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Research and Applications

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Neighborhood deprivation increases the risk of Post-induction cesarean delivery

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ABSTRACT

Objective: The purpose of this study was to measure the association between neighborhood deprivation and cesarean delivery following labor induction among people delivering at term (≥37 weeks of gestation).

Materials and Methods: We conducted a retrospective cohort study of people ≥37 weeks of gestation, with a live, singleton gestation, who underwent labor induction from 2010 to 2017 at Penn Medicine. We excluded people with a prior cesarean delivery and those with missing geocoding information. Our primary exposure was a nationally validated Area Deprivation Index with scores ranging from 1 to 100 (least to most deprived). We used a generalized linear mixed model to calculate the odds of postinduction cesarean delivery among people in 4 equally-spaced levels of neighborhood deprivation. We also conducted a sensitivity analysis with residential mobility.

Results: Our cohort contained 8672 people receiving an induction at Penn Medicine. After adjustment for confounders, we found that people living in the most deprived neighborhoods were at a 29% increased risk of post–induction cesarean delivery (adjusted odds ratio = 1.29, 95% confidence interval, 1.05–1.57) compared to the least deprived. In a sensitivity analysis, including residential mobility seemed to magnify the effect sizes of the association between neighborhood deprivation and postinduction cesarean delivery, but this information was only available for a subset of people.

Conclusions: People living in neighborhoods with higher deprivation had higher odds of postinduction cesarean delivery compared to people living in less deprived neighborhoods. This work represents an important first step in understanding the impact of disadvantaged neighborhoods on adverse delivery outcomes.

Key words: neighborhood deprivation, labor induction, cesarean delivery, maternal health

INTRODUCTION

Among the over 3.7 million pregnant people who give birth in the United States annually, more than 20% of them will experience a labor induction, making induction one of the most common procedures done during pregnancy.[1–3] Of these inductions, about one-third will end in a cesarean delivery.[4,5] While the definition of a "failed induction" is not as simple as a cesarean delivery after labor induction,[6] a vaginal delivery is often the preferred outcome by pregnant people. We use 'pregnant people' to be inclusive of all genders identified by delivering people. There are many identifiable risk factors for cesarean delivery such as hypertension, obesity, parity, and gestational age, however, 1 plausible systemic risk factor with limited evaluation to date is neighborhood deprivation. Neighborhood deprivation is a measure of a neighborhood's overall access to resources, with high levels of deprivation indicating low access to income, education, and other resources. Additionally, neighborhood deprivation has been associated with poor health outcomes such as cancer[7] and Alzheimer's disease[8] and has been associated with adverse pregnancy outcomes including pregnancy-induced hypertension and preterm birth.[9] Therefore we sought to evaluate the link between neighborhood deprivation and postinduction cesarean delivery.

People of color disproportionately undergo cesarean delivery in the United States. Even when controlling for sociodemographic factors and medical comorbidities, Black people have a 50% increased odds of cesarean delivery when compared to White people.[10,11] We know that these persistent disparities are not genetic in nature, but rather arise from a complex system of elements that include provider-, hospital-, and geographic-level factors that lead to large variations in cesarean delivery rates by race. Longstanding racial residential segregation leads to large differences in neighborhood exposures by race in the United States.[12,13] Indeed, a recent paper by Nardone et al[14] illustrates the deleterious effect of redlining on birth outcomes. Given the interaction of environmental stressors with hormonal pathways,[13,15–18] it is biologically plausible that people from areas of neighborhood deprivation may respond more or less favorably to labor induction. Because differences in cesarean delivery outcomes cannot be attributed to sociodemographic factors and patient comorbidities alone, we must evaluate novel systemic risk factors for increased cesarean risk, such as neighborhood deprivation.

While approximately one-third of labor inductions do end in cesarean deliveries, the ability to predict who will have a vaginal delivery after labor induction has been limited.[5,19,20] An exception is the work of Hamm et al, whose team was able to create a successful risk prediction model for cesarean delivery after induction.[21] While they, and others, have investigated patient-level risk factors such as height, Body Mass Index (BMI), parity, cervical examination findings, and gestational age to estimate risk of cesarean after labor induction,[21,22] studies of the role of neighborhood-level exposures, such as neighborhood deprivation, on labor induction outcome are lacking.

The aim of this study is to evaluate the contribution of neighborhood deprivation on risk of cesarean delivery after labor induction.

MATERIALS AND METHODS

Our study population included people who had a pregnancy-related delivery diagnosis and procedure codes in their University of Pennsylvania Health System (UPHS) EPIC Electronic Health Record

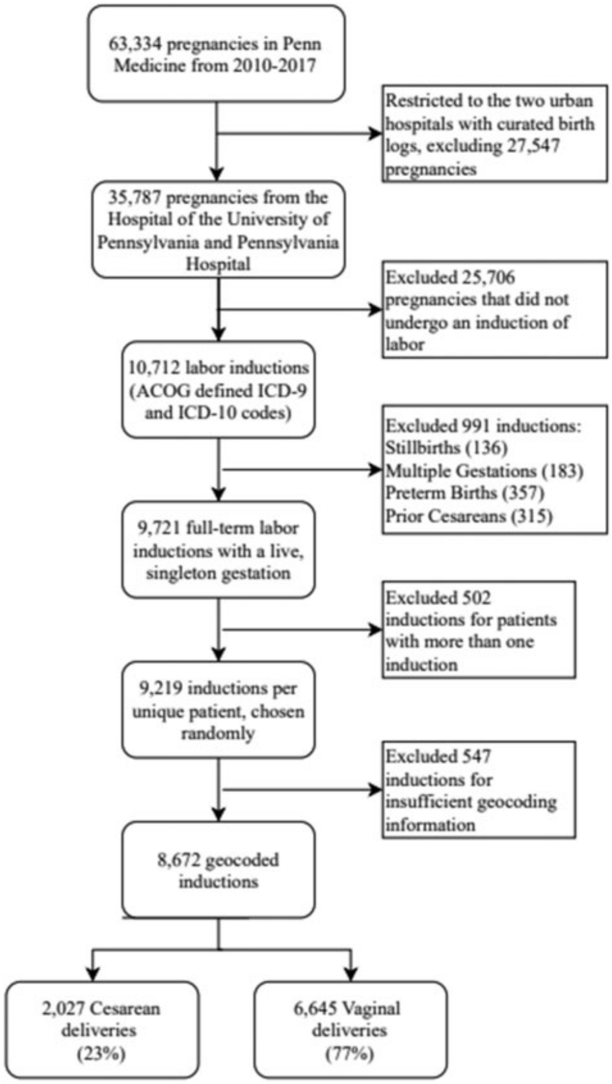

Figure 1. Flow diagram showing final cohort composition, including exclusions and percentage of cesarean deliveries and vaginal deliveries after labor induction.

(EHR) system[23,24] from 2010 to 2017 as well as an International Classification of Diseases versions 9 and 10 codes (ICD-9 and ICD-10) for labor induction validated by the American College of Obstetrics and Gynecologists (Supplementary Appendix S1).[25] We then linked our data with detailed birth logs obtained from 2 hospitals within UPHS, the Hospital of the University of Pennsylvania (Philadelphia, PA) and Pennsylvania Hospital (Philadelphia, PA).[26] We included all people who delivered at term (≥37 weeks) with a live, singleton gestation. We excluded people with a prior cesarean captured in the EHR and people lacking address information precluding geocoding (Figure 1). All individual covariates, such as pregnancy-related hypertension and diabetes, used in this study were defined using ICD-9 and ICD-10 codes. We also identified clinically recognized obesity as those with obesity-related ICD-9 and ICD-10 codes. For people with more than 1 delivery within our health system during the study period, we randomly chose 1 pregnancy in order to achieve independence between deliveries.

The primary outcome for this study was postinduction cesarean delivery for any indication, which was determined using ICD-9 and

ICD-10 codes for cesarean delivery. The primary exposure of interest was neighborhood deprivation. We chose to utilize the University of Wisconsin's Neighborhood Atlas Area Deprivation Index (ADI), composed of 17 education, employment, housing-quality, and poverty measures from long-form Census data and American Community Survey data. We used the ADI national rank score for the United States, which ranges from 1 to 100, with a score of 100 being the highest level of deprivation in the United States and a score of 1 being the lowest.[27] We assigned an ADI score for each of the geocoded, block group geoids based on the latitudes and longitude of address at delivery. For each delivery, we binned the change in deprivation score into 4 levels: lowest deprivation (ADI score of 0–24), moderate deprivation (ADI score of 25–49), high deprivation (an ADI score of 50–74), and highest deprivation (an ADI score of 75–100) using evenly spaced deprivation score categories. Binning of neighborhood deprivation into high versus low categories is commonly done in the literature as it increases interpretability of the results.[7,8]

We utilized a generalized linear mixed model for univariable and multivariable modeling. We first modeled the univariable association between the neighborhood deprivation levels and postinduction cesarean delivery. Based on clinical knowledge and plausibility, gestational age and parity were chosen *a priori* to be included in the multivariable model, regardless of their significance. We then sought to assess the level of confounding for the additional remaining individual-level covariates, including: pregnancy-related hypertension, diabetes, obesity, marital status, race/ethnicity, and patient age at time of delivery. We evaluated whether these variables confounded the association of neighborhood deprivation and cesarean delivery by adding them individually into the univariable model of neighborhood deprivation and postinduction cesarean delivery and assessing whether the most significant effect size for the association between ADI categories and postinduction cesarean delivery changed by about 10%. Based upon these determinations for confounding we built a parsimonious multivariable model. We then added back in the other variables to check to see if they further confounded the association. Those that did were then added into the multivariable model.

Our multivariable mixed-level model included a random effect for neighborhood to account for neighborhood clustering. As a secondary analysis, we also modeled neighborhood deprivation as a nonlinear spline, allowing for greater flexibility of the variable in modeling the association with postinduction cesarean, and to show the rationale behind the cutoffs we chose for the neighborhood deprivation categories in the mixed-level analysis.

We used R version 3.6.1 for all analysis. Major packages utilized for analysis include: tidyverse,[28] dplyr,[29] stats,[30] mgcv,[31] cowplot,[32] and ggplot2.[33] The University of Pennsylvania's Institutional Review Board approved this study.

RESULTS

We derived a cohort of 63 334 pregnant people from the UPHS health system.[24] We linked this with a birth log cohort obtained from the Hospital of the University of Pennsylvania and Pennsylvania Hospital from 2010 to 2017 resulting in a cohort of 35 787 people. After applying our inclusion and exclusion criteria, 24% of these people remained in our final cohort of 8672 inductions. The postinduction delivery outcomes included 2,027 cesarean deliveries (23%) and 6645 vaginal deliveries (77%). The average patient age at time of delivery was 28.4 ± 6.2 years. The predominant race self-designations were Black or African American, comprising 58% of people, and White, 30% of people. The majority of people reported their marital status as single (64%). In this cohort, 5% of people had diabetes, 18% had pregnancy-related hypertension, and 22% were clinically coded as obese (Table 1).

We found that living in neighborhoods with moderate, high, and highest levels of neighborhood deprivation resulted in elevated adjusted odds ratios (ORs) for postinduction cesarean delivery compared to the lowest level of neighborhood deprivation. The odds of postinduction cesarean delivery were elevated by 29% for the highest level of deprivation (95% confidence interval [CI], 1.05–1.57), 28% for the second highest-level (95% CI, 1.04–1.57), and 20% for the third highest or moderate level (1.00–1.44) (Table 2). The random effect for neighborhood clustering was not significant at an alpha level of 0.05 (P-value = .64). Unadjusted or crude ORs are also presented in Table 2, but are less clinically meaningful. Our models adjusted for individual-level confounders for postinduction cesarean delivery including parity, gestational age, disease status (obesity, diabetes, and pregnancy-related hypertension), patient age, race/ethnicity, and marital status.

We included race/ethnicity at the individual level in our full adjusted model of neighborhood deprivation on postinduction cesarean delivery. We included this important individual-level factor not because we believe that race/ethnicity plays a biological role in the association but to account for other factors of racism that are not captured via neighborhood deprivation. Race/ethnicity did change the most significant effect size by greater than 10%, and thus we included it in the model despite our belief that race/ethnicity's influence on postinduction cesarean delivery is not biological in nature, but rather due to systemic racism.

Our secondary analysis modeling neighborhood deprivation as a nonlinear spline also showed an increase in odds of postinduction cesarean delivery with increased neighborhood deprivation (Figure 2). We include this analysis to show that neighborhood deprivation and postinduction cesarean delivery are largely linearly related and not purely dependent on how we binned neighborhood deprivation levels in 4 categories. Lastly, we conducted a sensitivity analysis by running this multivariable model on a sub-population for whom we have residential mobility data, as defined by an address change within 1-year prior of delivery. By including residential mobility in the model in this subgroup, the effect sizes for neighborhood deprivation are increased across all levels (Supplementary Appendix S2). A table with the results from each of the 3 models is included in the Supplementary Appendix S3.

DISCUSSION

We studied the effect of neighborhood deprivation on postinduction cesarean delivery, accounting for individual level characteristics. We found that people living in neighborhoods with the highest deprivation scores (75–100) had the highest odds of postinduction cesarean delivery versus those living in areas experiencing the lowest levels of deprivation (0–24). Importantly, our work expands to risk factors beyond the traditional demographic and clinical factors normally considered when considering risk of postinduction cesarean delivery.[19,20,22]

This study illustrates that there is an association between levels of residential deprivation where one lives, even when adjusting for individual-level covariates. The idea that chronic and acute stress has physical implications for people is not new, a phenomenon that particularly affects people of color. Therefore, it is plausible that liv-

Table 1. Demographics for people[a] who underwent a labor induction between 2010 and 2017

Demographic	Total labor inductions ($n = 8672$) n (%)	Cesarean ($n = 2027$) n (%)	Vaginal ($n = 6645$) n (%)	P-values
Neighborhood deprivation				
Highest (75–100)	3863 (45)	865 (43)	2988 (45)	.05
High (50–74)	1637 (19)	399 (20)	1238 (19)	
Moderate (25–49)	1508 (17)	387 (19)	1121 (17)	
Lowest (0–24)	1664 (19)	376 (19)	1288 (20)	
Marital status				
Single	5534 (64)	1301 (64)	4233 (64)	.71
Married	3138 (36)	726 (36)	2414 (36)	
Age at time of delivery (years)	Mean 28.4 (SD: 6.2)	Mean 28.8 (SD: 6.5)	Mean 28.4 (SD: 6.1)	.01
Ethnicity				
Hispanic (vs non-Hispanic)	547 (6)	128 (6)	419 (6)	1.00
Race				
American Indian or Alaskan native	8 (0)	2 (0)	6 (0)	.51
Asian	567 (7)	145 (7)	422 (6)	
Black or African American	5023 (58)	1165 (58)	3858 (58)	
Native Hawaiian or other Pacific Islander	9 (0)	4 (0)	5 (0)	
White	2626 (30)	606 (30)	2020 (30)	
Unknown	164 (2)	44 (2)	120 (2)	
Other	275 (3)	61 (3)	214 (3)	
Diabetes (vs no diabetes)	439 (5)	122 (6)	317 (5)	.03
Pregnancy-related hypertensions (vs not)	1528 (18)	470 (23)	1058 (16)	<.001
Obesity (vs not obese)	1969 (22)	626 (31)	1343 (20)	<.001

Data presented as n (column %) unless otherwise specified.
[a]For people with multiple pregnancies, a pregnancy was chosen at random to ensure that each woman is represented only once in the model.
SD: standard deviation.

Table 2. Associations between neighborhood deprivation and cesarean delivery following labor induction

Covariate	Cesarean rate (%)	Crude OR	95% CI	Adjusted OR[a]	95% CI
Neighborhood deprivation					
Highest (75–100)	22.39	0.90	0.78–1.03	1.29	1.05–1.57
High (50–74)	24.37	1.07	0.91–1.26	1.28	1.04–1.57
Moderate (25–49)	25.66	0.91	0.77–1.06	1.20	1.00–1.44
Lowest (0–24)	22.60	1.00	Reference	1.00	Reference
Comorbidities					
Diabetes (vs no diabetes)	27.79	1.30	1.03–1.58	1.10	0.85–1.43
Pregnancy-related hypertensions (vs not)	30.76	1.59	1.41–1.80	1.70	1.47–1.97
Obesity (vs not obese)	31.79	1.76	1.58–1.97	1.95	1.70–2.23

[a]Additionally adjusted for maternal age (continuous), race/ethnicity, parity, gestational age, and marital status.
CI: confidence interval; OR: odds ratio.

ing in a stressful neighborhood, for example, one with high levels of neighborhood deprivation might impact delivery outcomes. Research by Krieger et al has demonstrated the effect of neighborhood deprivation on other health outcomes such as cancer,[34,35] assaults,[36] and excess mortality.[37] Work has also been done demonstrating the effect of neighborhood deprivation on pregnancy-related outcomes, such as preterm birth and low birth rate.[9] We add to the literature by evaluating the role of neighborhood deprivation in postinduction outcomes. Additionally, the result of our sensitivity analysis assessing the role of residential mobility on adverse postinduction outcomes suggests that mobility during pregnancy amplifies the effect of neighborhood deprivation.[38]

A major strength of our study is our large sample size of inductions (almost 9000 labor inductions) and our cohort comes from a diverse spectrum of neighborhood deprivation levels with some areas surrounding Philadelphia having very low levels of deprivation and some areas in inner city Philadelphia experiencing very high levels of neighborhood deprivation. This large spread of deprivation levels in terms of our exposure of interest was crucial for our models. In addition, the majority are people of color. Therefore, in addition to the diversity in terms of neighborhood deprivation exposures, there was also significant racial/ethnic diversity in our cohort. Our diverse cohort was made possible in part due to our utilization of a validated algorithm to identify deliveries within our

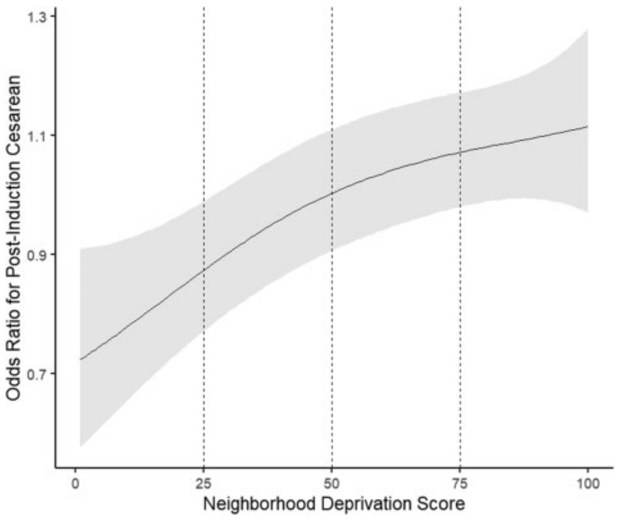

Figure 2. Association between neighborhood deprivation and odds of postinduction cesarean delivery. Model adjusted for parity, gestational age, race/ethnicity, patient age, obesity, pregnancy-related hypertension, diabetes, and marital status, with a random effect for neighborhood. Each point on the curve is the OR for people with that neighborhood deprivation score compared to all other people. Vertical dashed lines represent the binning of deprivation score in the primary generalized linear mixed model analysis.

health system's EHR, ensuring that we captured all people, allowing for our large cohort size with which to evaluate outcomes of induction.

Importantly, our study assesses the role of neighborhood deprivation on postinduction cesarean delivery as an adverse outcome of induction. We found that people from more deprived neighborhoods were at greater risk of postinduction cesarean delivery after adjusting for a multitude of confounders already known to increase risk, including race/ethnicity. We included race/ethnicity in our models, understanding that race/ethnicity and its role on postinduction cesarean delivery is not due to biological differences. Rather, in this case, race/ethnicity at the individual-level serves as a proxy for socioeconomic disparities, namely racism (both structural and direct against the individual), and other factors of living as a person of color that are not directly captured in our neighborhood deprivation score. Disparities among postinduction outcomes exist for a multitude of reasons. We explore one such potential mechanism underlying this difference—namely, neighborhood deprivation. Our exposure, neighborhood deprivation, is a product of structural racism, and explains only part of the racial disparities that exist in healthcare.[39] It is critical to note that neighborhood disparities are largely driven by inequitable policy, which is a systemic and social problem, not one over which the individual has control. We retained race/ethnicity in our fully adjusted model to address the racism that individuals may experience at the individual level, which may differ from the neighborhood-level deprivation that exists due to structural racism.

Limitations of utilizing EHR data include our reliance on coding for billing purposes and therefore our study is subject to misclassification due to coding biases. Additionally, important clinical factors that have been demonstrated to be predictors of cesarean (eg, cervical exam) were not available to us for the purposes of this study and therefore it is unclear how results may have been changed with inclusion of these parameters. We use the term, "pregnant people" in this paper to be inclusive of all delivering people. It is critical as the space of maternal health changes, that those who do research in this area can adapt their language to correctly reflect the identities of those who comprise the space. Thus, while most delivering people might identify as a 'woman', some will not, therefore the term "delivering people" or "pregnant people" is more apt. This is especially true due to the limitations of the EHR to capture accurate sex and gender data. Therefore, we are unable at this point to determine whether individuals' are transgender, cis-gender, nonbinary, and so forth. We do not want to make any assumptions of an individual with this regard, focusing rather on pregnant people who delivered at our health system. Future work could investigate the role of intersectionality between neighborhood deprivation and various marginalized sex and gender, and racial and ethnic groups. These groups may experience greater amounts of disparities overall.

Finally, residential mobility amplifies the association between neighborhood deprivation and cesarean delivery after induction; however, we did not have this data for the full cohort, and therefore this analysis exists only for a subset of our cohort as a sensitivity analysis.[38] In the future, we think that a qualitative, or multiple-methods study, would be well-suited to understanding further the nuances of this complicated and important topic of outcomes of labor induction.

In conclusion, this study assesses the role of structural neighborhood deprivation on labor induction outcomes. In finding that neighborhood deprivation is associated with postinduction cesarean delivery, we are able to illustrate that neighborhood context may be important to the health of those delivering. Given that labor inductions are one of the most commonly performed procedures during pregnancy, and that cesarean deliveries are associated with increased morbidity, it is important that research continues to better identify individual and neighborhood-level risk factors of postinduction cesarean delivery.[39] Importantly, the finding of a clear association with neighborhood deprivation and increased postinduction cesarean risk can inform public health practitioners and policy makers about the importance of evaluating risks among those from less-advantaged neighborhoods and improving neighborhood conditions through the remediation of antiquated inequitable policy, respectively.

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AUTHOR CONTRIBUTIONS

Conceived study design by J.R.M. and M.R.B.

J.R.M., M.R.B., H.H.B., L.D.L., and R.B. developed the methodology.

H.H.B. and L.D.L. provided clinical and epidemiological advice pertinent to study problem.

J.R.M. and M.R.B. wrote the paper.

Reviewed, edited, and approved manuscript by J.R.M., H.H.B., L.D.L., R.B., and M.R.B.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *Journal of the American Medical Informatics Association* online.

CONFLICT OF INTEREST STATEMENT

The authors do not report any potential conflicts of interest. Each author has confirmed compliance with the journal's requirements for authorship.

DATA AVAILABILITY

This study consists of retrospective analysis of existing Electronic Health Record data and as such contains protected Patient Health Information. Institutional Review Board approval was granted. However, the raw data used as part of this project are not available to the general public.

REFERENCES

1. Osterman MJK, Martin JA. Recent Declines in Induction of Labor by Gestational Age. Hyattsville, MD: US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics; 2014.
2. WHO. *Recommendations for Induction of Labour*. Geneva, Switzerland: World Health Organization; 2011.
3. Hamilton BE, Martin JA, Osterman MJK. Births: Provisional Data for 2019. Vital Statistics Rapid Release. 2020. Report No. 008. https://www.cdc.gov/nchs/data/vsrr/vsrr-8-508.pdf Accessed December 16, 2020.
4. Rouse DJ, Weiner SJ, Bloom SL, *et al.* Failed labor induction: toward an objective diagnosis. *Obstet Gynecol.* 2011; 117 (2 Pt 1): 267–72.
5. Vahratian A, Zhang J, Troendle JF, Sciscione AC, Hoffman MK. Labor progression and risk of cesarean delivery in electively induced nulliparas. *Obstet Gynecol*. 2005; 105 (4): 698–704.
6. Grobman WA, Bailit J, Lai Y, *et al.* Defining failed induction of labor. *Am J Obstet Gynecol*. 2018; 218 (1): 122 e1–e8.
7. Mora J, Krepline AN, Aldakkak M, *et al.* Adjuvant therapy rates and overall survival in patients with localized pancreatic cancer from high Area Deprivation Index neighborhoods. *Am J Surg*. 2020; 222: 10–17.
8. Powell WR, Buckingham WR, Larson JL, *et al.* Association of neighborhood-level disadvantage with Alzheimer disease neuropathology. *JAMA Netw Open* 2020; 3 (6): e207559.
9. Vinikoor-Imler LC, Messer LC, Evenson KR, *et al.* Neighborhood conditions are associated with maternal health behaviors and pregnancy outcomes. *Soc Sci Med*. 2011; 73 (9): 1302–11.
10. Moaddab A, Dildy GA, Brown HL, *et al.* Health care disparity and pregnancy-related mortality in the United States, 2005–2014. *Obstet Gynecol*. 2018; 131 (4): 707–12.
11. Stark EL, Grobman WA, Miller ES. The association between maternal race and ethnicity and risk factors for primary cesarean delivery in nulliparous women. *Am J Perinatol.* 2021; 38 (4): 350–6.
12. Burris HH, Hacker MR. Birth outcome racial disparities: a result of intersecting social and environmental factors. In: Saunders WB, ed. *Seminars in Perinatology*. Amsterdam, Netherlands: Elsevier; 2017; 41 (6): 360–6.
13. Mehra R, Boyd LM, Ickovics JR. Racial residential segregation and adverse birth outcomes: a systematic review and meta-analysis. *Soc Sci Med.* 2017; 191: 237–50.
14. Nardone AL, Casey JA, Rudolph KE, *et al.* Associations between historical redlining and birth outcomes from 2006 through 2015 in California. *PLoS One*. 2020; 15 (8): e0237241.
15. Patisaul HB, Adewale HB. Long-term effects of environmental endocrine disruptors on reproductive physiology and behavior. *Front Behav Neurosci.* 2009; 3: 10.
16. Henson MC, Chedrese PJ. Endocrine disruption by cadmium, a common environmental toxicant with paradoxical effects on reproduction. *Exp Biol Med (Maywood)*. 2004; 229 (5): 383–92.
17. Whirledge S, Cidlowski JA. Glucocorticoids, stress, and fertility. *Minerva Endocrinol.* 2010; 35 (2): 109–25.
18. Harris A, Seckl J. Glucocorticoids, prenatal stress and the programming of disease. *Horm Behav.* 2011; 59 (3): 279–89.
19. Grobman WA. Predictors of induction success. In: Saunders WB, ed. *Seminars in Perinatology*. Amsterdam, Netherlands: Elsevier; 2012; 36 (5): 344–7.
20. Tolcher MC. *Predicting Cesarean Delivery following Induction*. Larchmont, NY: Mary Ann Liebert, Inc.; 2020.
21. Hamm R, Downes K, Srinivas S, *et al.* Using the probability of cesarean from a validated cesarean prediction calculator to predict labor length and morbidity. *Am J Perinatol*. 2019; 36 (6): 561–6.
22. Levine LD, Downes KL, Parry S, *et al.* A validated calculator to estimate risk of cesarean after an induction of labor with an unfavorable cervix. *Am J Obst Gynecol*. 2018; 218 (2): 254.e1–e7.
23. Alur-Gupta S, Boland MR, Sammel MD, *et al.* Higher incidence of postpartum complications in women with polycystic ovary syndrome. *Fertil Steril*. 2019; 112 (3): e39.
24. Canelón SP, Burris HH, Levine LD, Boland MR. Development and evaluation of MADDIE: method to acquire delivery date information from electronic health records. *Int J Med Inform.* 2020; 145: 104339.
25. Main E. ICD-10-PCS coding advice for labor inductions. In: *A Review of ACOG Guidelines*. Stanford: CMQCC; 2016: 1–3. https://www.cmqcc.org/sites/default/files/ICD10%20Labor%20Induction%20FINAL_8.3.16.pdf.
26. Boland MR, Alur-Gupta S, Levine L, *et al.* Disease associations depend on visit type: results from a visit-wide association study. *BioData Min*. 2019; 12: 15.
27. Kind AJ, Buckingham WR. Making neighborhood-disadvantage metrics accessible—the neighborhood atlas. *N Engl J Med.* 2018; 378 (26): 2456–8.
28. Wickham H. Tidyverse: Easily Install and Load the 'Tidyverse'. 2017. https://CRAN.R-project.org/package=tidyverse Accessed December 16, 2020.
29. Wickham H, François R, Henry L, Müller K. dplyr: A Grammar of Data Manipulation. R package version 1.0.7. 2021. https://CRAN.R-project.org/package=dplyr.
30. R Development Core Team. *A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing; 2019.
31. Wood SN. Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. *J Royal Stat Soc (B)*. 2011; 73 (1): 3–36.
32. Wilke CO. cowplot: Streamlined Plot Theme and Plot Annotations for 'ggplot2'. R package version 1.1.1. 2020. https://cran.r-project.org/web/packages/cowplot/index.html.
33. Wickham H. *ggplot2: Elegant Graphics for Data Analysis*. New York, NY: Springer-Verlag New York; 2016.
34. Scally BJ, Krieger N, Chen JT. Racialized economic segregation and stage at diagnosis of colorectal cancer in the United States. *Cancer Causes Control*. 2018; 29 (6): 527–37.
35. Krieger N, Feldman JM, Kim R, *et al.* Cancer incidence and multilevel measures of residential economic and racial segregation for cancer registries. *JNCI Cancer Spectr*. 2018; 2 (1): pky009.
36. Krieger N, Feldman JM, Waterman PD, *et al.* Local residential segregation matters: stronger association of census tract compared to conventional city-level measures with fatal and non-fatal assaults (total and firearm related), using the index of concentration at the extremes (ICE) for racial, economic, and racialized economic segregation, Massachusetts (US), 1995–2010. *J Urban Health* 2017; 94 (2): 244–58.
37. Subramanian SV, Chen JT, Rehkopf DH, *et al.* Racial disparities in context: a multilevel analysis of neighborhood variations in poverty and excess mortality among black populations in Massachusetts. *Am J Public Health* 2005; 95 (2): 260–5.
38. Meeker JR, Burris H, Boland MR. An algorithm to identify residential mobility from electronic health-record data [published online ahead of print Apr 14, 2021]. *Int J Epidemiol*. 2021. doi: 10.1093/ije/dyab064.
39. Meeker JR, Canelón SP, Bai R, *et al.* Individual-level and neighborhood-level risk factors for severe maternal morbidity. *Obstet Gynecol*. 2021; 137 (5): 847–54.