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RESEARCH ARTICLE

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Geospatial variation in caesarean delivery

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Abstract

Aim: The purpose of this study was to evaluate the variation in caesarean delivery rates across counties in Georgia and to determine whether county-level characteristics were associated with clusters.

Design: This was a retrospective, observational study.

Methods: Rates of primary and repeat caesarean by maternal county of residence were calculated for 2008 through 2012. Global Moran's I (Spatial Autocorrelation) was used to identify geographic clustering. Characteristics of high and low-rate counties were compared using student's *t* test and chi-squared test.

Results: Spatial analysis of both primary and repeat caesarean rate identified the presence of clusters (Moran's I = 0.375; $p < .001$). Counties in high-rate clusters had significantly lower access to midwives, more deliveries paid by Medicaid, higher proportion of births for women belonging to racial/ethnic minority groups and were more likely to be rural.

KEYWORDS

caesarean section, maternal health services, nurses, nursing, spatial analysis

1 | INTRODUCTION

Healthy People 2020 goals included reduction in caesarean delivery, both primary and repeat. There is wide variation in the primary and repeat caesarean rate among hospitals in the United States and hospital characteristics, such as location, use of family physicians and practice culture, such as management of early admission for labour contribute to that variation. (Edmonds, O'Hara, Clarke, & Shah, 2017; Jolles, 2017; Plough et al., 2017; Prasad, Hung, Henning-Smith, Casey, & Kozhimannil, 2018; Sebastiao et al., 2016) Additional characteristics that vary by hospital, such as physician workload and access to hospital surgical resources, are associated with access to Trial of Labor after Cesarean (TOLAC). (Munro et al., 2017; Yee, Liu, & Grobman, 2017) It is not yet known how geographic characteristics of the county of maternal residence contribute to these hospital variations.

2 | BACKGROUND

County-level characteristics known to be drivers of access to health care may contribute to hospital-level variation in rates of primary and repeat caesarean. In the United States, rural areas bear the bulk of the burden of lack of access to care, particularly obstetrical care. Between 2004–2014, 9% of rural counties lost all hospital obstetric services and most of the counties that lack childbirth providers are rural counties. (ACOG Committee Opinion No, 2014; Hung, Henning-Smith, Casey, & Kozhimannil, 2017) However, both urban and rural counties have variations in important drivers of care quality such as access to specialty care and access to critical care units. (Brantley, Davis, Goodman, Callaghan, & Barfield, 2017; Glance et al., 2014) These county-level differences may result in clusters of high or low rates of caesarean delivery that are masked by analyses that rely on aggregating rural and urban counties. The ability to identify geographic clusters of rates of primary and repeat caesarean can help policymakers identify priorities for resource allocation. Identification of clusters would also provide a method for evaluating changes in access to quality care after hospital closures or implementation of new aspects of a regionalization programme.

The purpose of this study was to evaluate the occurrence of variation in rates of primary and repeat caesarean section according to maternal county of residence in Georgia and, furthermore, to determine whether county-level characteristics were associated with clusters of high or low rates of caesarean delivery. Georgia has several rural and urban counties, was an early adopter of perinatal regionalization and evaluation of perinatal services and maintains a linked hospital discharge and birth certificate data, making it an ideal state in which to conduct this analysis. Between 2009–2012, there was an overall decrease in the primary caesarean birth rate in Georgia, though there is no evidence, the decrease was equally distributed throughout the state. (Osterman & Martin, 2014) To understand the extent of geographic variation in caesarean delivery rates, we calculated primary and repeat caesarean rates by county of maternal residence for a sample of women from Georgia. We identified "hot spots" of high and low caesarean rates and compared county-level characteristics associated with these hot spots. County characteristics were selected based on prior evidence of associations with variations in caesarean rates.

3 | METHODS

3.1 | Sample

Using data files from the Georgia Department of Public Health for the years 2008–2012, we constructed a retrospective cohort by deterministically linking hospital discharge data, supplied by the Georgia Department of Public Health from the delivery hospitals, for all singleton delivery hospitalizations to birth, foetal death and maternal death certificates using a unique maternal identifier embedded in the files by the Georgia Department of Public Health Office of Health Indicators for Planning. Data were obtained with the permission of the Georgia Department of Public Health. The hospital discharge data contained up to ten ICD-9-CM diagnostic and five ICD-9-CM procedure codes for each hospitalization. Linkage of hospital discharge and delivery record was successful for over 86% of live births. This analysis was determined to be exempt because it was not considered human participants research by the Emory University Institutional Review Board. The procedures for obtaining, linking and analysing the health data used in this study were approved by the Emory University Institutional Review Board.

3.2 | Measures

3.2.1 | Caesarean delivery rate

We selected as our measure of caesarean delivery rate the Agency for Healthcare Quality and Research (AHRQ) calculations for Uncomplicated Primary Cesarean delivery rate and Uncomplicated Vaginal Birth after Cesarean (VBAC) Delivery rate. (Agency for Healthcare Research & Quality, 2013) These measures were calculated using standardized metrics based on the ICD-9-CM codes included in the delivery hospitalization discharge record and allow a measure of primary caesarean that a) is not limited to nulliparous women b) provides the most accurate measure of repeat caesarean and c) uses ICD-9-CM codes to accurately exclude cases with medically necessary caesareans. County-specific rates were calculated according to the maternal county of residence listed on the birth certificate.

Primary Caesarean Delivery Rate, Uncomplicated (IQI 33) is calculated as the number of first-time caesarean deliveries without a prior uterine scar (hysterotomy) per 1,000 deliveries. Deliveries with complications such as preterm delivery, multiple gestation, abnormal presentation or foetal death are excluded from this measure. The wide variations in use of caesarean in the United States suggest an overuse of caesarean delivery and prevention of low-risk primary caesarean is a goal of the American College of Obstetricians and Gynecologists. (American College of Obstetricians and Gynecologists , Cahill, Guise and Rouse (College)2014) Healthy People 2020 set a goal to reduce caesarean births among low-risk women with no prior caesareans by 10%. (Healthy People, 2020).

Repeat Caesarean Delivery Rate was calculated using AHRQs Vaginal Birth after Cesarean Delivery Rate, Uncomplicated (IQI 22). IQI 22 is calculated as the number of vaginal deliveries to women with any prior caesarean per 1,000 deliveries for women with any prior caesarean delivery. Deliveries with complications such as preterm delivery, multiple gestation, abnormal presentation or foetal death are excluded from this measure. The IQI 22 rate was converted to a repeat caesarean delivery rate by subtracting the numerator from 1,000, as the total of all repeat caesarean and vaginal births after caesarean would equal 1000/1000 deliveries. Healthy People 2020 set a goal to reduce the number of caesarean births among low-risk women with a prior caesarean by 10%. (Healthy People, 2020) Nationally, 74% of women who attempt a TOLAC give birth vaginally and though not every woman with a prior caesarean is a candidate for TOLAC, lower rates of repeat caesarean are considered desirable. (ACOG Practice Bulletin No, 2019; Attanasio & Paterno, 2019).

3.2.2 | County-level Characteristics

Rural counties were identified using the list available from the State office of Rural Health for December, 2011. The Office of Rural Health designates rural counties as those with population less than 35,000 individuals.

Providers per 1,000 live births were calculated using data from the Area Health Resource File. The number of obstetricians included all medical and osteopathic-trained obstetricians in clinical practice in 2010. These data originate from the American Medical Association Physician Masterfiles. Calculations for obstetricians excluded the number practicing in subspecialties or currently in training. The number of midwives included midwives for 2010 from the Centers for Medicare and Medicaid Services (CMS) National Provider Identification File. Family physicians were not included in the workforce calculations due to lack of a suitable data source, though few family physicians provide obstetrical care in Georgia. (Meyer et al., 2016) Because providers cluster in counties with maternity hospitals, but women travel to those hospitals from multiple counties, the providers per 1,000 live births were calculated for the primary care service area (PCSA) that encompasses the county. A PCSA is a group of counties that share primary care resources. In urban areas, the PCSA is generally one county while in rural areas a PCSA will include two to three counties.

Presence of any Midwife in the Primary Care Service Area was identified using the same midwife data from the Area Health Resource File and coded as a dichotomous variable.

The presence of any maternity hospital in the primary care service area was identified by the location of the delivery hospitals in the Georgia Maternal Child Health Repository and recorded as a dichotomous variable. Hospitals were included if they provided delivery services for more than 50 women during the study period, as some low volume hospitals in the repository no longer provide delivery care.

The proportion of Medicaid paid births was calculated from the primary payer source in the hospital discharge record.

The proportion of delivering mothers identified as racial or ethnic minorities was calculated from the mothers' race on the birth certificate. Maternal race and ethnicity data were transformed into a dichotomous variable that denoted White, non-Hispanic or minority.

3.3 | Analysis

Description of the county-level variation in primary and repeat caesarean delivery rate was presented as the range and mean or frequency as appropriate. The presence of statistically significant county-level variation was evaluated using student's *t* test to compare the first and fourth-ranked quartiles for each measure.

To find true clusters of high and low quality, we used the Global Moran's I (Spatial Autocorrelation) in ArcGIS 10. The global Moran's I is a common statistical technique employed to find true clusters in spatial/geographic data by attribute (i.e. county calculation of quality for this analysis). Spatial autocorrelation tests for random distribution of attributes by calculating an index for each attribute. The method then uses a z-test to determine spatial areas of high-high and low-low clustering where high-high is defined as two or more counties with high prevalence of the attribute whereas low-low clusters are areas with two or more counties with low prevalence of the attribute. Characteristics of high and low-quality cluster counties were compared using student's *t* test and chi-squared test. Maps were created to graphically display the clusters of high and low prevalence, known as hot spots.

TABLE 1 Characteristics of Georgia's 159 Counties, 2008–2009

Characteristic	Total *N* = 159 *M* (Min-Max) *N* (%)
Births (2010)	845.6 (13–13,387)
% births Medicaid payer	68.4 (20.2–96.2)
% births for women of ethnic minority	44.9 (5.5–93.5)
Providers per 1,000 births	6.8 (0–43.6)
Counties with a midwife in the PCSA	74 (46.5)
Counties with a maternity hospital in the PCSA	124 (78)
Rural Counties	118 (74.2)
Primary Caesarean Rate (per 1,000 births)	201.2 (120–317)
Repeat Caesarean Rate (per 1,000 births)	951.3 (778–1000)

4 | RESULTS

Characteristics of Georgia's 159 counties are presented in Table 1. In 2010, the mean proportion of births covered by Medicaid was 68.44 (*SD* 16.1). Just over three-quarters of the counties (78%) had a maternity hospital in the Primary Care Service Area (PCSA), though fewer than half (46.5%) had a midwife available in the PCSA. The rate of primary caesarean varied from 120 to 317 per 1,000 live births. There was a significant difference in primary caesarean rate between the first (mean 162.3; *SD* 12.2) and fourth (mean 252.2; *SD* 23.3) quartile counties ($p < .001$). Repeat caesarean delivery rate varied from 778 to 1,000 per 1,000 births. There was a statistically significant difference in repeat caesarean between the first (mean 900; *SD* 25) and fourth (mean 994; *SD* 6.1) quartile counties ($p < .001$).

A total of 99 of Georgia's 159 counties were identified as part of at least one cluster, with 16 counties included in clusters for both primary and repeat caesarean. Of the counties included in clusters for both primary and repeat caesarean, eight were included in low primary and repeat caesarean clusters, five were included in high primary and repeat caesarean and two counties were included in high-rate clusters primary caesarean and low-rate clusters for repeat caesarean.

Spatial analysis of primary caesarean rate identified 40 counties included in clusters (Moran's I = 0.375; $p < .001$). Full results for Moran's I are available in Table 2. Clusters included 20 counties identified with low primary caesarean rates and 20 counties identified with high primary caesarean rates. Every county workforce/access characteristic was significantly associated with clusters of high and low primary caesarean rate. Compared with low-rate clusters, counties in high-rate clusters had fewer providers, a higher proportion of deliveries paid by Medicaid and higher proportion of births for women in minority populations. High-rate cluster counties were less likely to have a midwife in the PCSA, less likely to have any hospital in the PCSA and were more likely to be rural (Table 3).

TABLE 2 Results of Global Moran's I for Caesarean Delivery Rate Clusters, Georgia 2008–2012

Measure	Moran's Index	Expected Index	*Z*-Score	*p*
Primary caesarean delivery rate	0.376	−0.006	7.25	<.001
Repeat caesarean delivery rate	0.607	−0.006	11.66	<.001

Spatial analysis for *repeat* caesarean *rate* identified the presence of 75 counties included in clusters (Moran's I = 11.665; $p < .001$) Clusters for *repeat caesarean rate* included 33 counties identified in low-rate clusters and 42 counties identified in high-rate clusters. Clusters were associated with some county-level characteristics. Compared with low-rate clusters, counties in high-rate clusters had less access to midwives, more deliveries paid by Medicaid, higher proportion of births for women in minority populations and were more likely to be rural (Table 3).

5 | CONCLUSION

This analysis identified statistically significant geographic variation in rates of caesarean delivery for women delivering in hospitals in Georgia. In addition, this analysis found clusters of high and low rates of primary and repeat caesarean. Compared with clusters of low caesarean rates, clusters of higher caesarean rates were associated with fewer providers, no midwives in the PCSA, rural designation, a higher proportion of births paid by Medicaid and more births to ethnic and racial minority women. The finding of statistically significant differences demonstrates that the study was adequately powered to find those associations despite the small sample. However, we are not able to determine if type II error occurred in analyses that did not find a statistically significant difference.

This study was limited by the aggregation of maternal residence data at the county level. Georgia has several densely populated urban counties for which smaller area analysis may reveal intra-county clusters. Future research should investigate the presence or absence of clusters smaller than county level. This study used the Primary Care Resource Area (PCSA) to measure the delivery workforce and presence of a hospital. This was considered appropriate for this initial investigation because counties often share medical resources; however, this delimited the study from more detailed measures of access such as distance to closest hospital. Future research should investigate associations with distance to care in high caesarean rate county clusters. This study measured access to a maternity hospital as the presence of any hospital in the PCSA. It is possible that more detailed analysis that accounts for the service level, bed size or teaching status of the hospital in the PCSA may provide a better understanding of the relationship between the presence of a hospital and county-level rate of caesarean delivery. Finally, this study was not able to include family physicians in the analysis because data were not available. Few family physicians attend deliveries in Georgia and 37% of PCSAs in Georgia had no provider when family physicians were included in the count. (Spelke, Zertuche, & Rochat, 2016).

These findings add to the discussion about the balance of supply-sensitive compared with provider-sensitive barriers to reducing caesarean delivery rates. (Jolles, 2017) While hospital variation in caesarean delivery rates has been explained as practice variation, in this sample, clusters of both primary and repeat caesarean were associated with characteristics of the maternal county of residence. The association of high caesarean delivery rate clusters with Medicaid as payer, providers per 1,000 births and absence of a maternity hospital suggests that use of caesarean may be, at least in part, driven by lack of resources. (Munro et al., 2017) Associations between quality of care and lack of resources have previously been described, such as lack of a local NICU resulting in low birth weight infants born at hospitals without a NICU and physician call schedules associated with use of TOLAC. (Kozhimannil, Hung, Casey, & Lorch, 2016; Yee et al., 2017).

Georgia was an early adopter of perinatal regionalization, a complex intervention designed to ensure women have access to the appropriate level of care within economic constraints. Prior analysis of these data found no difference in odds of maternal morbidity and

TABLE 3 Comparison of Low and High Caesarean Delivery Rate Counties; Georgia 2008–2012

	Primary caesarean delivery			Repeat caesarean delivery		
	High rate N = 20 *M (SD)* *N (%)*	Low rate N = 20 *M (SD)* *N (%)*	*p*	High rate N = 42 *M (SD)* *N (%)*	Low rate N = 33 *M (SD)* *N (%)*	*p*
Medicaid Births	75.3 (10.57)	59.5 (19.33)	.003	78.07 (11.96)	59.76 (17.19)	<.001
Minority Births	52.84 (19.82)	24.92 (13.22)	<.001	55.98 (17.11)	46.37 (23.43)	.053
Providers per 1,000 births	4.34 (*SD* 4.27)	8.17 (3.35)	.003	5.95 (4.62)	9.13 (8.15)	.036
Midwife in PCSA	1 (5%)	19 (95%)	<.001	11 (26%)	23 (67%)	<.001
Hospital in PCSA	12 (60%)	19 (95%)	.020	30 (71%)	26 (79%)	.649
Rural Status	19 (95%)	11 (55%)	.004	40 (95%)	13 (40%)	<.001

mortality for women at high risk of maternal morbidity based on the obstetric service level of the delivery hospital, however that analysis did not include women at low risk and did not look for geographic variations in morbidity and mortality. (Vanderlaan et al. 2019) It is possible similar geographic variation in poor maternal or neonatal outcomes exists and future research should investigate the potential for such variation.

The cluster of high repeat caesarean rate counties is associated with rural portions of the state and is not associated with the presence of a maternity hospital. This may be related to recommendations that TOLAC be limited to hospitals with particular surgical capabilities beyond those recommended for a general maternity hospital, a recommendation repeated in the most recent American College of Obstetricians and Gynecologist practice bulletin about TOLAC. (ACOG Practice Bulletin No, 2019) The counties included in the cluster are largely rural and most, but not all, are served by small hospitals with lower obstetrical service levels. These data are not able to determine if women are choosing to remain in a local community hospital without access to *TOLAC*, or if the option to transfer to a facility that could provide the service is not available to the women. *TOLAC* is a cost-effective strategy for a health system as it prevents morbidity in the current pregnancy and future pregnancies. (Wymer, Shih, & Plunkett, 2014) Because of this, lack of access to *TOLAC* may result in unnecessary higher costs of care and contribute to poor delivery outcomes.

It is unlikely that resource restriction is responsible for all of the observed variation in rates of caesarean delivery. Differences in caesarean rates based on the presence of midwives and family physicians suggest that practice differences between types of providers play some role in variation. (Carlson et al., 2019; Neal et al., 2019; Prasad et al., 2018) This conclusion is supported by the association between high caesarean rate clusters and counties without midwives in these data. In 2011, the last survey performed, less than 15% of PCSAs in Georgia had family physicians providing delivery care. (Spelke et al., 2016) The distribution of family physicians attending births was unable to be measured with these data.

Despite an association between rural versus urban counties and county-level caesarean rates in these data, about half of the low primary and repeat caesarean rate clusters were rural counties. This suggests that the association between rural versus urban county and caesarean delivery rate is moderated in Georgia by other county-level factors. Women in rural areas have different risk profiles than urban women and, in Georgia, rural and urban women have different causes of maternal mortality. (Nethery, Gordon, Bovbjerg, & Cheyney, 2017; Platner, Loucks, Lindsay, & Ellis, 2016) For example, cardiomyopathies were responsible for 17.6% of pregnancy-related deaths in rural areas and 42.2% in non-rural areas. Additionally, hypertensive disorders accounted for 29.4% of pregnancy-related deaths in rural areas compared with 12.7% in non-rural areas and 3% in metropolitan Atlanta. (Platner et al., 2016) This may indicate other measures of healthcare access, not measured by maternity care access, are associated with caesarean delivery rates.

One possible moderating factor is the proportion of deliveries paid by Medicaid. Counties in high caesarean clusters had a high mean proportion of births paid by Medicaid. The relationship between payer source and caesarean delivery is complex, with both private pay and Medicaid identified as increasing the odds of low-risk caesarean for some groups of women. (Haberman et al., 2014; Hamlin, 2017; Jolles, 2017) Low reimbursement by Medicaid is a barrier to providing maternity care in Georgia and some providers report scheduling extra patients to ensure costs of service delivery are covered. (Pinto, Rochat, Hennink, Zertuche, & Spelke, 2016) This increased patient load may contribute to variations in caesarean rate. Additionally, counties in high caesarean delivery rate clusters had fewer providers per 1,000 births, further exacerbating the workload of providers in these areas.

Another possible moderating factor is the presence of midwives in the PCSA. Giving birth in a facility with midwives available is associated with lower caesarean delivery risk for both nulliparous and multiparous women and midwives are more likely than obstetricians to attempt a TOLAC. (Carlson et al., 2019; Neal et al., 2019) These data are not able to determine a reason for the absence of midwives in the PCSAs. Georgia has a midwifery training programme and, in 2017, 13.7% of births in Georgia were attended by midwives. (Martin, Hamilton, Osterman, Driscoll, & Drake, 2018) However, in Georgia, midwifery practice requires a collaborative agreement with a physician. (Yang, Attanasio, & Kozhimannil, 2016) This requirement may result in lack of midwives if there is no collaborating physician available or if the medical culture is not friendly to midwifery practice. Prior research has found that, at the time of these data, some obstetricians in Georgia were reluctant to collaborate with certified nurse-midwives. (Pinto et al., 2016).

The proportion of births to women who identify as ethnic or racial minorities was associated with high primary caesarean rates. There was no association with repeat caesarean; however, these data are underpowered which may have caused a type II error. In the United States, variations in caesarean rates have been associated with racial and ethnic minority status when the unit of analysis is individual birthing people. (Edmonds, Hawkins, & Cohen, 2016; Janevic et al., 2014) Additionally, hospitals that are primarily minority-serving have been identified as having lower quality. (Creanga et al., 2014) This study adds to the literature on health equity by demonstrating that, in addition to individual-level inequity, disparities in use of primary caesarean are identifiable in communities based on maternal county of residence.

5.1 | Implications

This analysis has identified statistically significant variation in rates of caesarean delivery based on maternal county of residence. These variations are associated with known drivers of access to care such as the presence of obstetrical and midwifery services and access to health insurance. This finding suggests policies already proven to improve access to care may help reduce the clusters of counties with high caesarean delivery rates. Additionally, in these data, geographic variations in caesarean delivery rates were associated with county-level measures of poverty and minority status.

The presence of clusters of high and low rates of caesarean delivery by maternal residence provides insight into county-level characteristics that may play a role in driving hospital variation in caesarean rates. Variations in access to care are likely associated with variations of migration patterns for delivery and may play a role in decision-making, such as elective caesarean or indication of labour, that is not captured by measures of maternal risk. Because migration patterns are part of a state perinatal regionalization plan, if these findings are replicated and supported by data from other states, it would suggest that county-level rates of caesarean delivery should be included in the evaluation of state perinatal regionalization plans.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose.

AUTHOR CONTRIBUTIONS

JV and JE: data analysis. JV and AD: major contribution to the manuscript.

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