Spatial Diffusion of Elective Obstetric Interventions: A Population-Wide Study of New Jersey

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The rates of obstetric interventions have been rising in the U.S. during the past three decades: Cesarean-sections (C-sections) account for only 5% of all births in 1970 and now over 1/3, and induction has increased by 159% between 1990 and 2015 (Reichman et al. 2018). Changes in risk factors including obesity and multiple births cannot explain this rise of obstetric interventions (Declercq, Menacker and Macdorman 2006). "Elective" (non-medically necessary) interventions presumably explains at least 50% of the increase in C-sections in the U.S. between 1998 and 2010 (Menacker and Hamilton 2010).

Why has elective delivery rate increased drastically? Previous research has examined the role of supply side factors, e.g., different reimbursement rates between public and private insurance and malpractice liability caps (Currie and MacLeod 2008; Gruber, Kim and Mayzlin 1999). Although demand side factors are also thought to play a role in driving up rates of C-sections and inductions, the evidence in this regard is almost exclusively anecdotal. NIH (2006) pointed to a number of maternal factors that may be important, highlighting that few data are available to facilitate an understanding of the role of these factors. These include a desire to be in control of the birth process; fear of labor and delivery; scheduling issues surrounding work and childcare; ensuring that a specific doctor will be present during labor and delivery; concerns about quality of life after childbirth; and a potential "vicious cycle" wherein increasing rates of C-sections may result in C-sections being perceived as the norm. Many of these potential explanations could apply to inductions as well. The panel also suggested that shifts in obstetrical practice away from vaginal breech deliveries and vaginal deliveries after C-sections may have further contributed to societal acceptance of C- sections (NIH 2006). Baicker et al (2006) found that in areas with higher C-section rates, the procedure is performed more often in "medically less appropriate" situations; this finding provides some support for a "vicious cycle" and "contagion" effect.

This study exploits the spatial variations of elective deliveries to pinpoint the sources of the large increases. Spatial clustering can reflect selection, diffusion processes, or shared environments (Manski 1993). Women who have elective deliveries may select the same neighborhoods, those who live in the same neighborhoods may influence each other's behaviors, and those who live in the same neighborhoods may be influenced by local institutions (hospitals, providers). Using a unique population-wide dataset with information on hospital and physician identifiers, patient's address, and detailed clinical information that allows us to classify if a birth is low-risk and likely to be medically unnecessary, we seek to determine if social diffusion has contributed to the rise of elective deliveries.

Significance

The increases in elective C-sections and inductions has been speculated to be responsible for the decrease in gestational age (GA). Long GA (40 or even 41 weeks) has positive impacts to child health and development (Noble et al. 2012; Reichman et al. 2015; Rose et al. 2013). Understanding the reason for the rise of elective deliveries has public health implications.

Data

The New Jersey (NJ) Electronic Birth Certificate & Perinatal Database includes records for all births in the state from 1997–2011 (>1.7 million births). We linked these records to the mothers' and infants' hospital discharge records from the birth hospitalization. Because the birth and discharge records are from separate systems and collected for different purposes, we used probabilistic matching, with 93% of the birth records matching to maternal discharge records and 92% of the birth records matching to infant discharge records.

The matching allows us to identify the attending physician using their names and license number on the discharge record.

We define the low-risk population for elective deliveries following the Joint Commission's recommendations.[1] Women having singleton first births, not having any of the ICD-9 codes on the Joint Commission lists, not having had premature rupture of the membranes, not having had prior uterine surgery, not having had a trial of labor (except when labor was induced), and having an infant with GA between 37 and 40 completed weeks.

The restriction to first births is necessary because having a C-section for one birth almost guarantees that subsequent births will be C-sections. The ICD-9 exclusion restrictions have been validated in previous work. We excluded births with 41 weeks GA because many of those would be close to 42 weeks (e.g., 41 weeks plus 6 days), and thus on the margin for medically indicated inductions, and no method of assessing of GA is accurate to the day. Under these criteria, about 10% of all births in NJ is included in our low-risk sample.

Statistical analyses

The preliminary results presented below are based on Kulldorff's Spatial Scan Statistic (Kulldorff 1999) to identify zip codes with a significant excess of obstetric interventions among low risk birth in 1998-2010.

We also fit logistic regression models on the likelihood of a low-risk mother having a C-section without induction. Our key independent variable is (1) the distance to the nearest mother who had a C-section without induction[2] within the 10-month period prior to the birth. For comparison, we also include (2) the distance to the nearest mother who had a birth *without* any obstetric intervention in the same model. If there is a social diffusion of obstetric interventions, we should only observe an effect associated with (1) but not (2).

To rule out selection effects, we then introduce a range of individual-level covariates. We control for year of birth, gender and gestational age in weeks of the child. We control for the following characteristics of the mother: foreign born (Y/N), married(Y/N), Medicaid(Y/N), smoked(Y/N), mother's age categories (<21, 21-34, 35+) mother's race (non-Hispanic (NH) white, NH African American, and others), and education level (<high school, graduated from high school, some college, graduated from college). 2-level models are then used to control for hospital and attending physician random effects.

To sum up, if there exists a process of social diffusion of elective interventions through interactions and that process is related to residential proximity, the effect of living close to other mothers who had obstetric interventions should remain significant after controlling for individual factors and provider random effects.

Preliminary results

The left panel of Figure 1 shows the % of obstetric interventions (both inductions and C-sections) among low-risk births by zip code in 1998-2010. Spatial Scan Statistic confirms that elective deliveries are not distributed randomly over space (right panel).

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[1] The Joint Commission's Specifications Manual for Joint Commission National Quality Core Measures.

[2] This calculation is done with the complete NJ birth record data and regardless of whether the neighbor's birth is low risk or not. We assume mothers in our low-risk sample do not have information on neighbors' medical risk.

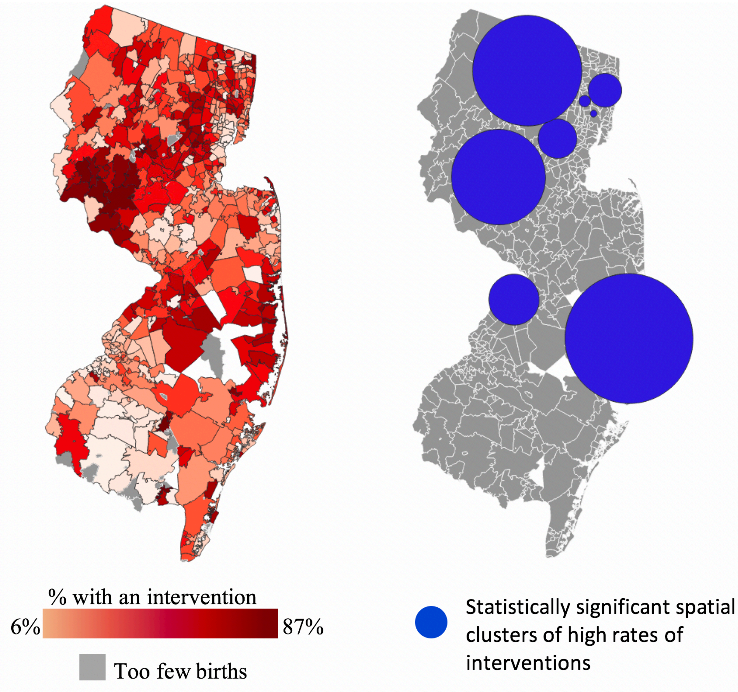

Figure 1. spatial pattern of obstetric interventions among low medical risk births, New Jersey, 1998-2010

As mentioned above, the spatial patterns we see in Figure 1 could have been driven by selection, diffusion, or shared enviroments. Figure 2 report results from logistic regression models controling for some of the potential selection and shared environment effects.

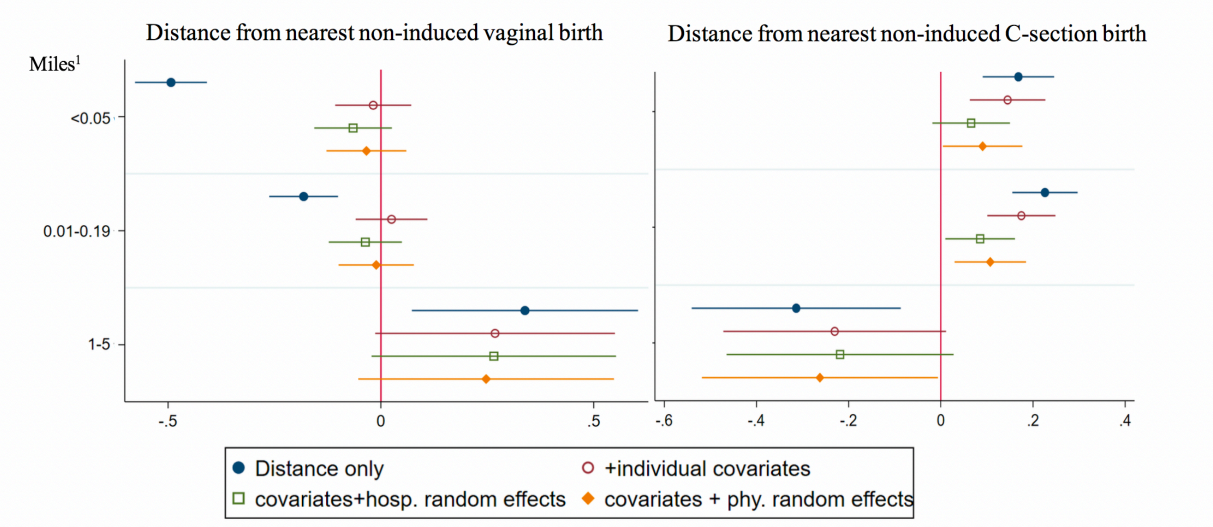

Figure 2. Effects of nearest distance to mothers by delivery method on non-induced C-section, Low-risk sample, New Jersey, 2007-2010

1. Reference category: 0.20-0.99 miles; N=114,597

The left panel of Figure 2 shows that the distance to the nearest mother who had a non-induced C-section is positively associated with the odds of using the same delivery method despite low medical risk. Compared to the reference category (0.20-0.99 miles), living <0.2 miles from someone who had a non-induced C-section has a positive effect on the log-odds of an non-induced C-section. Living >1 mile away has the opposite effect as expected. The 2nd model shows that including individual covariates in the model only leads to small reductions in the effect sizes. The 3rd and 4th models shows that controlling for hopsital or physican random effects also only had limited impacts.

The right panel of Figure 2 shows that living in close proximity to someone who had a birth without intervention appears to have a negative effect of non-induced C-section. However, the effects are no longer satistically significant after controling for the indivdiual correlates in our model. In constrast, the effects of proximity to mothers who also had an non-induced C-section are robust to the inclusion of the control variables and the random effects.

Conclusion

The prelimiary results suggest the positive effect of proximity to other C-sections on the chance of an elective C-section cannot be readily explained by observed socioecnomic factors or hospital/ physican random effects. This paper will further evaluate the extent to which the spatial clustering of elective deliveries might reflect other individual and provider factors that are not examined here, e.g., provider networks. We will also consider dose-response and threshold effects related to the recent-ness of neighbors' elective deliveries and density of elective deliveries in neighborhoods.

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References:

Baicker, K. , K.S. Buckles, and A. Chandra. 2006. "Geographic Variation In The Appropriate Use Of Cesarean Delivery." *Health Affairs* 25(5):w355-w67.

Currie, Janet, and W. Bentley MacLeod. 2008. "First Do No Harm? Tort Reform and Birth Outcomes*." *The Quarterly Journal of Economics* 123(2):795-830.

Declercq, E., F. Menacker, and M. Macdorman. 2006. "Maternal risk profiles and the primary cesarean rate in the United States, 1991-2002." *Am J Public Health* 96(5):867-72.

Gruber, J., J. Kim, and D. Mayzlin. 1999. "Physician fees and procedure intensity: the case of cesarean delivery." *J Health Econ* 18(4):473-90.

Kulldorff, Martin. 1999. "Spatial Scan Statistics: Models,Calculations, and Applications." Pp. 303-22 in *Scan Statistics and Applications*, edited by Joseph Glaz and N. Balakrishnan: Birkhäuser Boston.

Manski, Charles F. 1993. "Identification of Endogenous Social Effects: The Reflection Problem." *Review of Economic Studies* 60(3):531-42.

Menacker, F., and B. E. Hamilton. 2010. "Recent trends in cesarean delivery in the United States." *NCHS Data Brief* (35):1-8.

Noble, Kimberly G., William P. Fifer, Virginia A. Rauh, Yoko Nomura, and Howard F. Andrews. 2012. "Academic Achievement Varies With Gestational Age Among Children Born at Term." *Pediatrics* 130(2):e257-e64.

Reichman, N, J Teitler, R Plaza, L Kruse, and T Hegyi 2018. "Elective Deliveries Increase Neonatal Morbidities and Costs in Full-Term Pregnancies. Working paper."

Reichman, N. E., J. O. Teitler, S. Moullin, B. M. Ostfeld, and T. Hegyi. 2015. "Late-preterm birth and neonatal morbidities: population-level and within-family estimates." *Ann Epidemiol* 25(2):126-32.

Rose, Olga, Estela Blanco, Suzanna M. Martinez, Eastern Kang Sim, Marcela Castillo, Betsy Lozoff, Yvonne E. Vaucher, and Sheila Gahagan. 2013. "Developmental Scores at 1 Year With Increasing Gestational Age, 37–41 Weeks." *Pediatrics* 131(5):e1475-e81.