ARTICLE

Physician cesarean delivery rates and severe perinatal morbidity among low-risk nulliparas

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OBJECTIVE: To estimate the individual physician cesarean delivery rate associated with serious perinatal morbidity.
STUDY DESIGN: Study of nulliparous, term, singleton, vertex deliveries with maternal-neonatal dyad data (2015–2017) in the MarketScan Research Database. An individual cesarean delivery rate was calculated for all delivering physicians. The primary maternal outcome included transfusion of ≥4 units of blood, intensive care unit (ICU) admission, venous thromboembolism, or hysterectomy. The primary neonatal outcome included hypoxic ischemic encephalopathy, seizure, cardiopulmonary resuscitation or ventilator use (within 24 h), or ICU admission. Multivariable modeling of the association between physician cesarean delivery rate and each outcome was performed.
RESULTS: Among 77,058 maternal-neonatal dyads, the maternal composite occurred in 1.3% of deliveries and neonatal composite in 3.6% of deliveries. The likelihood of the maternal (aOR 1.03 for each 3% increase in physician cesarean delivery rate, 95% CI 1.021–1.043) and neonatal (aOR 1.02 for each 3% increase, 95% CI 1.014–1.027) composite outcome increased linearly with increasing physician cesarean delivery rate.
CONCLUSIONS: Severe perinatal morbidity was associated with increasing individual physician cesarean delivery rates.

Journal of Perinatology (2023) 43:34–38; https://doi.org/10.1038/s41372-022-01540-0

INTRODUCTION

Cesarean delivery is associated with significant maternal morbidity [1–5]. While cesarean delivery may have selected neonatal benefits, increasing cesarean rates nationally have not resulted in a reduction in neonatal morbidity or mortality [1, 6, 7]. In the absence of clear benefit, multiple organizations have developed clinical care guidelines, toolkits, and safety bundles focused on reducing cesarean rates [8–10].

Healthy People 2020 published goals including a reduction in first time and repeat cesarean delivery in low risk individuals to 24.7% and 81.7%, respectively [11]. However, these efforts at cesarean rate reduction are lacking an evidence-based target that minimizes perinatal morbidity. Molina et al. identified a cesarean delivery rate of 19% as the rate associated with the lowest maternal and neonatal mortality at a world-wide level using cross-sectional data from 54 countries [12]. It remains unclear what cesarean delivery rate is associated with a nadir in maternal and neonatal mortality and morbidity in a resource-rich setting.

Particular focus has been devoted to reducing cesarean delivery rates among the nulliparous, term, singleton, vertex (NTSV) population [13, 14]. Use of this "low risk" population for quality metrics reduces hospital- and regional-level variation in cesarean rates driven by patient risk factors [13, 15]. Reduction in this group also reduces the downstream effects of multiple cesarean deliveries. Therefore, state quality collaboratives have focused on reduction in the NTSV cesarean delivery rate [9–11]. Yet, evidence-based targets are needed. We aimed to estimate the individual physician cesarean delivery rate that is associated with serious maternal and neonatal morbidity in a retrospective U.S. cohort of low-risk NTSV pregnancies.

METHODS

This was a retrospective cohort study of all nulliparous, live, non-anomalous, term, singleton, vertex deliveries with maternal-neonatal dyad data available from January 1, 2015 to December 31, 2017 in the IBM® MarketScan Research Database. MarketScan contains deidentified patient information from commercial health insurance claims for all U.S. states.

All deliveries >20 weeks' gestation were identified within the MarketScan database during the study period using a validated algorithm for delivery identification by International Classification of Diseases 10th edition (ICD-10) codes [16]. Only the first delivery encounter for a given individual was included. Those deliveries categorized as "high risk" by the Society for Maternal Fetal Medicine (SMFM) diagnostic code definition were excluded [14]. The SMFM classification is adapted from the Joint Commission and Agency for Healthcare Research and Quality (AHRQ) ICD-based definitions for the NTSV population [13, 14]. Application of these codes excluded pregnancies with contraindication to vaginal delivery (e.g., placenta previa, malpresentation), multifetal pregnancies, and pregnancies with conditions associated with high risk for cesarean delivery (e.g., fetal growth restriction, alloimmunization, preeclampsia). See Appendix 1 for the full list of conditions excluded as adapted from the SMFM "high risk" definition [14]. The analysis was further limited to nulliparous individuals and pregnancies without known fetal anomalies [14, 17].

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Received: 9 August 2022 Revised: 9 October 2022 Accepted: 11 October 2022
Published online: 27 October 2022

MarketScan contains encrypted National Provider Identifier (NPI) data which allows individual practitioners to be tracked in a deidentified fashion over time. For all delivering physicians with ≥5 deliveries, their NPI was used to associate them with individual births. The total number of births for a single physician and the proportion that were cesarean deliveries were used to calculate an individual physician cesarean delivery rate. The lower delivery threshold (≥5 deliveries) was selected as delivery volume below this threshold was not thought to be adequate for calculation of an individual physician cesarean delivery rate with any reasonable precision.

The primary composite maternal outcome included transfusion of ≥4 units blood products, intensive care unit (ICU) admission, venous thromboembolism (VTE), or hysterectomy within 6 weeks postpartum. MarketScan revenue claims link paid insurance claims to inpatient and outpatient services provided [18]. For example, use of revenue claims allows for identification of inpatient admission unit type (e.g., intensive care unit), hospital procedures (e.g., ventilator use), and blood transfusion (e.g., quantified amounts and type). In order to improve outcome and co-variate ascertainment, both ICD-10 and revenue claims data were used as informed by existing literature and MarketScan database informatics. Maternal blood transfusion and ICU admission were identified using MarketScan revenue claims. VTE and hysterectomy were ascertained using ICD-10 codes consistent with the Alliance for Innovation on Maternal health severe maternal morbidity (SMM) definitions [19, 20].

The primary composite neonatal outcome included hypoxic ischemic encephalopathy (HIE), seizure, cardiopulmonary resuscitation within 24 h of life, ventilator use within 24 h of life, or neonatal intensive care unit admission. HIE and seizure were ascertained using ICD-10 codes (P91.6 and P90, respectively) during the delivery admission.

Cardiopulmonary resuscitation and ventilator use were ascertained using revenue claims within 24 h of life.

Secondary outcomes included prolonged hospital admission for mother or neonate (defined as >4 nights after cesarean delivery or >2 nights after vaginal delivery) ascertained using MarketScan delivery and hospital discharge dates, maternal postpartum fever (defined by ICD-10 codes O86.4 and R50.9) during delivery admission, postpartum hemorrhage (defined by ICD-10 code O72) during delivery admission, any blood product transfusion (defined using MarketScan revenue claims) during delivery admission, and any additional procedure for control of bleeding excluding hysterectomy (defined by Washington State Hospital Association ICD-10 codes) during delivery admission [21].

Baseline demographics and outcomes were reported for the entire cohort. Multivariable modeling of the association between individual physician cesarean delivery rate and primary and secondary outcomes was performed adjusting for clinically relevant covariates. Outcomes were reported as unadjusted and adjusted odds ratio based on a 3% higher individual physician cesarean delivery rate. The 3% rate was selected a priori as a clinically meaningful difference in cesarean rates at the individual physician level. For maternal outcomes, we planned a priori to adjust for maternal age and co-morbid conditions (gestational diabetes, pre-gestational diabetes, chronic hypertension, and hypertensive disorders of pregnancy), as these have been associated with maternal morbidity. The maternal co-morbid conditions were defined using ICD-10 codes, assessed from nine months prior to delivery through the delivery admission (Appendix 2) [22, 23]. Selected covariates for neonatal outcomes include the listed maternal covariates, as well as neonatal sex. An interaction between delivery mode and cesarean delivery rate was included. Robust sandwich estimators were used to account for non-independence between physicians.

Information on maternal and neonatal mortality is only available in MarketScan through 2016. Mortality was therefore not included in the outcomes of the primary analysis. However, given that mortality is a competing outcome to our morbidity composites, a sensitivity analysis limited to 2015–2016 was completed including maternal and neonatal mortality in the composite outcomes. Maternal mortality was defined as maternal death during delivery admission or through 6 weeks postpartum. Neonatal mortality was defined as death within 28 days of delivery.

A p value <0.05 was considered statistically significant. All analyses were completed using R version 4.0. This study was exempt from Institutional Review Board approval as all data were deidentified. STROBE reporting guidelines for observational studies were followed [24].

RESULTS

Overall 77,058 maternal-neonatal dyads and 6234 individual physicians met inclusion criteria. Of all included deliveries, there were 22,804 cesarean deliveries (29.6%). The median individual physician cesarean delivery rate was 33.3% (interquartile range 20.0—44.4%). The mean maternal age was 31.3 ± 4.5 years. In this selected "low risk" population, rates of gestational diabetes (1.93%), pre-gestational diabetes (0.34%), chronic hypertension (0.97%), and hypertensive disorders of pregnancy (2.92%) were low. Half of the neonates (51.1%) were male.

The maternal composite primary outcome occurred in 1.3%, and the neonatal composite primary outcome in 3.6% of deliveries in the full cohort. The likelihood of the maternal composite increased linearly with increasing physician cesarean delivery rate (aOR 1.032 for each 3% increase in physician cesarean delivery rate, 95% CI 1.021–1.043) (Table 1; Fig. 1). The neonatal composite also increased linearly with increasing physician cesarean delivery rate (aOR 1.021 for each 3% increase, 95% CI 1.014–1.027; Fig. 2).

Prolonged maternal hospital admission occurred in 20.2%, and prolonged neonatal hospital admission occurred in 8.2% of the full cohort. The likelihood of prolonged hospital admission increased linearly with increasing physician cesarean delivery rate (maternal aOR 1.012 for each 3% increase in physician cesarean delivery rate, 95% CI 1.007–1.018; neonatal aOR 1.021 for each 3% increase in physician cesarean delivery rate, 95% CI 1.012–1.029). The likelihood of postpartum fever, any blood product transfusion, or need for additional procedures to control bleeding did not differ by individual physician cesarean delivery rate. The likelihood of postpartum hemorrhage decreased with increasing physician cesarean delivery rate (aOR 0.945 for each 3% increase in physician cesarean delivery rate, 95% CI 0.909–0.983).

In the sensitivity analysis including maternal and neonatal mortality, results were similar. There were four maternal deaths and 37 neonatal deaths in the study period. The maternal composite including mortality occurred in 1.3% and neonatal composite in 3.6% of deliveries in the full cohort. The likelihood of the maternal and neonatal composite primary outcomes increased linearly with increasing physician cesarean delivery rate (maternal aOR 1.032, 95% CI 1.021–1.044; neonatal aOR 1.019, 95% CI 1.012–1.026).

DISCUSSION

In this low-risk population, increasing individual physician cesarean delivery rates were associated with severe maternal and neonatal morbidity. A nadir in morbidity by physician cesarean delivery rate could not be identified, but higher cesarean delivery rates were not associated with decreased morbidity. Results were similar in a sensitivity analysis including perinatal mortality.

Studies evaluating the relationship between cesarean delivery rates and perinatal mortality have been completed internationally [12, 25, 26]. Molina et al. aimed to evaluate the historical World Health Organization (WHO) recommendation that cesarean delivery rates not exceed 10–15 per 100 livebirths [12, 27]. Using population-level neonatal and maternal mortality rates and cesarean delivery rates from 54 WHO member states, a national cesarean delivery rate of 19 per 100 livebirths was associated with the lowest neonatal and maternal mortality [12]. A subsequent population-level analysis using data from 31 high-income WHO countries found an association between increasing cesarean delivery rate and neonatal mortality (Pearson Correlation coefficient: 0.41, $p < 0.005$) [28]. These ecological studies have not translated to a cesarean delivery target for the U.S. given differences in available resources and focus on perinatal mortality alone.

In the U.S., Healthy People 2020 published a goal for reduction in primary cesarean delivery from the 2007 rate of 27.4% to 24.7% [11]. National organizations and state-level quality collaboratives developed guidelines and toolkits focused on reducing the U.S. primary cesarean delivery rate using the Healthy People 2020 goal [8–10, 29]. However, these efforts are in the absence of a known cesarean delivery target rate that minimizes perinatal morbidity. In a cross-

Table 1. Primary and secondary maternal and neonatal outcomes among low-risk nulliparas with unadjusted and adjusted odds ratio of outcomes for each 3% higher individual physician cesarean delivery rate.

Outcome	Cohort *N* = 77,058	OR (95% CI)	aOR (95% CI)
Primary Maternal Composite	1001 (1.30%)	1.059 (1.055–1.064)	1.032 (1.021–1.043)
Transfusion of ≥4 units blood products	6 (0.01%)		
Intensive care unit (ICU) admission	978 (1.27%)		
Venous thromboembolism	23 (0.03%)		
Hysterectomy	0 (0%)		
Primary Neonatal Composite	2747 (3.56%)	1.061 (1.055–1.066)	1.021 (1.014–1.027)
Hypoxic ischemic encephalopathy (HIE)	8 (0.01%)		
Seizures	8 (0.01%)		
Cardiopulmonary resuscitation (within 24 h)	2 (0%)		
Ventilator use (within 24 h)	37 (0.05%)		
Neonatal intensive care unit admission	2726 (3.54%)		
Secondary outcomes			
Maternal			
Prolonged hospital admission[a]	15,532 (20.16%)	0.990 (0.988–0.993)	1.012 (1.007–1.018)
Postpartum fever	39 (0.05%)	1.014 (0.973–1.056)	0.990 (0.916–1.069)
Postpartum hemorrhage	631 (0.82%)	0.945 (0.932–0.958)	0.945 (0.909–0.983)
Any blood product transfusion	566 (0.73%)	1.029 (1.018–1.040)	0.993 (0.977–1.009)
Additional procedure for control of bleeding	17 (0.02%)	0.837 (0.757–0.925)	1.001 (0.997–1.006)
Neonatal			
Prolonged hospital admission[a]	3110 (8.18%)	1.029 (1.024–1.035)	1.021 (1.012–1.029)

Data presented as *n*(%); odds ratio (OR); adjusted odds ratio (aOR); confidence interval (CI).
Odds ratios for each 3% higher cesarean delivery rate. Adjustment for maternal age, delivery mode, chronic hypertension, hypertensive disorders of pregnancy, preexisting diabetes mellitus, and gestational diabetes.
[a]Defined as >4 days following cesarean delivery or >2 days following vaginal delivery.

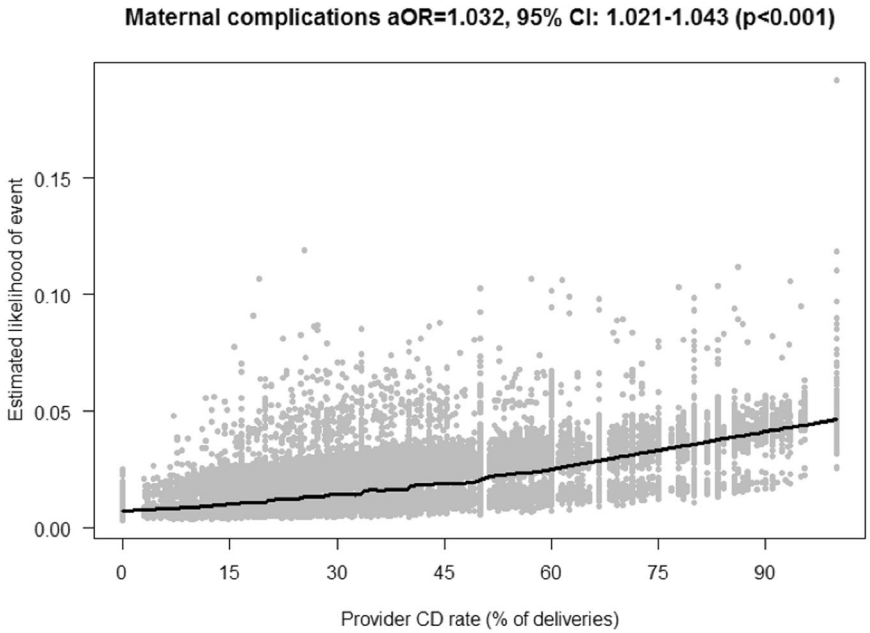

Fig. 1 Maternal severe perinatal morbidity by delivery mode and physician cesarean delivery rate. Likelihood of primary composite maternal outcome following birth by delivery mode and physician cesarean delivery rate. Adjusted odds ratios with 95% CI for each 3% higher cesarean delivery rate. Model adjusted for maternal age, delivery mode, chronic hypertension, hypertensive disorders of pregnancy, preexisting diabetes mellitus, and gestational diabetes.

sectional study of 831,111 low-risk deliveries from 621 hospitals identified in the Nationwide Readmission Database in 2016, Clapp et al found a 3.3% (95% CI 1.7–4.9%) increase in SMM for each 1% increase in hospital cesarean delivery rate. There was no association between hospital cesarean delivery rate and unexpected newborn complications [30]. Using individual physician cesarean delivery rates, we found similar results with a linear relationship between cesarean delivery rate and maternal morbidity. Further, we

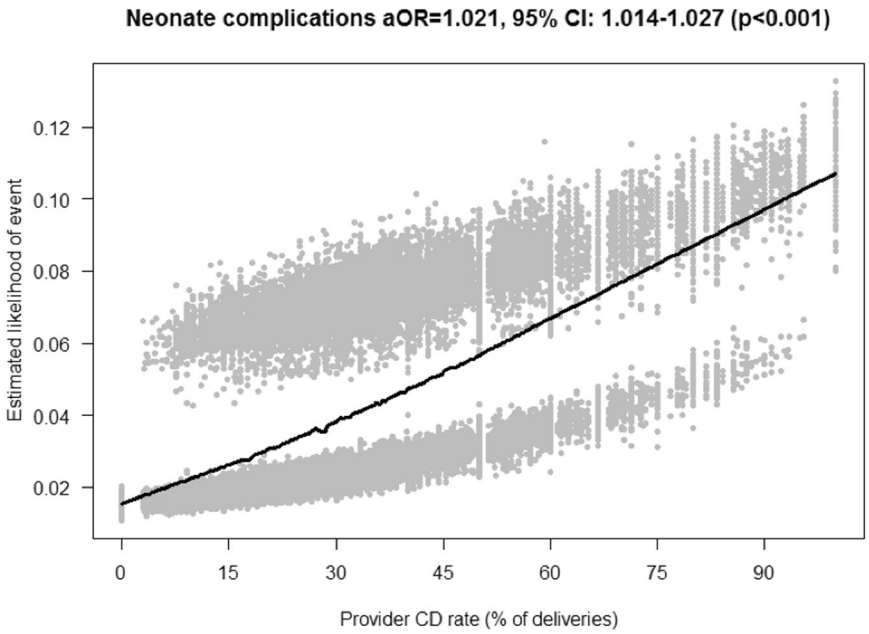

Fig. 2 Neonatal severe perinatal morbidity by physician cesarean delivery rate with vaginal and cesarean deliveries reported separately. Likelihood of primary composite neonatal outcome following birth by delivery mode and physician cesarean delivery rate. Adjusted odds ratios with 95% CI for each 3% higher cesarean delivery rate. Model adjusted for maternal age, delivery mode, chronic hypertension, hypertensive disorders of pregnancy, preexisting diabetes mellitus, gestational diabetes, and neonatal sex.

also identified a linear relationship between individual physician cesarean delivery rate and neonatal morbidity. However, in neither our study at the physician level, nor the Clapp et al. study at the hospital level, was a nadir in neonatal and maternal morbidity identified [30].

Our study has limitations. The MarketScan database is not representative of the U.S. population as it is limited to those covered by commercial insurance plans. Outcome and covariate identification via ICD-10 codes risks under-ascertainment and misclassification, as it relies on the accuracy of practitioner medical coding and billing. Granular details of labor and delivery practices, such as induction of labor, medications for augmentation, or labor stage at time of cesarean delivery are unknown. We are unable to differentiate temporality in maternal morbidity that may have occurred prior to or during delivery, such as the rare event of a perimortem cesarean delivery.

In addition, there were limited mortality data available for the study timeframe. In a sensitivity analysis, we included perinatal mortality within the composite primary outcomes with similar results. However, mortality was a rare outcome with small numbers limiting meaningful conclusions for perinatal mortality alone.

Strengths of this analysis include the large sample size and use of a database providing a geographically diverse patient sample. The database provides individual longitudinal healthcare information, as well as maternal-neonatal data linking. The selection of an NTSV study cohort was completed using an established ICD-10 definition for "low risk" pregnancies by the Joint Commission, AHRQ, and SMFM [13, 14]. We considered maternal and neonatal morbidity outcomes which are more representative of the risk-benefit tradeoff of cesarean delivery as compared to the rare outcome of mortality alone. The selected data source also allows for more detail on some outcomes with use of revenue claims data as compared to ICD-10 codes alone.

In this selected low-risk population, an increasing individual physician cesarean delivery rate was associated with increasing severe perinatal morbidity. Therefore, ongoing national efforts aimed to reduce cesarean delivery rates are prudent. Future research should continue to focus on defining evidence-based targets for ongoing national quality work committed to cesarean delivery reduction. Granular data with information about labor management practices and additional clinical characteristics may help with further differentiation of an optimal target for cesarean delivery rates moving forward.

DATA AVAILABILITY

The dataset analyzed during the current study is available from the corresponding author upon reasonable request.

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ACKNOWLEDGEMENTS

We thank the University of Utah Department of Surgery and the Surgical Population Analysis Research Core for their role in facilitating data collection, database management, and analysis. There was no funding for this work.

AUTHOR CONTRIBUTIONS

AMB participated in study conception, planning, interpretation of results, and manuscript drafting. JJH, RD, and NP contributed to data collection, data cleaning and statistical analysis. AAA contributed to study conception, planning, and interpretation of results. RMS contributed to study conception, study planning, and manuscript edits. TDM contributed to study conception and planning, interpretation of results, and manuscript edits.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41372-022-01540-0.

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