Published in final edited form as:
*Am J Kidney Dis*. 2020 January ; 75(1): 148–150. doi:10.1053/j.ajkd.2019.07.007.

# Health Outcomes and Health Care Utilization Among Obstetric Deliveries With Concurrent CKD in the United States

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## To the Editor:

The increasing contribution of pre-existing chronic medical conditions to maternal morbidity and mortality has recently garnered national attention,[1,2] but there are limited data on the epidemiology of CKD, including ESKD, in reproductive-aged women. We sought to estimate the prevalence of CKD among delivering women in the United States, describing their health outcomes, patterns of health care utilization, and delivery-related costs. This study fills crucial knowledge gaps regarding the impact of CKD among women giving birth in the United States.

Using the National Inpatient Sample (NIS), a nationally representative 20% stratified sample of US hospital discharges compiled by the Healthcare Cost and Utilization Project (HCUP),[3] we identified all delivery hospitalizations for live births occurring from 2006 to 2015.[4] *ICD-9-CM* codes were used to classify delivery hospitalizations into 4 distinct cohorts: those with diagnoses of non-ESKD CKD, ESKD treated by maintenance dialysis, ESKD treated by kidney transplantation, and all other hospital deliveries. Clinical outcomes of interest, including severe maternal morbidity and mortality, preterm delivery, and cesarean delivery,

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**Authors' Contributions:** Research idea and study design: ALO, LKA; data acquisition: LKA, TNAW; data analysis/interpretation: ALO, LKA, LHM, TNAW, VKD; statistical analysis: LKA, TNAW; supervision or mentorship: LHM, VKD. 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.

**Peer Review:** Received February 7, 2019. Evaluated by 3 external peer reviewers, with direct editorial input from a Statistics/Methods Editor, an Associate Editor, and the Editor-in-Chief. Accepted in revised form July 5, 2019.

Financial Disclosure: The authors report that they have no relevant financial interests.

were identified using standard diagnosis and procedure codes. Delivery-associated hospital costs were calculated using HCUP's cost to charge ratio files.[3]

Demographics were described for each group using survey-weighted proportions. Clinical outcomes were estimated for each group using multivariable logistic regression models with predictive margins. Delivery-related health care utilization and hospital costs were estimated using generalized linear models with a gamma distribution and log-link function. Two-sided $P < 0.05$ was considered statistically significant. Diagnosis and procedure codes, model adjustments, and detailed methods are described in Item S1.

We identified an estimated 39,025,671 hospital deliveries (unweighted n = 7,906,820) occurring from 2006 to 2015. Of these, 11,369 (unweighted n = 2,322), 1,315 (unweighted n = 273), and 2,071 (unweighted n = 426) included diagnoses for non-ESKD CKD, dialysis, and transplantation, respectively. Demographics are in Table S1.

The overall prevalences of non-ESKD CKD, dialysis, and transplantation were 3.0 (95% CI, 2.8–3.2), 0.35 (95% CI, 0.30–0.39), and 0.54 (95% CI, 0.49–0.61), respectively, per 100,000 delivery hospitalizations. The odds of each clinical outcome and health care utilization outcome were greater in the presence of CKD, as shown in Table 1. Notably, the odds of severe maternal morbidity and mortality was greater across all groups: 5.8 (95% CI, 4.8–6.9), 22.2 (95% CI, 16.7–29.4), and 6.0 (95% CI, 4.2–8.5) times greater in deliveries with non-ESKD CKD, dialysis, and transplantation, respectively, versus all other hospital deliveries. The most common indicator of severe maternal morbidity was blood transfusion. Results limited to 2012 to 2015 were similar, to account for potential temporal changes in CKD coding (Table S2). Delivery hospitalizations with comorbid diagnoses of chronic diabetes, hypertension, or both were at higher odds of preterm and cesarean delivery than those with CKD alone (Table 2).

The findings of this study reveal significantly greater odds of severe maternal morbidity and mortality among deliveries to women with CKD compared with those without. CKD was associated with higher odds of peripartum blood transfusions, which may amplify sensitization during pregnancy[5] and diminish the likelihood of a future successful transplantation.[6] Future work is needed to understand indications for transfusion in this population to appropriately target interventions aimed at risk reduction. For example, the use of erythropoiesis-stimulating agents prenatally may reduce the risk for blood transfusions among women with CKD; however, it is unclear how current recommendations for their use are followed in pregnancy.[7]

These data also demonstrate significantly increased odds of preterm delivery and cesarean delivery among deliveries to women with CKD who had comorbid diagnoses of hypertension or diabetes mellitus or both. These findings support prior smaller studies suggesting that mediators of adverse gestational outcomes in CKD include uncontrolled hypertension and proteinuria.[8]

The results of our study should be interpreted in light of certain limitations. We relied on ICD-9-CM codes, which are susceptible to misclassification and ascertainment bias, potentially biasing our results toward the null if CKD is unrecognized before pregnancy.

CKD *ICD-9-CM* code specificity is generally reported at >90%,[9] and as such, our point estimates of prevalence are likely conservative. Second, the non-ESKD CKD category was heterogeneous, including CKD stages 1 to 5; however, other studies suggest that even stage 1 CKD is associated with increased risk for adverse gestational outcomes.[10]

This study provides important information on health outcomes and patterns of health care utilization among a nationally representative sample of delivering women with CKD. Evidence-based interventions are needed to mitigate the excess risks at delivery faced by women with CKD, particularly those with chronic hypertension and diabetes. Improved efforts allying obstetricians and nephrologists to develop policies and practices to support the reproductive health care of women with CKD, including those treated by dialysis or transplantation, may improve outcomes for this population.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

## Acknowledgements:

These analyses would not be possible without the data collection efforts of HCUP's data partners: https://www.hcup-us.ahrq.gov/db/hcupdatapartners.jsp.

### Support:

Dr Oliverio is funded by NIH T32 DK007378–38. Dr Mariani is funded by NIH K08 DK115891–01. Dr Dalton is funded by AHRQ HS023784–03. The funding source had no involvement in study design, conduct, writing the report, or the decision to submit the report for publication.

### Other Disclosures:

The following support is unrelated to this work: Dr. Dalton is a paid expert witness for Bayer. Dr Mariani receives grant support from Boehringer Ingelheim and consulting fees from Reata.

## References

1. Creanga AA, Syverson C, Seed K, Callaghan WM. Pregnancy-related mortality in the United States, 2011–2013. Obstet Gynecol. 2017;130(2):366–373. [PubMed: 28697109]
2. Admon LK, Winkelman TNA, Moniz MH, Davis MM, Heisler M, Dalton VK.Disparities in chronic conditions among women hospitalized for delivery in the United States, 2005–2014. Obstet Gynecol. 2017;130(6):1319–1326. [PubMed: 29112666]
3. Healthcare Cost and Utilization Project (HCUP) databases. http://www.hcup-us.ahrq.gov/databases.jsp. Accessed January 22, 2018.
4. Kuklina EV, Whiteman MK, Hillis SD, et al. An enhanced method for identifying obstetric deliveries: implications for estimating maternal morbidity. Matern Child Health J. 2008;12(4):469–477. [PubMed: 17690963]
5. Hyun J, Park KD, Yoo Y, et al. Effects of different sensitization events on HLA alloimmunization in solid organ transplantation patients. Transplant Proc. 2012;44(1):222–225. [PubMed: 22310619]
6. Claas FH. Clinical relevance of circulating donor-specific HLA antibodies. Curr Opin Organ Transplant. 2010;15(4): 462–466. [PubMed: 20613523]
7. Reddy SS, Holley JL. Management of the pregnant chronic dialysis patient. Adv Chronic Kidney Dis. 2007;14(2): 146–155. [PubMed: 17395117]

8. Zhang JJ, Ma XX, Hao L, Liu LJ, Lv JC, Zhang H. A systematic review and meta-analysis of outcomes of pregnancy in CKD and CKD outcomes in pregnancy. Clin J Am Soc Nephrol. 2015;10(11):1964–1978. [PubMed: 26487769]

9. Grams ME, Plantinga LC, Hedgeman E, et al. Validation of CKD and related conditions in existing data sets: a systematic review. Am J Kidney Dis. 2011;57(1):44–54. [PubMed: 20692079]

10. Piccoli GB, Cabiddu G, Attini R, et al. Risk of adverse pregnancy outcomes in women with CKD. J Am Soc Nephrol. 2015;26(8):2011–2022. [PubMed: 25766536]

**Table 1.**

Health Outcomes, Health Care Utilization, and Expenditures Among Hospital Deliveries Complicated by CKD, National Inpatient Sample 2006–2015

| | All Other Hospital Deliveries (n = 7,903,799) | CKD | | |
|---|---|---|---|---|
| | | Non-ESKD CKD (n = 2,322) | ESKD-Dialysis (n = 273) | ESKD-Transplantation (n = 426) |
| Adj OR (95% CI) for clinical outcomes | | | | |
| Preterm delivery[a] | 1.0 (reference) | 4.1 (3.7–4.6) | 14.0 (10.9–18.0) | 7.0 (5.7–8.6) |
| Cesarean delivery | 1.0 (reference) | 2.1 (1.9–2.2) | 3.1 (2.4–4.0) | 2.4 (1.9–2.9) |
| Severe maternal morbidity/mortality | 1.0 (reference) | 5.8 (4.8–6.9) | 22.2 (16.7–29.4) | 6.0 (4.2–8.5) |
| Blood transfusion | 1.0 (reference) | 5.9 (4.8–72) | 20.3 (15.0–27.5) | 7.5 (5.2–10.7) |
| Health care utilization | | | | |
| Adj OR (95% CI) for hospital transfer | 1.0 (reference) | 4.5 (3.4–5.8) | NA | NA |
| Length of stay, d[b] | 2.6 (2.6–2.7) | 5.8 (5.4–6.1) | 10.9 (9.2–12.7) | 5.7 (4.9–6.4) |
| Health care expenditures: cost per delivery hospitalization[c] | $4,400 ($4,300–$4,500) | $8,100 ($7,700–$8,500) | $25,000 ($20,000–$30,000) | $9,300 ($8,300–$10,300) |

*Note:* N = 7,906,820. Observations are presented as unweighted N. Results are survey weighted unless otherwise noted. All models are adjusted for age, income, payer, rural versus urban residence, and hospital region.

Abbreviations and definitions: Adj, adjusted; OR, odds ratio; CI, confidence interval; NA, not applicable, based on HCUP reporting requirements (<10 cases identified); CKD, chronic kidney disease; ESKD, end-stage kidney disease; OR, odds ratio.

[a]Delivery at less than 37 weeks' gestational age.

[b]Predicted means, reported with 95% CIs.

[c]Costs are inflation-adjusted to 2015 US dollars and are reported as predicted means with 95% CIs.

**Table 2.**

Adjusted Health Outcomes, Health Care Utilization, and Expenditures Among Hospital Deliveries Complicated by non-ESKD CKD With and Without DM or HTN, National Inpatient Sample 2006–2015

| | | Comorbid Condition | | |
|---|---|---|---|---|
| | **Neither Comorbid DM nor HTN (n = 1,019)** | **DM (n = 72)** | **HTN (n = 982)** | **DM and HTN (n = 249)** |
| Adj OR (95% CI) for clinical outcomes | | | | |
| Preterm delivery[a] | 1.0 (reference) | 6.0 (3.1–11.4) | 2.9 (2.2–3.8) | 4.6 (3.1–6.9) |
| Cesarean delivery | 1.0 (reference) | 2.4 (1.3–4.7) | 2.0 (1.6–2.6) | 5.5 (3.7–8.4) |
| Severe maternal morbidity/mortality | 1.0 (reference) | NA | 1.9 (1.2–3.2) | 6.6 (3.8–11.3) |
| Health care utilization | | | | |
| Adj OR (95% CI) for hospital transfer | 1.0 (reference) | NA | 1.7 (0.9–3.3) | 2.0 (0.8–4.7) |
| Length of stay, d[b] | 3.3 (3.0–3.6) | 6.7 (3.3–10.2) | 5.5 (5.1–6.0) | 10.0 (8.3–11.7) |
| Health care expenditures: cost per delivery hospitalization[c] | $5,800 ($5,400–$6,300) | $11,800 ($7,500–$16,100) | $8,900 ($8,200–$9,500) | $14,400 ($12,500–$16,300) |

*Note:* N = 2,322. Observations are presented as unweighted N. Results are survey weighted unless otherwise noted. All models are adjusted for age, income, payer, rural versus urban residence, and hospital region.

Abbreviations and definitions: Adj, adjusted; OR, odds ratio; CI, confidence interval; DM, diabetes mellitus; HTN, hypertension; NA, not applicable, based on HCUP reporting requirements (<10 cases identified); OR, odds ratio.

[a]Delivery at less than 37 weeks' gestational age.

[b]Predicted means, reported with 95% CIs.

[c]Costs are inflation-adjusted to 2015 US dollars and are reported as predicted means with 95% CIs.