Original Investigation

Sociodemographic and Geographic Disparities in Obstetrical Ultrasound Imaging Utilization: A Population-based Study

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Rationale and Objectives: Obstetrical ultrasound imaging is an important part of prenatal care, though not all patients have readily available access to ultrasound services. This study aimed to assess the association between sociodemographic and geographic factors and (1) having a second trimester complete obstetrical ultrasound and (2) overall obstetrical ultrasound utilization.

Methods: All pregnancies and obstetrical ultrasound exams billed from 2014-2018 in Saskatchewan, Canada were identified from province-wide databases. Generalized estimating equation (GEE) models with binomial and Poisson distributions were used to identify factors associated with having a second trimester ultrasound and overall obstetrical ultrasound utilization, respectively.

Results: 80,536 pregnancies from 57,881 individuals were included. Of 57,186 pregnancies carried to ≥23 weeks, a second trimester ultrasound was performed in 50,180 (87.7%). Patients living in rural areas (adjusted odds ratio [aOR], 0.70; 95% confidence interval [CI], 0.63-0.77; p <0.0001), remote areas (aOR, 0.35 for greatest vs. least remoteness level; 95% CI, 0.32-0.39; p <0.0001), and status First Nations individuals (aOR, 0.50; 95% CI, 0.46-0.53; p <0.0001) were less likely to have a second trimester ultrasound. Patients living in higher income neighbourhoods (aOR, 1.86 for highest vs. lowest quintile; 95% CI, 1.62-2.13; p <0.0001) were more likely to have a second trimester ultrasound. GEE Poisson regression analysis demonstrated these same factors, except rural residence, were associated with overall obstetrical ultrasound utilization.

Conclusion: Substantial disparities in obstetrical ultrasound utilization exist among patients in remote geographic areas, Indigenous peoples, and patients in low income neighbourhoods. Addressing barriers which these demographic groups face in accessing ultrasound imaging is critical to ensure health equity.

Keywords: Ultrasound; Utilization; Obstetrical; Prenatal; Health disparities; Health equity.

Abbreviations: aIRR adjusted incidence rate ratio, **aOR** adjusted odds ratio, **CI** confidence interval, **CSD** census subdivision, **GEE** generalized estimating equation, **IRR** incidence rate ratio, **LMP** last menstrual period, **MSB** Medical Services Branch, **OR** odds ratio, **RIS** radiology information system, **SD** standard deviation

INTRODUCTION

Ultrasound imaging is an important component of prenatal care to predict adverse pregnancy events, inform obstetrical management, and improve pregnancy outcomes (1). Despite the importance of obstetrical ultrasound imaging in prenatal care, access to obstetrical ultrasound is limited for many patients across North America (2,3). Access is particularly limited for women in rural and remote communities, where the closest facility to offer ultrasound services may be hundreds of kilometres away (2). Our previous research found that geographic isolation from ultrasound facilities was a central barrier for patients in northern, remote, Indigenous communities to access ultrasound imaging (4). Other barriers to accessing ultrasound imaging, such as competing family and work responsibilities, were exacerbated by geographic distance from ultrasound imaging facilities and the increased time required to travel to an ultrasound facility (4). As a high proportion of patients in remote

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communities are Indigenous, these barriers disproportionately impact Indigenous peoples, who face multiple barriers to accessing healthcare services (5).

Distinction must be made between *access* to ultrasound services, which has been defined as "the opportunity to reach and obtain appropriate health care services in situations of perceived need for care" (6), and *utilization* of ultrasound services, which can be thought of as "realized access (7)." The relationship between access and utilization is complex, and based on a dominant theoretical paradigm, predicting and explaining imaging utilization relies on understanding individuals' predisposition to use services, factors which enable or impede use (such as availability of ultrasound facilities), and individuals' need for care (8).

Research investigating sociodemographic and geographic factors associated with obstetrical ultrasound utilization is limited, though a number of studies have investigated factors associated with prenatal care utilization in general. Younger maternal age, lower socioeconomic status (including lower income and education level), Indigenous ancestry, immigration status, multiparity, and substance use have each been shown to be associated with lower rates of prenatal care (9−13).

Despite increased recognition of the importance of exploring and addressing healthcare disparities in other specialties, there are relatively few papers in the radiological literature exploring health care disparities, and there have been calls for radiology to focus on research and curricula in healthcare disparities (14). Identification of specific demographic groups with decreased rates of obstetrical ultrasound imaging is critical to identify disparities in guideline-recommended obstetrical care in health systems. Such findings may inform approaches to improve access to obstetrical ultrasound for specific demographic groups and thereby ensure equitable opportunity for all pregnant women to receive obstetrical imaging, including second trimester obstetrical ultrasound exams which are considered standard of care (15). Thus, the objective of this study was to assess the association between sociodemographic and geographic factors and (1) having a second trimester complete obstetrical ultrasound exam during a pregnancy, which is recommended that all pregnant women be offered between 18 and 22 weeks' gestation (15) and (2) overall obstetrical ultrasound utilization. Based on empirical findings in the literature (5,9−13) and theoretical frameworks of healthcare utilization (8,16), we hypothesized that due to structural barriers, specific demographic groups, including Indigenous patients, patients in rural communities, and patients with increased remoteness from major centres, would be less likely to have a second trimester complete obstetrical ultrasound exam and have lower rates of obstetrical ultrasound imaging utilization.

METHODS

Study Cohort

A population-based study was undertaken in the province of Saskatchewan, Canada. The research protocol was submitted to the University of Saskatchewan Research Ethics Board and was deemed to be exempt from research ethics review and approval.

Inclusion criteria were (1) women registered for medical services in the province of Saskatchewan, Canada at any time between January 1, 2014 and December 31, 2018 (the "study period") and (2) women who had at least one pregnancy with the date of the first day of the last menstrual period (LMP) and the date of delivery or abortion both within the study period. Data for women with multiple pregnancies were documented separately for each pregnancy. From this cohort, a sub-cohort of pregnancies carried to at least 23 weeks was defined to identify sociodemographic and geographic factors associated with having specifically a second trimester complete obstetrical ultrasound exam, which is recommended between 18 and 22 weeks' gestation (15). Pregnancies with the first day of the LMP or date of delivery outside of the study period and pregnancies in women who relocated to another province or country during their pregnancy were excluded. All women included in the cohort were identified by querying the provincial Discharge Abstract Database and Ministry of Health Medical Services Branch physician billing data for diagnosis and procedure codes associated with pregnancy as previously described (17).

Explanatory and Outcome Variables

Explanatory variables. Variables were selected for inclusion based on theoretical models of healthcare utilization (e.g. Andersen's Behavioral Model of Health Services Use) and prior literature exploring sociodemographic and geographic factors associated with prenatal care utilization in general (8−13,16). Demographic information, including maternal age and First Nations status, was abstracted from the Personal Health Registration System. Maternal age was defined at the time of the estimated first day of the LMP for each pregnancy. First Nations status is self-declared by First Nations persons registered under the *Indian Act*.

The Obstetric Comorbidity Index was used as a proxy for maternal health status (18,19), and was calculated for each individual based on ICD-10-CA diagnosis codes from the Discharge Abstract Database. Additional health information, including the number of pregnancies (gravidity), number of past deliveries (parity), and pregnancy outcomes, were also determined based on ICD-10-CA codes from the Discharge Abstract Database.

As a proxy for geographic remoteness, an index of remoteness was determined for each individual based on the census subdivision (CSD—a municipality or an area equivalent to a municipality for statistical reporting purposes) of each individual's physical address as available within the Personal Health Registration System at the beginning of each pregnancy. This index of remoteness, publicly released by Statistics Canada in 2020, is based on (1) the proximity of a CSD to all population centres within a given radius that permits daily accessibility and (2) the population size of each population centre to reflect general service availability within that population centre (20,21). Travel cost, rather than network distance or travel time, was used as a common measure of "distance" to account for communities with various transportation infrastructures. The index of remoteness is a continuous variable scaled from 0 (least remote) to 1 (most remote) and demonstrates high correlation to accessibility measures specific to healthcare services (21). As the two largest cities in the province, Saskatoon and Regina, both had index of remoteness values slightly less than 0.23, an index of remoteness level of <0.23 was chosen as the reference category for subsequent analyses.

In addition, urban vs. rural status was assigned for each individual based on residence location at the beginning of each pregnancy as indicated in the Personal Health Registration System. Urban was defined as comprising all population centres, defined by Statistics Canada as a defined geographic unit with a population of at least 1,000 and a population density of 400 persons or more per square kilometre population (22). Rural was defined as all territory lying outside population centres (urban centres) (23).

Neighbourhood income quintile was used as a proxy for socioeconomic status, similar to prior studies (24−26). Dissemination area, the smallest geographical unit available for analysis in the Canadian census, was extracted for each individual based on their residence at the beginning of each pregnancy. Neighbourhood income quintiles for each dissemination area were based on average income per single person equivalent and based on data from the 2011 Census as previously described (27). The neighbourhood income quintile of each individual's respective dissemination area was assigned to each individual (27). Based on data limitations of the Personal Health Registration System, data for urban vs. rural status and neighbourhood income quintile were available only from January 2014 to October 2017.

Outcome variable. Ultrasound exams were abstracted from (1) the provincial Radiology Information System (RIS), which captures all ultrasound exams performed in public facilities in the province, and (2) provincial Ministry of Health Medical Services Branch (MSB) physician billing data, which captures all ultrasound exams performed in private facilities in the province. Together, these two data sources capture all formal diagnostic ultrasound exams billed in the province.

Obstetrical ultrasound exams were identified in RIS and MSB physician billing data through a query of exam codes indicating a first trimester ultrasound exam, second trimester ultrasound exam, third trimester ultrasound exam, obstetrical ultrasound exam with trimester not specified, and biophysical profile. In cases where the exam code did not specify the trimester, the trimester was estimated based on estimated gestational age as determined through the Discharge Abstract Database. Nuchal translucency exams and amniocenteses were excluded. All obstetrical ultrasound exams performed on the same day (e.g. transabdominal and transvaginal exams coded with two separate exam codes) were counted as a single exam. The performance of a second trimester complete obstetrical exam as well as the total number of obstetrical exams performed during each pregnancy was determined.

Statistical Analysis

Descriptive statistics, including means (± standard deviation) for continuous variables and frequencies (%) for categorical variables, were used to summarize population demographic characteristics and obstetrical ultrasound exam count data.

Second trimester obstetrical ultrasound utilization. In the subcohort of women with pregnancies carried to at least 23 weeks' gestation, the number and proportion of women who had a second trimester obstetrical ultrasound exam were determined for each stratum of each explanatory variable. Univariate logistic regression was used to evaluate odds ratios (ORs) and 95% confidence intervals (CIs) for each predictor in a generalized estimating equation (GEE) model.

Variables from univariate analysis with $p < 0.20$ were considered for inclusion in a multivariate GEE logistic regression model using stepwise selection. Odds ratios and adjusted odds ratios (aORs) and 95% CIs were estimated. Multicollinearity among independent variables was assessed using variance inflation factors and interactions between covariates were examined. Additionally, aORs of having a second trimester obstetrical ultrasound exam were estimated for each census division and medium and large population centre in Saskatchewan and were visually represented on a choropleth map with a color progression used to represent different aOR values.

Overall obstetrical ultrasound utilization. The total numbers of obstetrical ultrasound exams performed during each pregnancy within each stratum of each variable were represented as incidence rate ratios (IRRs), and GEE Poisson regression modeling was used to identify significant variables.

Variables from univariate analysis with $p < 0.20$ were considered for inclusion in a multivariate GEE Poisson regression model using stepwise selection to identify sociodemographic and geographic factors which were associated with the total number of obstetrical ultrasound exams performed during each pregnancy. Gestational age at the time of delivery was included as an offset variable to account for increased potential for additional ultrasound exams as gestational age increases. Interactions between covariates were examined. Multicollinearity among independent variables was assessed using variance inflation factors. Adjusted incident rate ratios (aIRRs) were estimated for each census division and medium and large population centre in Saskatchewan and were represented on a choropleth map.

Significance level (α) was set at 0.05 for all analyses. Statistical analyses were performed with SAS, version 9.4 (SAS Institute, Cary, NC). Choropleth maps were created using MapInfo Pro 2019 (Precisely, Pearl River, New York).

RESULTS

Population characteristics

A total of 655,770 women were registered for medical services during the study period, and of these individuals, 57,881 (8.9%) had at least one pregnancy with the estimated first day of the LMP and delivery date both during the study period

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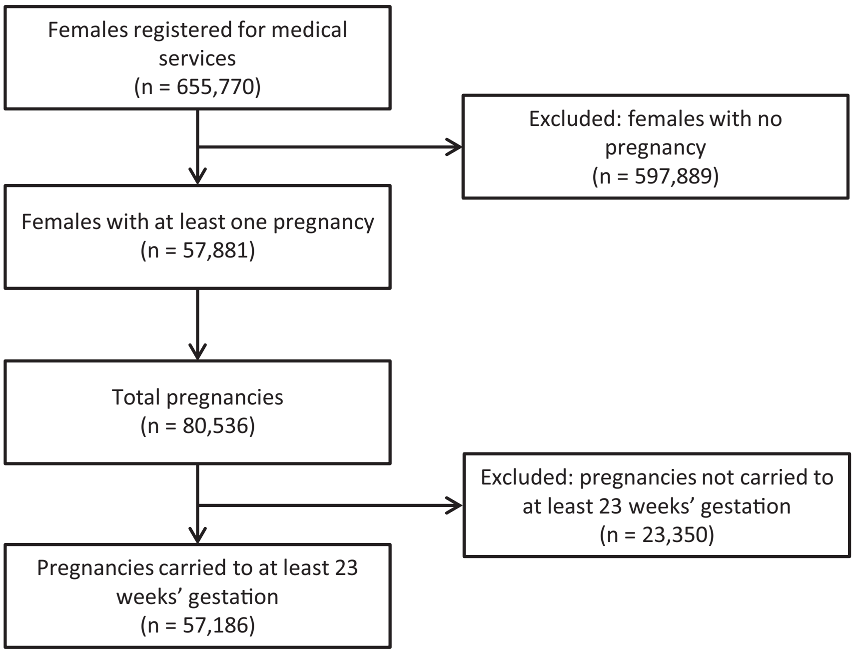

Figure 1. Flowchart of the study population. The study cohort was identified from the Saskatchewan Personal Health Registration System, which includes all individuals registered for medical services in Saskatchewan, Canada, during the study period (January 1, 2014 and December 31, 2018).

(Fig 1). As some individuals had multiple pregnancies during the study period, a total of 80,536 pregnancies were identified. Of these, 57,186 pregnancies were carried to at least 23 weeks' gestational age. Population characteristics are summarized in Table 1.

Predictors of having a second trimester complete ultrasound exam

In the sub-cohort of pregnancies carried to at least 23 weeks' gestation, a second trimester complete obstetrical ultrasound was performed during 50,180 (87.7%) pregnancies. In univariate analyses, maternal age, First Nations status, gravidity, parity, Obstetric Comorbidity Index, urban vs. rural residence, index of remoteness, and neighbourhood income quintile were statistically significant factors associated with having a second trimester obstetrical ultrasound performed (all $p < 0.0001$) and were included in the multivariate model.

In the multivariate GEE model, advanced maternal age was associated with being more likely to have a second trimester obstetrical ultrasound exam (aOR, 1.03 for each 1 year increase in age; 95% CI, 1.03-1.04; $p < 0.0001$). Individuals who were status First Nations (aOR, 0.50; 95% CI, 0.46-0.53; $p < 0.0001$), had higher parity (aOR, 0.44 for parity ≥3 vs. 1; 95% CI, 0.37-0.52; $p < 0.0001$), lived in a rural area (aOR, 0.70; 95% CI, 0.63-0.77; $p < 0.0001$), and lived in a more remote area (aOR, 0.35 for index of remoteness ≥0.41 vs. <0.23; 95% CI, 0.32-0.39; $p < 0.0001$) were significantly less likely to have a second trimester obstetrical ultrasound.

Compared to individuals who resided in a neighbourhood in the lowest income quintile, those who resided in a neighbourhood in the highest income quintile were 86% more likely to have a second trimester obstetrical ultrasound exam (aOR, 1.86 highest vs. lowest income quintile; 95% CI, 1.62-2.13; $p < 0.0001$), though individuals in the second-lowest income quintile were 16% less likely to have a second trimester obstetrical ultrasound exam (aOR, 0.84; 95% CI, 0.76-0.93; $p < 0.0001$). It is acknowledged that data for neighbourhood income quintile were available only from January 2014 to October 2017, resulting in a substantial proportion of missing data.

Women with an Obstetric Comorbidity Index value of 3 or 4 were more likely to have a second trimester ultrasound exam (aOR, 1.15 vs. Obstetric Comorbidity Index of 0; 95% CI, 1.07-1.24; $p < 0.0001$) and women with an Obstetric Comorbidity Index value of ≥5 were less likely to have a second trimester ultrasound exam (aOR, 0.90 vs. Obstetric Comorbidity Index of 0; 95% CI, 0.83-0.98; $p < 0.0001$), though adjusted odds ratios at other levels were not statistically significant (Table 2).

Census divisions with individuals most likely to have a second trimester obstetrical ultrasound were generally those adjacent to large population centres (population of 100,000 or more, including Saskatoon and Regina) or medium population centres (population 30,000 to 99,999, including Prince Albert and Moose Jaw), as shown in Figure 2. Individuals residing in the northern part of the province where limited ultrasound facilities exist, as well as the western census divisions of the province, were less likely to have a second trimester ultrasound. Variation was seen among the medium and large population centres in Saskatchewan, despite each of these cities having readily available ultrasound facilities. Adjusted odds ratios of having a second trimester ultrasound were 0.77 (95% CI, 0.69-0.86), 0.83 (95% CI, 0.62-1.12), and 1.38 (95% CI, 0.96-1.99) for Regina, Prince Albert, and Moose Jaw, respectively, relative to Saskatoon.

TABLE 1. Population characteristics.

	For each unique individual (n = 57,881)	For each pregnancy within the study period (*n* = 80,536)*
Years of follow-up data available per individual during the 5 year study period, mean (± SD)	4.8 (± 0.5)	
Pregnancies during the study period, n (%)		
1	40,000 (69%)	
2	14,010 (24%)	
≥3	3,871 (7%)	
Status First Nations, n (%)		
Yes	11,592 (20%)	
No	46,289 (80%)	
Maternal age at the beginning of pregnancy, mean (± SD)		28.1 (±5.8)
Gestational age at the time of delivery in weeks, mean (± SD)		30.8 (±13.2)
Pregnancy outcome, *n* (%)		
Live birth		56,869 (71%)
Stillbirth		424 (1%)
Spontaneous abortion		13,904 (17%)
Induced abortion		9,301 (12%)
Birth type mixed or unspecified		38 (0%)
Gravidity, *n* (%)		
1		29,609 (37%)
2		21,380 (27%)
3		12,855 (16%)
≥4		16,692 (21%)
Parity, *n* (%)		
0		57,099 (71%)
1		12,671 (16%)
2		5,683 (7%)
≥3		5,083 (6%)
Obstetric Comorbidity Index, *n* (%)		
0		50,099 (62%)
1-2		5,847 (7%)
3-4		15,389 (19%)
≥5		9,201 (11%)
Location of residence, *n* (%)		
Urban		50,747 (63%)
Rural		7,597 (9%)
Missing		22,192 (28%)
Index of remoteness, *n* (%)		
<0.23		35,794 (44%)
0.23-0.30		18,168 (23%)
0.31-0.40		15,675 (19%)
≥0.41		10,395 (13%)
Missing		504 (1%)
Neighbourhood income quintile, *n* (%)		
1 (lowest)		13,865 (17%)
2		11,214 (14%)
3		10,226 (13%)
4		11,174 (14%)
5 (highest)		7,993 (10%)
Missing		26,064 (32%)

SD, standard deviation.

* Across all pregnancy outcomes (live birth, stillbirth, spontaneous abortion, and induced abortion).

TABLE 2. Comparison of individuals with and without a second trimester ultrasound exam performed.

Variable	Pregnancies with a second trimester ultrasound exam performed (*n* = 50,180)	Pregnancies with no second trimester ultrasound exam performed (*n* = 7,006)	Adjusted odds ratio of a second trimester ultrasound exam performed (95% CI)*	*p*-value
Maternal age, years, mean (± SD)	27.7±5.4	26.0±5.9	1.03 (1.03-1.04)†	<0.0001
Status First Nations, *n* (%)				
No (reference)	40,865 (81%)	4,044 (58%)	–	<0.0001
Yes	9,315 (19%)	2,962 (42%)	0.50 (0.46-0.53)	
Gravidity, *n* (%)				
1 (reference)	25,583 (51%)	3,237 (46%)	–	<0.0001
2	11,783 (23%)	1,364 (19%)	1.19 (1.10-1.28)	
3	6,298 (13%)	898 (13%)	1.22 (1.08-1.37)	
≥4	6,516 (13%)	1,507 (22%)	1.25 (1.09-1.43)	
Parity, *n* (%)				
0 (reference)	39,112 (78%)	4,706 (67%)	–	<0.0001
1	6,416 (13%)	993 (14%)	0.77 (0.69-0.86)	
2	2,542 (5%)	618 (9%)	0.54 (0.46-0.63)	
≥3	2,110 (4%)	689 (10%)	0.44 (0.37-0.52)	
Obstetric Comorbidity Index, *n* (%)				
0 (reference)	28,433 (57%)	3,908 (56%)	–	<0.0001
1-2	3,791 (8%)	507 (7%)	0.92 (0.82-1.02)	
3-4	11,483 (23%)	1,521 (22%)	1.15 (1.07-1.24)	
≥5	6,473 (13%)	1,070 (15%)	0.90 (0.83-0.98)	
Location of residence, *n* (%)				
Urban (reference)	32,329 (64%)	3,146 (45%)	–	<0.0001
Rural	4,672 (9%)	820 (12%)	0.70 (0.63-0.77)	
Missing	13,179 (26%)	3,040 (43%)	0.51 (0.43-0.61)	
Index of remoteness, *n* (%)				
<0.23 (reference)	22,837 (46%)	1,533 (22%)	–	<0.0001
0.23-0.30	11,031 (22%)	2,043 (29%)	0.44 (0.41-0.48)	
0.31-0.40	9,995 (20%)	1,491 (21%)	0.54 (0.49-0.59)	
≥0.41	5,970 (12%)	1,901 (27%)	0.35 (0.32-0.39)	
Missing	347 (1%)	38 (1%)	1.04 (0.72-1.52)	
Neighbourhood income quintile, *n* (%)				
1 (reference)	8,461 (17%)	1,225 (17%)	–	<0.0001
2	6,793 (14%)	1,025 (15%)	0.84 (0.76-0.93)	
3	6,491 (13%)	688 (10%)	1.15 (1.03-1.29)	
4	7,350 (15%)	587 (8%)	1.50 (1.34-1.69)	
5	5,278 (11%)	336 (5%)	1.86 (1.62-2.13)	
Missing	15,807 (32%)	3,145 (45%)	1.79 (1.50-2.13)	

SD, standard deviation.
* Adjusted for all other variables in the multivariate GEE model.
† Odds ratio for each 1-year increase in age.

Overall ultrasound imaging utilization during pregnancy

At least one obstetrical ultrasound exam was performed during 71,227 (88.4%) pregnancies. The average number (± standard deviation) of obstetrical ultrasound visits per pregnancy was 3.3 (±3.0) across all pregnancies and 4.1 (±3.1) in pregnancies carried to at least 23 weeks. This included first trimester (*n* = 80,922), second trimester (*n* = 76,254), and third trimester (*n* = 49,390) exams; biophysical profiles (*n*= 29,420); and fetal echocardiography (*n* = 807).

Advanced maternal age, higher Obstetrical Comorbidity Index, and higher neighbourhood income quintile were associated with a higher rate of obstetrical ultrasound exams based on univariate Poisson regression analysis (all $p < 0.0001$). First Nations status, higher gravidity, higher parity, rural residence, and higher index of remoteness were associated with a lower rate of obstetrical ultrasound exams based on univariate Poisson regression analysis (all $p < 0.0001$).

Following multivariate GEE Poisson regression analysis, advanced maternal age (aIRR, 1.33 for women ≥33 years old vs. <23 years old; 95% CI 1.31-1.36; $p < 0.0001$), higher

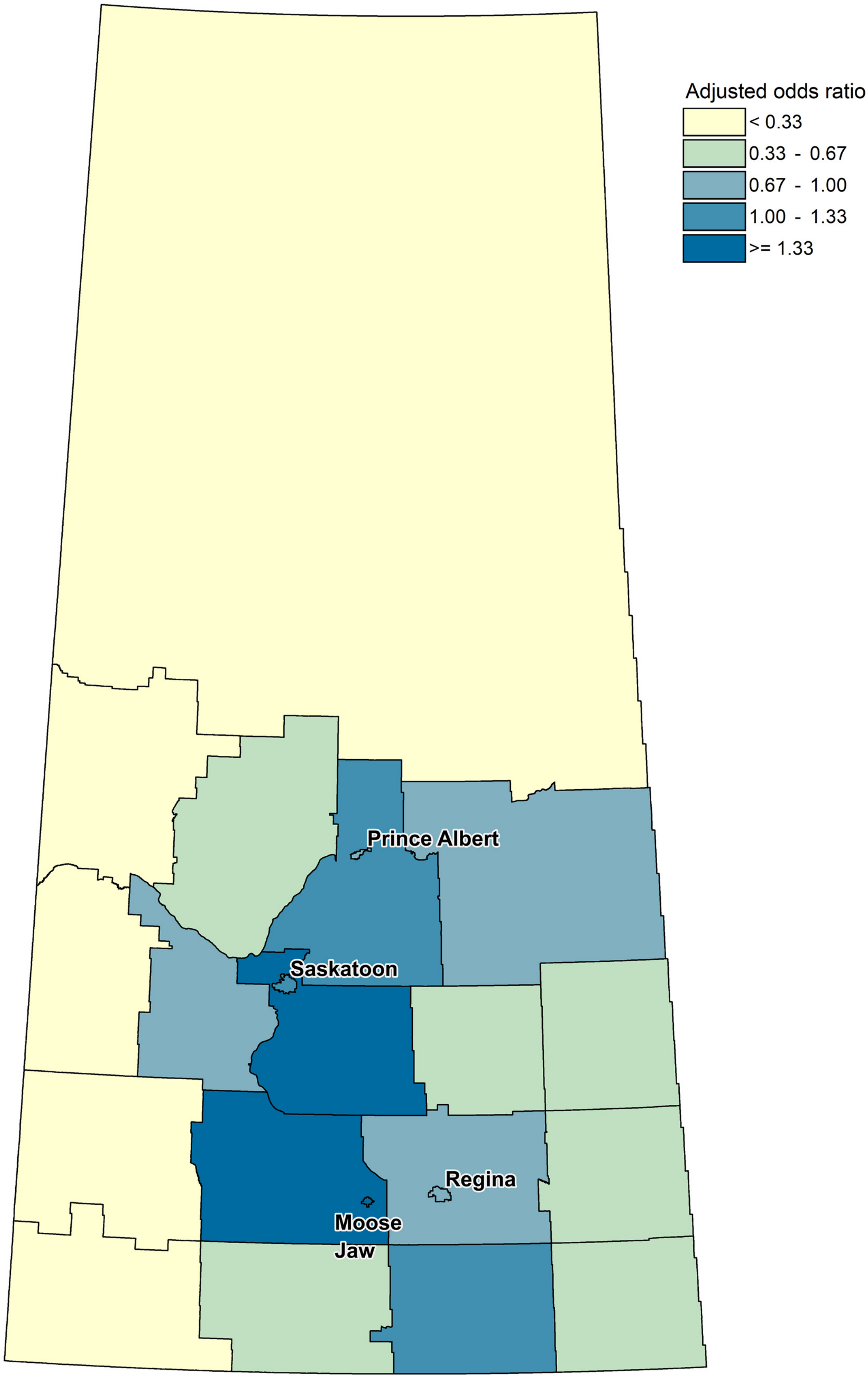

Figure 2. Choropleth map indicating adjusted odds ratios of having a second trimester obstetrical ultrasound exam for each census division in Saskatchewan. Boundaries of all 18 census divisions in the province are outlined in black. In addition, all large and medium population centres (Saskatoon, Regina, Prince Albert, and Moose Jaw) are labeled. The reference category is Saskatoon, the largest population centre in the province.

Obstetric Comorbidity Index (aIRR, 2.13 for Obstetric Comorbidity Index ≥5vs. 0; 95% CI, 2.09-2.17; p <0.0001), and higher neighbourhood income (aIRR, 1.10 for highest vs. lowest quintile; 95% CI, 1.07-1.12; p <0.0001) were significantly associated with a higher rate of obstetrical ultrasound examinations (Table 3).

First Nations status (aIRR, 0.80; 95% CI, 0.78-0.81; p<0.0001), higher parity (aIRR, 0.73 for parity ≥3 vs. 1; 95% CI, 0.71-0.76; p <0.0001), and higher index of remoteness (aIRR, 0.79 for index of remoteness ≥0.41 vs. <0.23; 95% CI, 0.77-0.81; p <0.0001) were significantly associated with lower rates of obstetrical ultrasound exams. Rural residence was not statistically significant in the multivariate GEE model and no clear trend was observed with increasing gravidity.

While northern and western census divisions were found to have lower aIRRs compared to census divisions in the central aspect of the province (similar to that seen for second trimester complete obstetrical ultrasound utilization), census divisions in the southeast had the highest rates of overall obstetrical ultrasound utilization (Fig 3). Adjusted incidence rate ratios for overall obstetrical ultrasound utilization were 1.19 (95% CI, 1.17-1.21), 0.94 (95% CI, 0.90-0.98), and 1.13 (95% CI, 1.08-1.18) for Regina, Prince Albert, and Moose Jaw, respectively, relative to Saskatoon.

DISCUSSION

This study identifies marked disparities in obstetrical ultrasound utilization, including utilization of second trimester obstetrical ultrasound, among specific demographic groups. Individuals residing in lower income neighbourhoods, status First Nations individuals, and those residing in rural and remote areas, among other factors, were less likely to have a second trimester ultrasound exam and/or had lower rates of obstetrical ultrasound imaging utilization in general.

Findings from this study can be understood in the context of theoretical frameworks of health services utilization. A dominant theoretical framework to understand health services utilization is Andersen's Behavioral Model of Health Services Use (8,16). Initially described in the late 1960s,(16) this model posits that use of health services is a function of individuals' predisposition to use services ("predisposing characteristics"), factors which enable or impede use ("enabling resources"), and individuals' perceived and evaluated need for care (8). Predisposing characteristics include demographic characteristics, including age and sex; social structure, including education, occupation, and ethnicity; and health beliefs. Enabling resources according to the Behavioral Model include health personnel, facilities, a referral for obstetrical ultrasound, as well as the means for individuals to avail themselves of ultrasound services, including income, means of travel, and reasonable wait times (8). Andersen's concept of "enabling resources" reflects dimensions of accessibility as described by Levesque *et al.* in his framework of access to care, including approachability, acceptability, availability and accommodation, affordability, and appropriateness (6). In our study, consistent with Andersen's theoretical model, predisposing characteristics (including maternal age) and women's need for ultrasound (comorbidities and risk factors as reflected in the Obstetric Comorbidity Index) were independently associated with increased levels of obstetrical ultrasound imaging utilization.

Other factors need to be unpacked further in the context of this model and other literature. Our study found that Indigenous peoples were less likely to have a second trimester obstetrical ultrasound exam and had a lower rate of obstetrical ultrasound exams overall, consistent with prior literature which has found Indigenous peoples to have lower rates of prenatal care in general (11−13). Prior research has also demonstrated lower utilization of screening mammography programs among Indigenous peoples (28), including when those services are provided using a mobile mammography unit as has recently been described on Native American reservations in the United States (29). Our previous qualitative study exploring access to ultrasound in northern, remote, Indigenous communities found that Indigenous peoples highly value obstetrical ultrasound to provide reassurance about fetal development, and, in some cases, considered diagnostic information provided by ultrasound imaging to be "lifesaving (4)." Considering these findings, decreased utilization of obstetrical ultrasound among Indigenous peoples cannot be attributed solely to personal or cultural values among Indigenous peoples. Rather, other systemic barriers (represented by predisposing characteristics as part of the "social structure" in Anderson's model) must be explored and addressed. It is recognized in the literature that Indigenous peoples face racism and discrimination when accessing care and as a result Indigenous peoples may be reluctant to access healthcare services (30). Providing culturally-safe imaging care through increased cultural safety training among healthcare providers and collaborating with Indigenous patients and Elders to co-design culturally safe programs to enhance equitable access to obstetrical ultrasound and ensure culturally safe imaging experiences are potential approaches to help ensure Indigenous peoples have equitable opportunity to receive obstetrical ultrasound. Ensuring optimal access to obstetrical ultrasound among Indigenous peoples may be particularly important, as Indigenous peoples have a higher rate of stillbirths compared to non-Indigenous peoples (31,32) and two-fold higher maternal mortality rate relative to the general Canadian population (33).

Our study also demonstrated that patients living in rural and remote communities were less likely to have a second trimester ultrasound exam. This is in contrast to some previous research in Canada which has presented mixed results regarding whether urban-rural status is associated with inadequate prenatal care utilization (9,12,13). These differences might be explained by the outcome measured. For example, a study which did not find urban-rural status to be significantly associated with inadequate prenatal care used the Adequacy of Prenatal Care Utilization Index to assess adequacy of prenatal

TABLE 3. Number of pregnancies, number of obstetrical ultrasound exams, and rates of obstetrical ultrasound examinations per pregnancy by sociodemographic and geographic factors.

Variable	Number of pregnancies	Total number of obstetrical ultrasound exams	Average number of ultrasound exams per pregnancy	Adjusted IRR for obstetrical ultrasound exams per pregnancy (95% CI)*	*p*-value
Maternal age, years, *n* (%)					
<23 (reference)	18,157 (23%)	46,565 (18%)	2.56	–	<0.0001
23-26	13,171 (16%)	41,137 (16%)	3.12	1.19 (1.16-1.21)	
27-29	16,440 (20%)	56,103 (21%)	3.41	1.25 (1.23-1.28)	
30-32	14,616 (18%)	53,139 (20%)	3.64	1.30 (1.28-1.33)	
≥33	18,152 (23%)	67,515 (26%)	3.72	1.33 (1.31-1.36)	
Status First Nations, n (%)					
No (reference)	63,158 (78%)	221,066 (84%)	3.50	–	<0.0001
Yes	17,378 (22%)	43,393 (16%)	2.50	0.80 (0.78-0.81)	
Gravidity, *n* (%)					
1 (reference)	29,609 (37%)	98,864 (37%)	3.34	–	<0.0001
2	21,380 (27%)	73,173 (28%)	3.42	0.98 (0.97-0.99)	
3	12,855 (16%)	42,896 (16%)	3.34	1.02 (1.00-1.04)	
≥4	16,692 (21%)	49,526 (19%)	2.97	1.01 (0.98-1.03)	
Parity, *n* (%)					
0 (reference)	57,099 (71%)	196,457 (74%)	3.44	–	<0.0001
1	12,671 (16%)	39,073 (15%)	3.08	0.87 (0.86-0.89)	
2	5,683 (7%)	16,108 (6%)	2.83	0.82 (0.80-0.85)	
≥3	5,083 (6%)	12,821 (5%)	2.52	0.73 (0.71-0.76)	
Obstetric Comorbidity Index, *n* (%)					
0 (reference)	50,099 (62%)	128,489 (49%)	2.56	–	<0.0001
1-2	5,847 (7%)	22,797 (9%)	3.90	1.48 (1.45-1.51)	
3-4	15,389 (19%)	63,705 (24%)	4.14	1.65 (1.63-1.67)	
≥5	9,201 (11%)	49,468 (19%)	5.38	2.13 (2.09-2.17)	
Location of residence, *n* (%)					
Urban (reference)	50,747 (63%)	175,477 (66%)	3.46	–	<0.0001
Rural	7,597 (9%)	25,006 (9%)	3.29	1.01 (0.99-1.04)	
Missing	22,192 (28%)	63,976 (24%)	2.88	0.93 (0.90-0.96)	
Index of remoteness, *n* (%)					
<0.23 (reference)	35,794 (44%)	130,177 (49%)	3.64	–	<0.0001
0.23-0.30	18,168 (23%)	54,657 (21%)	3.01	0.86 (0.85-0.88)	
0.31-0.40	15,675 (19%)	51,336 (19%)	3.28	0.94 (0.93-0.96)	
≥0.41	10,395 (13%)	26,760 (10%)	2.57	0.79 (0.77-0.81)	
Missing	504 (1%)	1,529 (1%)	3.03	0.93 (0.85-1.00)	
Neighbourhood income quintile, *n* (%)					
1 (reference)	13,865 (17%)	43,957 (17%)	3.17	–	<0.0001
2	11,214 (14%)	35,993 (14%)	3.21	0.97 (0.95-0.99)	
3	10,226 (13%)	35,151 (13%)	3.44	1.01 (0.99-1.04)	
4	11,174 (14%)	40,094 (15%)	3.59	1.04 (1.02-1.06)	
5	7,993 (10%)	29,929 (11%)	3.74	1.10 (1.07-1.12)	
Missing	26,064 (32%)	79,335 (30%)	3.04	1.07 (1.04-1.10)	

IRR, incidence rate ratio; CI, confidence interval.

* Adjusted for all other variables in the multivariate GEE model.

care (9). This index considers only the timing of initiation of prenatal care and the frequency of prenatal visits, and does not consider obstetrical ultrasound, which requires specialized personnel and equipment that is not as readily available in many communities (34). Applying Andersen's Behavioural Model (8), lower rates of obstetrical ultrasound in rural and remote communities may relate to disparities in "enabling resources," including a referral for an obstetrical ultrasound, increased remoteness from ultrasound facilities, limited means to travel to an ultrasound facility, and lengthy wait times for an ultrasound appointment in remote communities. Indeed, the barriers identified in our group's previous research on

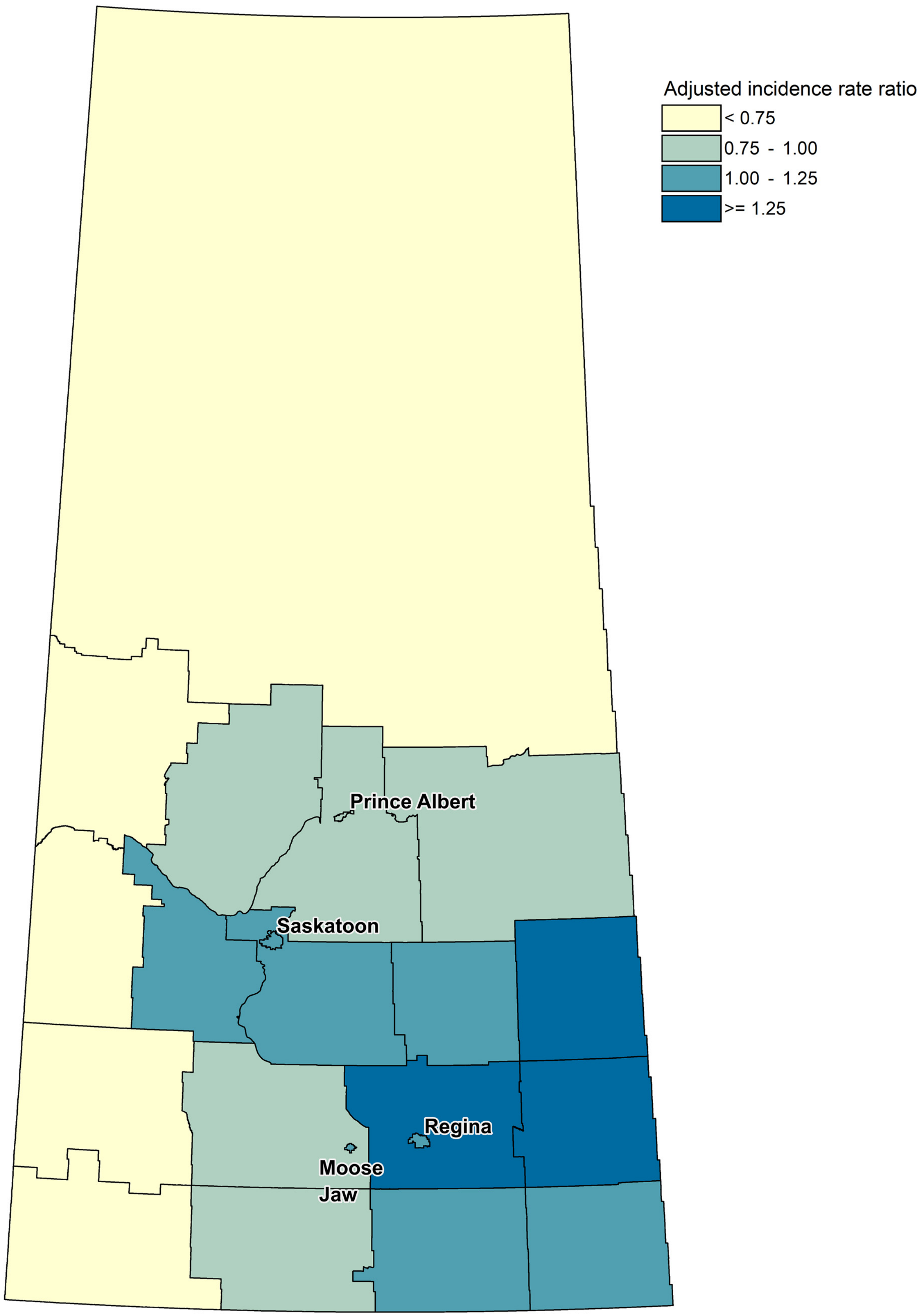

Figure 3. Choropleth map indicating adjusted incidence rate ratios of overall obstetrical ultrasound imaging for each census division in Saskatchewan. Boundaries of all 18 census divisions in the province are outlined in black. In addition, all large and medium population centres (Saskatoon, Regina, Prince Albert, and Moose Jaw) are labeled. The reference category is Saskatoon, the largest population centre in the province.

access to ultrasound imaging (4) appear to be reflected as decreased ultrasound imaging utilization in the present study.

The use of innovative technologies such as telerobotic ultrasound should be explored to improve access to ultrasound services for rural and remote populations (35,36). Telerobotic ultrasound allows sonographers, radiologists, or obstetricians to remotely scan patients from a central location while patients stay in their home community for their obstetrical ultrasound exam (35−37). Our experience using telerobotic ultrasound in northern Saskatchewan during the COVID-19 pandemic indicates clinical effectiveness and a high degree of patient acceptance of this technology, suggesting that this may be a viable means of improving access to ultrasound services in rural and remote communities (38). Ensuring culturally safe implementation of imaging services is critical to ensure acceptability and approachability (39).

Consistent with prior literature investigating inadequate prenatal care in general, (10,12,13,40) in our study there was a trend of patients with higher socioeconomic status being more likely to have a second trimester ultrasound exam, with higher rates of obstetrical ultrasound overall. This is in contrast to a study which found increased rates of obstetrical ultrasound imaging among patients of lower socioeconomic status in an urban setting in Manitoba, Canada. This difference may be explained by our study controlling for covariates such as First Nations status, multiparity, and obstetrical risk factors, which the previous study did not control for (24). Interestingly, individuals in the second-lowest income quintile in our study had lower rates of obstetrical ultrasound and lower odds of having a second trimester ultrasound exam compared to the lowest income quintile. It is plausible that patients in the lowest income quintile are recognized as being most at-risk for inadequate prenatal care and thus are followed more closely by their primary healthcare provider and provided with additional supports to ensure they are able to access investigations such as obstetrical ultrasound.

While two obstetrical ultrasound exams are recommended in an uncomplicated pregnancy (first trimester ultrasound and second trimester ultrasound), there are multiple clinical indications in which additional obstetrical ultrasound exams are recommended (1,41). The number of clinically-indicated ultrasound exams during a pregnancy is individual- and pregnancy-specific, and for this reason the appropriate number of exams for this cohort is not known. The average number of obstetrical ultrasound visits reported in our study is within the range previously reported in the literature, which has ranged from 2.14 ultrasound exams per pregnancy (in a randomized controlled trial in Finland) (42) to 4.55 ultrasound exams per pregnancy (based on United States data provided by insurance providers and underwriters for singleton, low-risk deliveries, with the potential for multiple exam codes to be billed at each ultrasound visit) (43). Differences in utilization between sociodemographic groups even after controlling for variables which may result in an increased number of obstetrical ultrasound exams—such as maternal age and Obstetric Comorbidity Index—suggest unequal utilization potentially stemming from inequitable access. This is of particular concern considering that some sociodemographic groups identified in this study—including Indigenous patients and low income patients—have increased rates of adverse pregnancy outcomes (31−33). While overutilization of obstetrical ultrasound imaging is not specifically accounted for in this study, the fact that the same sociodemographic and geographic predictors of having a second trimester complete ultrasound (which is recommended for all pregnant women) were also significant predictors of overall obstetrical ultrasound utilization suggests that disparities in utilization are not simply due to overutilization among some sociodemographic groups. Future work should include subgroup analyses, including among First Nations people and non-First Nations people, to better understand factors associated with obstetrical ultrasound utilization among each subgroup. Future work should also investigate differences in maternal and fetal outcomes as a result of variation in obstetrical ultrasound utilization.

Despite each of the medium and large population centres in the province having readily available access to ultrasound facilities, substantial variability was observed for second trimester obstetrical ultrasound utilization and overall obstetrical ultrasound utilization after controlling for covariates such as maternal age, First Nations status, neighbourhood income, and Obstetric Comorbidity Index. This may reflect differences in regional physician ordering practices or the type of obstetrical care provider. One study based on survey data found that obstetricians were more likely to order obstetrical ultrasound exams for a given patient compared to family physicians, midwives and nurse practitioners (44). While this may be due to the complexity of patients who are managed by obstetricians compared to family physicians, midwives and nurse practitioners, variation by type of obstetrical care provider deserves further attention. Lack of obtaining a second trimester ultrasound may be secondary to patient barriers in accessing ultrasound facilities, patients not being connected with an obstetrical care provider by the gestational age the exam is usually performed, or the obstetrical care provider simply not offering patients a second trimester ultrasound.

There are some limitations to this study, including those related to the use of administrative data as the basis for the study. Administrative data may have coding errors and incomplete data, potentially introducing systematic biases (12). In our study, data for urban vs. rural status and neighbourhood income quintile were available only from January 2014 to October 2017, resulting in a substantial proportion of missing data for these variables. As posited by various theoretical models of healthcare utilization, additional variables may help explain obstetrical ultrasound utilization, such as education level, occupation, and culture, but are not reliably captured in available administrative datasets. There is a trade-off between being able to obtain detailed individual level data (as might be achieved through conducting a chart review or prospective survey) and being able to capture the entire population in the study cohort. This study favoured the latter, though a future, complementary study might investigate the association between obstetrical imaging utilization and additional variables using a different study design.

Another limitation due to lack of data availability is the use of neighbourhood (area-level) income quintile rather than individual income as a co-variate to represent socioeconomic status. While studies have found that there can be substantial variability between household-level income and area-level income, (45,46) area-level income remains recognized as an independently meaningful predictor and remains commonly used as a proxy of socioeconomic status (46,47). Additionally, from a social-ecologic perspective, area-level measures of socioeconomic status are considered meaningful indicators in and of themselves and should not be simply considered proxies for individual-level data (12,48). Another limitation is that location of residence (including urban vs. rural status and index of remoteness) was determined only at the start of each pregnancy. Individuals may have moved during their pregnancy, though the proportion of patients who moved is considered minimal. Further, although the Obstetrical Comorbidity Index was used as a proxy to reflect certain clinical conditions, such as multiple gestation, which may predispose individuals to an increased number of obstetrical ultrasound exams, the comorbidities on which it is based is not all-encompassing.

In conclusion, this study identifies specific sociodemographic groups who were less likely to have a second trimester ultrasound exam and had lower rates of obstetrical ultrasound imaging utilization in general. Disparities in utilization may reflect structural barriers to accessing obstetrical ultrasound which are faced by specific sociodemographic groups, including rural and remote, Indigenous, and low-income individuals. This study may inform the development of programs and services targeted towards sociodemographic groups and geographic regions which currently have lower rates of obstetrical ultrasound utilization to ensure that all women have equitable opportunity for obstetrical ultrasound imaging. It is our hope that this study stimulates further work exploring solutions to overcome these systemic barriers, including the use of innovative technologies to improve access to diagnostic ultrasound services for vulnerable and marginalized populations.

CONFLICT OF INTEREST

None

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DISCLOSURE

This study is based on de-identified data provided by the Saskatchewan Ministry of Health and eHealth Saskatchewan. The interpretation and conclusions contained herein do not necessarily represent those of the Government of Saskatchewan, the Saskatchewan Ministry of Health, or eHealth Saskatchewan.

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