 1)  |
| 20–34 yr                                           | 1.62 (1.46 to 1.80)  | 0.86 (0.7 to 1.04) |
| **Comorbidities**                                  |                     |            |           |
| AIDS                                               | 11.43 (7.40 to 17.66) | 0.52 (0.29 to 0.92) |
| Alcohol abuse                                      | 5.5 (4.3 to 7.1)     | 0.88 (0.52 to 1.48) |
| Congestive heart failure                           | 83.85 (76.18 to 92.29) | 0.69 (0.57 to 0.83) |
| Chronic liver disease                              | 13.54 (11.34 to 16.15) | 1.68 (1.21 to 2.35) |
| Chronic pulmonary disease                          | 1.85 (1.67 to 2.04)  | 0.65 (0.53 to 0.79) |
| Deficiency anemias                                 | 3.92 (3.67 to 4.19)  | 1.25 (1.11 to 1.4)  |
| Diabetes mellitus                                  | 38.8 (34.4 to 43.8)  | 1.22 (0.9 to 1.65)  |
| Drug abuse                                         | 3.43 (3.07 to 3.84)  | 1.17 (0.93 to 1.48) |
| Electrolyte imbalance                              | 77.34 (73.22 to 81.69) | 3.2 (2.9 to 3.6)  |
| Hypothyroidism                                     | 1.68 (1.47 to 1.91)  | 1.09 (0.84 to 1.41) |
| Hypertension                                       | 14.24 (13.45 to 15.07) | 1.77 (1.55 to 2.02) |
| Metastatic cancer                                  | 42 (27.36 to 64.51)  | 0.46 (0.18 to 1.17) |
| Obesity                                            | 2.8 (2.6 to 3.1)     | 0.98 (0.81 to 1.18) |
| Psychoses                                          | 2.9 (2.5 to 3.4)     | 1.19 (0.9 to 1.58)  |
| CKD                                               | 348.76 (319.89 to 380.23) | 9.97 (7.99 to 12.44) |
| Rheumatoid arthritis                               | 13.93 (12.07 to 16.08) | 1.25 (0.94 to 1.65) |
| Median household income category for patient’s zip code |                     |            |           |
| 76–100th percentile (reference)                    |                     |            |           |
| 51–75th percentile                                 | 1.24 (1.14 to 1.35)  | 0.88 (0.78 to 0.99) |
| 26–50th percentile                                 | 1.41 (1.30 to 1.54)  | 0.85 (0.74 to 0.97) |
| 0–25th percentile                                  | 1.9 (1.8 to 2.1)     | 0.79 (0.67 to 0.93) |
| **Admission Characteristics**                      |                     |            |           |
| Admission type                                     |                     |            |           |
| Elective (reference)                               | 3.47 (3.23 to 3.73)  | 1.06 (0.95 to 1.19) |
| Nonelective                                        |                     |            |           |
| All Patient Refined–Diagnosis Related Group         |                     |            |           |
| 1 (reference)                                      | >999.99 (>999.99 to >999.99) | >999.99 (>999.99 to >999.99) |>999.99 (>999.99 to >999.99) |
| 2                                                  | >999.99 (>999.99 to >999.99) | >999.99 (>999.99 to >999.99) |
| 3                                                  | >999.99 (>999.99 to >999.99) | >999.99 (>999.99 to >999.99) |
| 4                                                  | >999.99 (>999.99 to >999.99) | >999.99 (>999.99 to >999.99) |
| **Primary payer type**                             |                     |            |           |
| Medicare (reference)                               |                     |            |           |
| Medicaid                                           | 0.19 (0.16 to 0.22)  | 0.84 (0.64 to 1.12) |
| Commercial                                         | 0.12 (0.10 to 0.14)  | 0.82 (0.62 to 1.07) |
| Self-pay                                           | 0.24 (0.20 to 0.29)  | 0.85 (0.61 to 1.18) |
| No charge                                          | 0.26 (0.15 to 0.46)  | 0.93 (0.39 to 2.22) |
| Others                                             | 0.15 (0.12 to 0.19)  | 0.76 (0.52 to 1.1)  |
| **Hospital Characteristics**                       |                     |            |           |
| Hospital bed size                                  |                     |            |           |
| Large (reference)                                  | 0.72 (0.65 to 0.8)   | 0.82 (0.66 to 1)  |
| Small                                              | 0.55 (0.49 to 0.61)  | 0.89 (0.74 to 1.07) |
| **Hospital region**                                |                     |            |           |
| Northeast (reference)                              |                     |            |           |
| Midwest or North Central                           | 1.22 (1.08 to 1.37)  | 0.85 (0.71 to 1.02) |
| South                                              | 1.2 (1.1 to 1.4)     | 0.87 (0.75 to 1)  |
| West                                               | 0.92 (0.81 to 1.05)  | 0.9 (0.8 to 1.1)  |
Discussion

In a large, nationally representative database, we have found that PR-AKI is increasing and the largest increase was seen in older patients and black patients. We also show that several patient characteristics were significantly different between PR-AKI and non-PR-AKI hospitalizations, including socioeconomic factors and medical comorbidities. PR-AKI was associated with several adverse maternal outcomes and this persisted in several race/ethnic groups. Finally, even after adjustment for age, medical comorbidities, and socioeconomic and hospital factors, in patients with PR-AKI there remained higher odds of adverse events in minority patients compared to white patients.

Contrary to the decreasing trend of PR-AKI in developing countries, we and others have found an increase in the incidence of PR-AKI (8,29,30). In particular, older patients and black patients had the highest incidence and largest increase in incidence. Although part of this increase may be due to increased coding and recognition, this would not be expected to affect racial/ethnic groups differently. This is supported by the increases in PR-AKI and maternal mortality found in this study and others (8). How the increase in PR-AKI incidence contributes to the increasing maternal mortality rates in the United States needs to be further explored.

The increase in adverse events in the AKI group is likely related to a higher prevalence of comorbidities including CKD, HTN, and DM. This is most evident for the outcome of mortality, given the marked reduction in odds ratios between the unadjusted and adjusted models. It has been previously demonstrated that CKD is associated with adverse maternal and fetal outcomes and this risk increases with the stage of CKD (25,31). Additionally, chronic HTN not only increases the risk of PR-AKI but is also associated with increased maternal and perinatal outcomes. Lastly, patients with any form of DM have an increased risk for both fetal and maternal outcomes including AKI, HTN, and mortality (24). Of great concern is the increasing proportion of patients with preexisting DM during pregnancy in the United States (32). Unfortunately, NIS does not have vital signs or laboratory information and we are unable to determine differences in CKD stage and HTN and DM control between racial/ethnic groups. However, in patients with PR-AKI (even after adjustment for comorbidities, social demographic factors, and hospital characteristics), there remained a higher risk of preeclampsia/eclampsia in black and Hispanic patients compared with white patients. It has

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Table 2. (Continued)

| Characteristic                              | Unadjusted | Adjusted* |
|--------------------------------------------|------------|-----------|
| Hospital teaching status                   |            |           |
| Urban teaching (reference)                 |            |           |
| Urban nonteaching                          | 0.46 (0.42 to 0.5) | 0.45 (0.34 to 0.58) |
| Rural                                      | 0.24 (0.21 to 0.28) | 0.78 (0.68 to 0.88) |

*Adjusted for age, all comorbidities (diabetes mellitus, hypertension, anemia, chronic pulmonary disease, congestive heart failure, hypothyroidism, electrolyte imbalance, chronic liver disease, obesity, renal failure, AIDS, metastatic cancer, rheumatoid arthritis, psychosis, alcohol abuse, drug abuse), median household income, primary payer (Medicare/Medicaid, private insurance, self-pay, or no charge), admission type, and hospital-level characteristics such as hospital bed size (small, medium, and large), region (Northeast, Midwest or North Central, South, and West), and teaching status.

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Table 3. Adjusted odds ratio for maternal outcomes by pregnancy-related AKI status

| Outcomes                        | Unadjusted | Adjusted* |
|---------------------------------|------------|-----------|
| Miscarriage                     | 7.93 (6.8 to 9.25) | 1.64 (1.3 to 2.07) |
| Preterm labor                   | 1.72 (1.61 to 1.85) | 0.88 (0.8 to 0.98) |
| Pre-/eclampsia                  | 8.88 (8.39 to 9.41) | 1.07 (0.98 to 1.16) |
| Adverse discharge               | 7.96 (6.61 to 9.45) | 1.12 (0.98 to 1.27) |
| Maternal mortality              | 439.01 (381.50 to 505.18) | 1.53 (1.25 to 1.88) |

*Adjusted for age, all comorbidities (diabetes mellitus, hypertension, anemia, chronic pulmonary disease, congestive heart failure, hypothyroidism, electrolyte imbalance, chronic liver disease, obesity, renal failure, AIDS, metastatic cancer, rheumatoid arthritis, psychosis, alcohol abuse, drug abuse), median household income, primary payer (Medicare/Medicaid, private insurance, self-pay, or no charge), admission type, and hospital-level characteristics such as hospital bed size (small, medium, and large), region (Northeast, Midwest or North Central, South, and West), and teaching status.
been previously documented that preeclampsia is more common in nonwhite patients without PR-AKI and we demonstrate that this also holds true in patients with PR-AKI (22). There is a complex interplay between race/ethnicity, AKI, and preeclampsia/eclampsia, and this needs to be studied further.

Despite the overall low rates of PR-AKI, hospitalizations complicated by PR-AKI had a 50% increase in the odds of maternal mortality in women who are historically considered to be healthy. The increased odds of mortality was seen in white and Hispanic patients but was most pronounced in Hispanic patients. Hospitalizations with PR-AKI also had a higher risk of miscarriage; however, after adjustment, this was only significant in white and black patients.

Prenatal care before delivery is an important predictor of maternal and fetal adverse outcomes. According to the CDC, black and Hispanic women, compared with white women (Table 4 and Figure 3).

Table 4. Adjusted odds ratio for pregnancy outcomes by pregnancy-related AKI status stratified by race/ethnicity

| Race       | Miscarriage | Preterm | Pre-/Eclampsia | Adverse Discharge | Mortality |
|------------|-------------|---------|----------------|-------------------|-----------|
| White      | 1.61 (1.06 to 2.44) | 0.85 (0.7 to 1.0) | 0.9 (0.8 to 1.1) | 1.14 (0.93 to 1.39) | 1.62 (1.09 to 2.41) |
| Black      | 2.3 (1.5 to 3.5) | 0.95 (0.79 to 1.15) | 0.92 (0.76 to 1.11) | 0.80 (0.61 to 1.06) | 1.42 (0.96 to 2.09) |
| Hispanic   | 1.34 (0.67 to 2.68) | 0.8 (0.6 to 1.1) | 1.2 (0.9 to 1.7) | 1.04 (0.71 to 1.52) | 1.9 (1.0 to 3.5) |
| Other      | 0.75 (0.22 to 2.59) | 1.02 (0.7 to 1.48) | 1.16 (0.76 to 1.78) | 0.5 (0.2 to 1.3) | 1.8 (0.9 to 3.8) |

*Adjusted for age, all comorbidities (diabetes mellitus, hypertension, anemia, chronic pulmonary disease, congestive heart failure, hypothyroidism, electrolyte imbalance, chronic liver disease, obesity, renal failure, AIDS, metastatic cancer, rheumatoid arthritis, psychosis, alcohol abuse, drug abuse), median household income, primary payer (Medicare/Medicaid, private insurance, self-pay, or no charge), admission type and hospital-level characteristics such as hospital bed size (small, medium, and large), region (Northeast, Midwest, or North Central, South, and West), and teaching status.

![Figure 3. Forest plot demonstrating increased odds of preeclampsia/eclampsia for blacks and Hispanics and increased odds of mortality for Hispanics with white as reference in women hospitalized with PR-AKI even after adjustment.](image-url)

Adjusted for age, all comorbidities (diabetes mellitus, hypertension, anemia, chronic pulmonary disease, congestive heart failure, hypothyroidism, electrolyte imbalance, chronic liver disease, obesity, renal failure, AIDS, metastatic cancer, rheumatoid arthritis, psychosis, alcohol abuse, drug abuse), median household income, primary payer (Medicare/Medicaid, private insurance, self-pay, or no charge), admission type, and hospital-level characteristics such as hospital bed size (small, medium, and large), region (Northeast, Midwest or North Central, South, and West), and teaching status. aOR, adjusted odds ratio; Ref, reference.
women, have approximately double the proportion of women who receive late or no prenatal care (33). Unfortunately, because NIS is an inpatient database, outpatient prenatal-care information is not available.

Our study should be interpreted in light of the following limitations. The NIS is an administrative database, therefore information such as medications and laboratory values are unavailable and we cannot determine the degree and duration of AKI. Unfortunately, we do not have any data regarding prior pregnancies which may potentially affect outcomes of future pregnancies (24). Only limited social determinants of health are captured in NIS, therefore we are unable to determine if additional social determinants of health contribute to the discrepancies in PR-AKI outcomes we have identified. We are unable to capture nonmedically related reasons (e.g., preexisting homelessness) for adverse discharges which may be confounding our results. Despite the limitations, this is the first article to look at racial/ethnic disparities in pregnancy outcomes in patients who have PR-AKI using a nationally representative database.

In conclusion, although overall rates of PR-AKI are low, they have increased over the past decade. Whereas PR-AKI has increased in all races/ethnicities, it is most pronounced in black patients. PR-AKI is associated with miscarriages, adverse dis-charge, and mortality. Even after adjustment for patient age, medical comorbid conditions, socioeconomic, and hospital factors; black and Hispanic patients with PR-AKI were more likely to have adverse maternal and fetal outcomes than white patients with PR-AKI. Further research is needed to identify patient and system-level features contributing to these discrepancies.

Author Contributions
K. Beers, L. Chan, S. Coca, and G. Nadkarni conceptualized the study; K. Beers wrote the original draft; K. Beers, S. Coca, and G. Nadkarni reviewed and edited the manuscript; L. Chan, K. Chauhan, M. Dave, A. Saha, and H. Wen were responsible for formal analysis; L. Chan provided supervision; K. Chauhan was responsible for data curation; and A. Saha and H. Wen were responsible for the methodology.

Disclosures
S. Coca reports personal fees from CHF Solutions; personal fees from Goldfinch; personal fees from Janssen; and personal fees and other from pulseData; personal fees from Relypsa; grants, personal fees, and other from RenalytixAI; and personal fees from Takeda; outside the submitted work. G. Nadkarni reports personal fees from AstraZeneca; personal fees from BioVie; personal fees from GLG consulting; grants from Goldfinch Bio; nonfinancial support from Pensieve Health; personal fees from Reata Pharma; and grants, personal fees, and nonfinancial support from Renalytix AI; outside the submitted work. K. Beers, L. Chan K. Chauhan, M. Dave, A. Saha, and H. Wen have nothing to disclose.

Supplemental Material
This article contains the following supplemental material online at http://kidney360.asnjournals.org/lookup/suppl/doi:10.34067/KID.000102019//DCCSupplemental.

Supplemental Table 2. Adjusted odds ratio for maternal outcomes by PR-AKI status with and without adjustment for preeclampsia.

Supplemental Figure 1. Study flow diagram.

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Supplemental Table 1: ICD 9/10 codes used for cohort and outcome identification

Supplemental Table 2: Adjusted odds ratio for maternal outcomes by PR-AKI status with and without adjustment for preeclampsia

Supplemental Figure 1: Study flow diagram
Supplemental Table 1: ICD 9/10 codes used for cohort and outcome identification.

| Condition                                      | NIS   | ICD 9 | ICD10                        |
|------------------------------------------------|-------|-------|------------------------------|
| Pregnancy, childbirth, and the puerperium      | NEOMAT|       |                              |
| ESRD                                           | 585.6 | N186  |                              |
| Renal transplant patient                       | V420  | Z940  | T8610, T8611, T8612          |
|                                                | 99681 |       | OTS00ZZ, OTS10ZZ             |
|                                                | 5561  |       | OTY00Z0, OTY00Z1, OTY00Z2, OTY10Z0, OTY10Z1, OTY10Z2 |
| AKI                                            | 5845  | N17.0 |                              |
|                                                | 5846  | N17.1 |                              |
|                                                | 5847  | N17.2 |                              |
|                                                | 5848  | N17.8 |                              |
|                                                | 5849  | N17.9 |                              |
| Miscarriage                                    | 634.00 to 634.92 | O00-O08, O03, O03.9 |
| Preterm                                        | 644.00 to 644.21 | O60.00, O60.02, O60.03, O47.00, O47.9, O47.02, O47.03, O47.1, O60.10X0, O60.12X0, O60.13X0, O60.14X0 |
| Preeclampsia                                   | 642.4 and 642.5 | O14   |
| Eclampsia                                      | 642.6 | O15   |
| Hemorrhage                                     | 666.x | O72.x |                              |
Supplemental Table 2: Adjusted odds ratio for maternal outcomes by PR-AKI status with and without adjustment for preeclampsia.

| Outcomes          | Adjusted OR w/o preeclampsia | Adjusted OR with preeclampsia |
|-------------------|------------------------------|------------------------------|
| Miscarriage       | 1.64 (CI 1.3 – 2.07)         | 1.71 (1.35 - 2.17)           |
| Preterm labor     | 0.88 (CI 0.8 - 0.98)         | 0.84 (0.76 - 0.93)           |
| Pre / Eclampsia   | 1.07 (CI 0.98 - 1.16)        | -                            |
| Adverse Discharge | 1.12 (CI 0.98 -1.27)         | 1.1 (0.96 – 1.25)            |
| Maternal Mortality| 1.53 (CI 1.25-1.88)          | 1.57 (1.27 - 1.93)           |
48,411,843 Maternal Hospitalizations in NIS 2005-2015

- Exclusions:
  - Aged <12 or >50 (n=50,496)
  - ESRD (n=6,235)
  - Kidney Transplant Recipient (n=4,681)

48,350,431 Maternal Hospitalizations

48,316,430 Maternal Hospitalizations without PR-AKI

34,001 Maternal Hospitalizations With PR-AKI