FACTORS ASSOCIATED WITH PRENATAL ULTRASOUND UTILIZATION

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ABSTRACT

Background and objectives

Ultrasound is commonly used in pregnancy and serves a very important purpose in maternal and fetal screening and diagnosis. However, when not medically necessary it may have an economic impact and may lead to unnecessary interventions. The purpose of this dissertation was to increase the knowledge about prenatal ultrasound utilization which has not been adequately explored. The specific objectives of this dissertation were to 1) study the relationship between having single versus multiple prenatal care providers and the number of prenatal ultrasounds in the USA, 2) explore the factors associated with the timing of the first prenatal ultrasound in Canada, and 3) assess the relationship between the number of prenatal ultrasounds and primary caesarean delivery in Canada and the USA.

Methods

Responses from two national, cross-sectional surveys were analyzed to address these objectives. The two surveys were the Maternity Experiences Survey from Canada and the Listening To Mothers III survey from the USA. Negative binomial (for objective 1), multinomial (objective 2) and binary (for objective 3) logistic regression models were used to analyze the data. The provided survey weights were applied to both surveys to make the data nationally representative. Bootstrap weights were also applied to the analyses involving the Maternity Experiences Survey.

Results

The results of objective 1 showed no significant relationship between having single versus multiple prenatal care providers and the number of prenatal ultrasounds in the USA. The findings of objective 2 showed that multiple factors were associated with the timing of prenatal ultrasound in Canada including province of prenatal care, maternal age and country of birth. The results of objective 3 showed a significant relationship between the number of prenatal ultrasounds and caesarean delivery in Canadian multiparas and primiparas as well as in American multiparas.

Conclusions

The findings of this dissertation form a baseline of attributes of prenatal ultrasound utilization in Canada and the USA and may be used to inform efforts aimed at the optimization of prenatal ultrasound utilization. Future studies can further investigate these relationships, perhaps using more robust databases that may allow for better control of confounding variables.

DEDICATION

To Hala. Your guidance, mentorship and unwavering support are the reason I am here today.

To my parents, Rafah & Basil. You are and always have been my role models.

To my second set of parents, Fatma & Mudhar. Your endless care and support kept me going.

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LIST OF ABBREVIATIONS

95%CI: 95% Confidence Interval

ACOG: American College of Obstetricians and Gynecologists

ALARA: As Low As Reasonably Achievable

BMI: Body Mass Index

CATI: Computer Assisted Telephone Interview

CD: Caesarean Delivery

CHIP: Children's Health Insurance Program

FEHB: Federal Employee Health Benefits program

IRR: Incidence Rate Ratio

LTM III: Listening To Mothers III

MES: Maternity Experiences Survey

OB/GYN: Obstetrician/Gynaecologist

OR: Odds Ratio

SOGC: Society of Obstetricians and Gynaecologists

USA: United States of America

WHO: World Health Organization

CHAPTER 1
Dissertation introduction

Background

Ultrasound is an imaging modality that utilizes sound waves and their interactions with bodily tissues to generate real-time images on a screen [1]. Sound waves may be scattered, reflected by or absorbed into the tissues, displaying different images that can be clinically interpreted [1]. Ultrasound has been used in obstetrics since the 1950s and has become an essential part of current prenatal care [2]. The use of ultrasound in pregnancy can provide valuable information that can predict fetal outcomes and aid in the detection of cardiac [3], gastrointestinal [4], renal [5], and neural abnormalities [6] as well as chromosomal anomalies including Down's Syndrome [2]. Ultrasound can also help in the detection of serious maternal conditions such as placenta previa, placental abrubtion and placenta accreta spectrum disease that may arise during pregnancy [7]. Current recommendations by the Society of Obstetricians and Gynaecologists of Canada (SOGC) [8] and the American College of Obstetricians and Gynecologists (ACOG) [9] state that all pregnant women should be offered an ultrasound scan between 18-22 weeks to screen for fetal anomalies and to provide information about the placenta, gestational age and number of fetuses. In addition, both the SOGC [10] and ACOG [11] recommend that all pregnant women be offered the option of having one of several prenatal screening tests for fetal aneuploidies, some of which include a first trimester ultrasound. Moreover, certain situations can put a pregnant woman at risk which may lead to additional tests including ultrasounds. These situations include maternal obesity, twin pregnancies, and gestational diabetes, as well as others [12]. A detailed list of factors that put a pregnancy at risk is provided in Appendix A. Moreover, a detailed list of situations that might entail additional ultrasounds are provided in Appendix B. In addition to Appendix B, the American College of Obstetricians and Gynecologists has recommended fetal monitoring with ultrasound in cases of maternal hypertension [13] and gestational diabetes [14].

Potential harms of prenatal ultrasound

Though generally considered safe [15], ultrasound has been associated with some adverse outcomes. For instance, ultrasound has been shown to cause tissue heating [16,17], and increases in maternal body temperature whether due to fever or heat exposure, have been shown to have teratogenic effects on the fetus [17–20]. In addition, animal studies have found an association between prenatal ultrasound and low birth weight [21,22], as well as harmful effects to growth and development [23]. Prenatal ultrasound has also been associated with increased anxiety in the mother [24,25], increased fetal cell death in the early stages of pregnancy [26,27] and a lower likelihood of being right-handed [28]. While non-right handedness is of no clinical significance, it is concerning to see this association because if prenatal ultrasound exposure can lead to changes in handedness, it may potentially have other effects on fetal development that may, directly or indirectly, result in more serious neurological outcomes. Moreover, overutilization of diagnostic imaging in general has been associated with an increased likelihood of unnecessary medical interventions [29]. In the case of prenatal ultrasound, it has been shown that having a third trimester scan can lead to increased prenatal interventions without a significant improvement in perinatal outcome [30]. Moreover, having an ultrasound too early in the pregnancy may lead to misinterpretation of findings leading to unnecessary interventions that can harm an otherwise normal pregnancy [31]. Another important aspect to consider with prenatal ultrasound scans is the cost associated with performing these tests, which can burden the healthcare system if used excessively [32].

Conceptual framework

Despite the potential harms discussed above, prenatal ultrasound utilization is increasing in Canada [32] and the USA [33], and this increase is not explained by a higher proportion of 'high risk' cases [32,34]. Moreover, the increased use of prenatal ultrasound has not been associated with reductions in perinatal mortality, except in women who chose to terminate the pregnancy due to abnormal ultrasound findings [34,35]. Overutilization of prenatal ultrasound falls within the realm of 'medical overuse' which suffers from several knowledge gaps [36]. Morgan et al designed a research agenda in 2015 to navigate researchers in this field [36]. The definition of overuse used by these researchers is "care in the absence of a clear medical basis for use or when the benefit of therapy does not outweigh risks" [36]. Morgan et al's research agenda suggests 5 main headings that researchers should target: 1) measure frequency of overuse, 2) identify factors promoting overuse, 3) explore how clinical uncertainty and cognitive biases may lead to overuse, 4) strategies to mitigate overuse, and 5) modifications to research infrastructure [36]. They also designate several subheadings as research priorities, including two that will be targeted in this dissertation: 1) identify the most important drivers of overuse and 2) measure the impact of overuse [36].

It is important to note here that the "appropriate" or "optimal" use of prenatal ultrasound can have many definitions and can be complicated by several situations that may need to be assessed on a case-by-case basis. Formulating a broad, standardized definition for "appropriate" or "optimal" use of prenatal ultrasound is, therefore, challenging because different researchers and practitioners may value the various aspects of prenatal ultrasound differently. For the purposes of this dissertation, the phrases "appropriate" or "optimal" utilization of prenatal ultrasound represent misuse of this diagnostic test, specified by utilization when not medically necessary.

Objectives

The aim of this dissertation is to investigate some of the factors associated with the utilization of prenatal ultrasound, to shed some light on some aspects of prenatal ultrasound that have thus far been underexplored or unexplored at all. The three specific objectives of this dissertation are:

1. To investigate the relationship between having single versus multiple prenatal care providers and the number of ultrasounds received during pregnancy in the USA.
2. To investigate the factors associated with the timing of the first prenatal ultrasound in Canada.
3. To assess the relationship between the number of prenatal ultrasounds and primary caesarean delivery in Canada and the USA.

Each of these objectives will be addressed in a separate manuscript in this dissertation. The next two chapters (chapters 2 and 3) will explore prenatal ultrasound utilization as an outcome, studying factors that may influence its frequency and timing.

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CHAPTER 2

The relationship between single versus multiple prenatal care provider and the number of ultrasounds received during pregnancy: Findings from the Listening To Mothers III survey

Abstract

Objectives
This study aimed to investigate the relationship between having single/multiple prenatal care providers and the number of prenatal ultrasounds.

Methods
This was a secondary data analysis of the Listening To Mothers III survey which was a national cross-sectional survey covering different aspects of pregnancy in the USA. Bivariable and multivariable negative binomial regression models were used to investigate the relationship between having single or multiple prenatal care providers and the number of prenatal ultrasounds while adjusting for several sociodemographic, maternal medical and prenatal and birth factors.

Results
78.1% women received prenatal care from a single provider and 21.9% received prenatal care from 2 or more providers. Women under single provider prenatal care received an average of 4.5 ultrasounds and those cared for by multiple providers received an average of 4.6 ultrasounds. No significant difference was observed in the number of prenatal ultrasounds between women seeing a single provider and those seeing multiple providers (‘single’ adjusted IRR=0.95, 95%CI:0.84-1.08). Factors significantly associated with the number of prenatal ultrasounds were being an African American compared to being Caucasian (adjusted IRR=1.24, 95%CI:1.07-1.44), gestational diabetes (adjusted IRR=1.18, 95%CI:1.01-1.37), receiving prenatal care from a ‘family doctor or other doctor’ or ‘midwife or other’ compared to obstetrician/gynecologist (‘family doctor or other doctor’ adjusted IRR=0.84, 95%CI:0.71-1.00; ‘midwife or other’ adjusted IRR=0.80, 95%CI:0.67-0.96) and caesarean delivery (adjusted IRR=1.18, 95%CI:1.05-1.32).

Conclusions
No significant relationship between single/multiple provider and the number of prenatal ultrasounds was found. This may indicate that models of prenatal care involving more than one provider may offer informational continuity and seamless transition between providers. However, this finding needs to be replicated and explored in different settings. African American race, gestational diabetes and caesarean birth were associated with more ultrasound, while receiving care from a midwife or a family doctor was associated with fewer ultrasounds.

Background

Having multiple healthcare providers, as opposed to a single provider leading the care of a patient, can have an impact on health service utilization in the form of higher likelihood of hospitalization [1], increased number of visits to the emergency department [2], higher healthcare costs [3] and higher likelihood of ordering diagnostic tests [4,5]. In pregnancy, a woman can have multiple prenatal care providers if she is cared for by a group practice (as opposed to a solo practice) [6], or if she is seen within a team-based (also known as shared-care) model, where prenatal, intrapartum and postpartum care is provided by two or more providers [7,8]. Team-based care is encouraged by the American College of Obstetricians and Gynecologists (ACOG) [7–9] and has been reported in the USA [7]. In the United States, around 22% of women indicated that two or more providers took the lead in their prenatal care in 2011/2012 [10].

Previous studies suggest that having multiple healthcare providers can lead to an increased frequency of imaging tests [5,11,12]. In pregnancy, imaging tests, usually in the form of prenatal ultrasounds, are routinely ordered. Current recommendations by the ACOG state that: 1) all pregnant women should be offered an ultrasound scan between 18-22 weeks to screen for fetal anomalies and to provide information about the placenta, gestational age and number of fetuses [13] and 2) recommend that all pregnant patients be offered the option of having one of several prenatal screening tests for fetal aneuploidies, some of which include a first trimester ultrasound [14]. In certain situations such as maternal obesity, twin pregnancies, and gestational diabetes, a pregnant woman might require further tests including additional ultrasounds to monitor the wellbeing of the mother and the baby [15]. However, it is important to note that the utilization of non-medically indicated diagnostic testing can lead to increased costs [16] and potentially unnecessary medical interventions [17]. For instance, increased frequency of prenatal ultrasounds may lead to increased detection of incidental findings, possibly triggering a cascade of additional testing and intervention.

To our knowledge, the impact of having multiple prenatal care providers on the number of diagnostic tests ordered during pregnancy, particularly prenatal ultrasound, has not been investigated. The number of ultrasounds received during pregnancy may serve as a good proxy for examining the number of diagnostic tests a pregnant woman receives. Investigating this relationship may shed some light on the potential costs, manifested by unnecessary testing, that may be associated with prenatal care models involving multiple providers, which are generally suggested to be cost efficient [8]. In addition, it is important to increase knowledge pertaining to factors contributing to prenatal ultrasound utilization. This can inform efforts aimed at reducing prenatal ultrasound utilization when not medically indicated, thereby potentially reducing unnecessary costs and interventions. The purpose of this study was to evaluate the relationship between having single versus multiple prenatal care providers and the number of ultrasounds received during pregnancy.

Methods

This study was a secondary data analysis of the Listening To Mothers III (LTM III) survey which was a national cross-sectional survey in the USA that was commissioned by Childbirth Connection, funded by the Kellogg Foundation and conducted by Harris Interactive® (a national market research firm). All of the LTM surveys are in compliance with the code and standards of the Council of American Survey Research Organizations and the code of the National Council of Public Polls.

The LTM III collected information about pregnancy, labour, birth and the postpartum period and targeted women who had given birth to a single baby in a hospital between July 1, 2011 and June

30, 2012, and who were: 18-45 years of age, whose baby was living at the time of the survey and who spoke English enough to complete the survey. The survey sample was drawn from the following panels: Harris Poll Online, Research Now/E-Rewards, GMI and Offerwise Hispanic. An email invitation was sent to women from the panels mentioned above, after which the women were asked a series of screening questions to determine eligibility before accessing the survey. The final sample included 2,400 women whose data was analyzed in this study. Details of the LTM III methodology have been described previously [18,19].

The outcome variable for this study was 'number of prenatal ultrasounds' and was used as a count variable. Information about this variable was obtained using the question "As best as you can remember, how many times did you have an ultrasound scan (sonogram) during your recent pregnancy?". This variable may serve as proxy for diagnostic prenatal testing. The main independent variable was 'single/multiple prenatal care providers' and had 2 levels: 'single' and 'multiple' prenatal care providers. Information about this variable was obtained from the question "During your pregnancy did…? 1) You always or almost always see the same person for your prenatal care 2) Two or more different people take the lead in providing your prenatal care". This variable may be viewed as a proxy for 'solo' versus 'group' practice.

Several covariates were included in the analysis and were divided into several categories: Sociodemographic, maternal medical history and prenatal and birth related factors. The sociodemographic category included: maternal age at birth, race, country of birth (two categories: USA born and born outside of the USA), region of residence (1. North East – Connecticut, Maine, Vermont, Rhode Island, New Hampshire, and Massachusetts, Pennsylvania, New York, and New Jersey. 2. Midwest – Wisconsin, Illinois, Michigan, Ohio, and Indiana, South and North Dakota, Iowa, Missouri, Kansas, Nebraska, and Minnesota. 3. South – District of Columbia, Texas, Louisiana, Oklahoma, and Arkansas, Tennessee, Mississippi, Alabama, and Kentucky, West Virginia, Georgia, Virginia, South and North Carolina, Maryland, Delaware, and Florida. 4. West – Oregon, Hawaii, Alaska, California, and Washington, Wyoming, Montana, and Idaho, New Mexico, Utah, Arizona, Nevada, and Colorado.), education, household income and source of payment for maternity care. The maternal medical factors category included: Pre-pregnancy BMI, parity, fertility care prior to index pregnancy, history of type 1 or type 2 diabetes, gestational diabetes during the index pregnancy, and whether the woman took medication for hypertension 1 month before the index pregnancy. Prenatal and birth factors included: Type of prenatal provider, whether the women felt she needed treatment for depression (asked by the question "During your recent pregnancy, did you feel you needed any of the following services?" 1. Food stamps, WIC food vouchers, or money to buy food. 2. Treatment for depression. 3. Help to quit smoking. 4. Counseling for nutrition". This was dichotomized to: 'Yes' which included women responding with yes to 'treatment to depression'; and 'No' which included all other women), gestational age at birth, birthweight and whether the baby was admitted to the intensive care unit after birth. The birth related variables were included as proxy for conditions that may have complicated the pregnancy, potentially confounding the relationship between single/multiple providers and the number of prenatal ultrasounds.

Statistical analyses

Bivariable and multivariable negative binomial regression was used to assess the relationship between having single/multiple prenatal care providers and the number of prenatal ultrasounds. Negative binomial regression was used because it accounted for the 'count' nature of outcome (number of prenatal ultrasounds). It also does not have an assumption of normality for the conditional distribution of the outcome count variable [20]. The simpler Poisson regression for count outcomes was not used because the outcome ‘number of prenatal ultrasounds’ was over-dispersed which does not satisfy the assumption of equi-dispersion for Poisson models. Moreover, the Poisson model did not provide a good model fit using the Pearson Goodness of Fit test. Negative binomial regression was, therefore, a suitable model when studying the outcome ‘number of prenatal ultrasounds’ and was flexible enough to account for its variability. This analysis produced adjusted Incidence Rate Ratios (IRR) and 95% Confidence Intervals (95%CI). The significance level was set at an α of 0.05. An interaction term between ‘single/multiple provider’ and ‘type of prenatal care provider’ was not found to be significant. The provided survey weights were applied to help ensure that estimates were nationally representative. All statistical tests were performed using IBM SPSS Statistics for Windows, version 24 (IBM Corp., Armnok, NY).

Results

American women received between 0 and 30 ultrasounds during their pregnancy, with a mean of 4.5 ultrasounds and a median of 3 ultrasounds. The percentage of women who received care from a single prenatal care provider was 78.1% and those who had 2 or more providers in their prenatal care comprised 21.9% (Table 1). Women receiving care from a single provider received an average of 4.5 ultrasounds and those receiving prenatal care from multiple providers received an average of 4.6 ultrasounds (Table 1).

The unadjusted and adjusted IRRs and 95%CI are presented in Table 1. No significant difference in the number of prenatal ultrasounds was found between women who had a single provider and those who had multiple prenatal care providers during their pregnancy (‘single’ adjusted IRR=0.95, 95%CI: 0.84-1.08) (Table 1). The only sociodemographic variable that was significantly associated with the number of prenatal ultrasounds was race, where being an

African American was associated with 24% more ultrasounds compared to being Caucasian (adjusted IRR=1.24, 95%CI: 1.07-1.44) (Table 1).

The only maternal medical factor that was significantly associated with the number of prenatal ultrasounds was having gestational diabetes which was associated with 18% more ultrasounds compared to not having gestational diabetes (adjusted IRR=1.18, 95%CI: 1.01-1.37) (Table 1). The prenatal and birth factors that were significantly associated with the number of prenatal ultrasounds were type of prenatal care provider, mode of delivery, and birthweight. Receiving prenatal care from a 'family doctor or other doctor' or 'midwife or other' was associated with a lower number of ultrasounds compared to receiving care from an obstetrician/gynecologist ('family doctor or other doctor' adjusted IRR=0.84, 95%CI: 0.71-1.00, P = 0.04; 'midwife or other' adjusted IRR=0.80, 95%CI: 0.67-0.96) (Table 1). Delivering via caesarean delivery was associated with 18% higher number of prenatal ultrasounds compared to vaginal delivery (adjusted IRR=1.18, 95%CI: 1.05-1.32) (Table 1). No other factors were significantly associated with the number of prenatal ultrasounds.

Discussion

This study was the first of its kind to explore the relationship between single versus multiple prenatal care providers and the number of prenatal ultrasounds. The present study found that American women receiving care from a single provider received an average of 4.5 ultrasounds, while those cared for by multiple providers received an average of 4.6 ultrasounds. This study did not show a significant relationship between having single or multiple prenatal care providers and the number of prenatal ultrasounds but did identify some factors that were significantly associated with the number of prenatal ultrasounds. These include African American race, gestational diabetes, having a family doctor or midwife as the prenatal care provider and caesarean birth. These findings are preliminary and need to be replicated and further explored by future studies.

The non-significant relationship between single versus multiple prenatal care providers and the frequency of prenatal ultrasounds may indicate that care models involving multiple prenatal care providers offer a seamless transition with informational continuity between providers. In this case, non-significance is reassuring that these models of prenatal care do not contribute to overutilization of diagnostic testing and, consequently, increased costs and unnecessary interventions. Alternatively, this non-significance could be due to factors that were not controlled for in the analysis of this study, particularly for the women who indicated receiving prenatal care from multiple providers. For example, the different combinations of the types of prenatal providers (e.g. obstetrician, family doctor, midwife and others) were not known. Moreover, it was not possible to discern what model of prenatal care (e.g. shared-care, group practice or others) these women received. Finally, the total number of prenatal care providers and the timing of when a new provider joined prenatal care were not controlled for and may have played a role in the findings. All of these factors may have opposing effects that 'cancel' each other out, rendering the overall association between single/multiple providers and the number of prenatal ultrasounds non-significant. Future studies can explore this relationship, while accounting for these factors to isolate the true effect of single/multiple providers on the number of prenatal ultrasounds. Therefore, even though no significant association was found, these findings are preliminary and need to be further explored and replicated due to the limitations of the dataset used in this study.

American women received, on average, between 4 and 5 prenatal ultrasounds during their pregnancy. This is higher than the current recommendations of the ACOG which generally suggests 2 ultrasounds, one in the first trimester as part of prenatal screening and one in the second trimester [13,14]. It is highly probable that some of these additional ultrasounds were medically indicated and required for the management of the women and their babies. It is also very likely that some of the factors contributing to this higher number of ultrasounds were not medical. Prenatal ultrasound utilization has significantly proliferated, to the point of commercialization. This is reflected by the emergence of 'non-medical' or 'keepsake' ultrasounds [21]. This widespread availability of prenatal ultrasound may have led to an expectation among pregnant women and their families of receiving prenatal ultrasounds whenever they wanted them.

The findings of the present study show that women experiencing a high-risk pregnancy are receiving more ultrasounds which suggests that most providers are ordering prenatal ultrasounds that are medically necessary. This is reflected by the findings that African American women (compared to Caucasian women) and women who had gestational diabetes (compared to those who did not) received 24% and 18% more ultrasounds, respectively. African American women are significantly more likely to experience high-risk pregnancies than Caucasian women [22–24]. Babies of African American mothers have a higher likelihood of fetal growth restriction [25], lower birthweight [26], being born prematurely [26] and infant, neonatal and post-neonatal mortality [27] than those born to Caucasian women. All of these situations warrant additional ultrasounds to diagnose and/or monitor these conditions or their associated outcomes [28]. Similarly, women afflicted with gestational diabetes often require additional ultrasounds due to increased rates of macrosomia and fetal demise [29].

Receiving prenatal care from a midwife or family doctor or other doctor for prenatal care was associated with significantly lower numbers of ultrasounds than receiving prenatal care from an obstetrician/gynecologist after adjusting for confounding factors. Midwives and family doctors tend to use fewer interventions when managing a pregnant woman than do obstetricians [30–32]. High-risk pregnancies fall within the obstetrician's scope of practice, which often requires them to use more tests, including ultrasounds, when caring for their patients [33]. Additionally, obstetricians are often targeted in malpractice lawsuits [34], which may lead them to use "defensive medicine" and order more ultrasounds to confirm normality [35]. Moreover, obstetricians may be more inclined to incorporate advanced technology such as prenatal ultrasound in their management of pregnant women, perhaps because they find it professionally rewarding or to attract more patients [36].

Finally, women who delivered via caesarean also received significantly more ultrasounds than those who delivered vaginally after adjusting for confounding factors. This is not unexpected because the indications for caesarean delivery sometimes overlap with the indications for additional prenatal ultrasounds such as in the cases of malpresentation and placental issues [28,37].

The main limitation of this study is that it was a secondary data analysis of survey responses which can lead to information bias either due to lack of recall or a respondent's attempt to present themselves more favourably. The survey was also cross-sectional which can introduce reverse causality. Moreover, it was not possible to adjust for all of the confounding variables that could have played a role in the analysis due to the absence of such variables in the LTM III dataset. These variables include conditions complicating pregnancy such as congenital malformations and placental issues. For this reason, birth related factors such as mode of delivery, gestational age at birth, birthweight and admission to the intensive care unit were used as proxy for conditions complicating pregnancies that may confound the relationships explored. Other potential confounding factors that were not available in the LTM III were different combinations of and the total number of providers of prenatal care, timing of the new providers and what model of prenatal care the women were under. In addition, the question used to create the variable 'single/multiple provider' may not be a reliable measure of the number of prenatal care providers women saw during their pregnancies. Despite these limitations, this study was the first to investigate this relationship in USA on a national scale, using the most recent available national database that addresses different aspects of maternity care in the USA. This study provides an opportunity to further discuss and explore the relationship between single/multiple provider and prenatal ultrasound utilization.

The present study was the first to examine the influence of single versus multiple provider prenatal care models on the number of diagnostic tests ordered using the proxy, number of ultrasounds. No association between single/multiple prenatal care provider models and the number of prenatal ultrasounds was found, which may indicate that models of prenatal care with more than one provider are as efficient in their utilization of diagnostic testing as models of care involving a single provider. This finding can be used as a baseline for future studies to build upon. Future studies may explore this relationship using more robust datasets such as administrative databases and hospital discharge records, that may allow for better control of clinical confounding variables. Finally, future studies may also aim to study this relationship further by isolating the different factors that may play a role within the 'multiple' prenatal care providers group, including the different combinations of prenatal care providers, model of prenatal care, total number of providers and timing of when a new provider joined care.

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Table 1: Percentages, adjusted and unadjusted Incidence Rate Ratio (IRR) and 95% Confidence Intervals (95%CI) for the number of ultrasounds received during pregnancy (The Listening To Mothers III Survey).

Variable	Overall %	Number of prenatal ultrasounds		
		Average	Unadjusted IRR (95%CI)	Adjusted IRR (95%CI)
MAIN EXPOSURE VARIABLE				
Single or multiple prenatal care provider				
Single	78.1	4.5	0.97 (0.87-1.09)	0.95 (0.84-1.08)
Multiple	21.9	4.6	1.00	1.00
SOCIODEMOGRAPHIC FACTORS				
Age at birth				
<20	7.0	5.4	1.26 (1.05-1.50)	1.21 (0.96-1.53)
20-34	77.9	4.4	1.00	1.00
35+	15.1	4.7	1.11 (0.98-1.27)	1.03 (0.89-1.20)
Race				
White	54.8	4.3	1.00	1.00
African American	15.4	5.5	1.28 (1.13-1.46)	1.24 (1.07-1.44)
Hispanic	23.3	4.3	0.99 (0.89-1.11)	0.97 (0.84-1.11)
Other	6.6	4.8	1.13 (0.94-1.36)	1.07 (0.86-1.33)
Country of birth				
USA	92.9	4.5	1.00	1.00
Other	7.1	4.7	1.05 (0.88-1.25)	1.14 (0.92-1.41)
Region of Residence				
Northeast	15.2	4.8	1.15 (0.99-1.34)	1.10 (0.92-1.31)
Midwest	22.7	4.5	1.06 (0.92-1.21)	1.01 (0.86-1.18)
South	39.7	4.5	1.05 (0.93-1.19)	1.01 (0.88-1.16)
West	22.4	4.3	1.00	1.00
Education				
High school or less	42.3	4.3	1.00	1.00
Some college	28.5	4.8	1.11 (0.99-1.24)	1.12 (0.99-1.27)
College graduate or higher	29.2	4.6	1.11 (0.99-1.24)	1.07 (0.92-1.24)

Household income				
$29,400 or less	28.5	4.2	0.85 (0.73-0.99)	0.94 (0.77-1.14)
$29,401-$60,000	32.4	4.3	0.88 (0.76-1.02)	0.95 (0.80-1.13)
$60,001-$98,200	24.1	4.9	1.01 (0.87-1.18)	1.04 (0.88-1.22)
>$98,200	15.0	4.8	1.00	1.00
Source of payment for maternity care				
Medicaid or CHIP	38.3	4.4	1.00	1.00
Other government program	9.6	4.6	1.01 (0.86-1.2)	1.10 (0.91-1.33)
Private insurance	46.9	4.6	1.05 (0.95-1.16)	1.06 (0.93-1.22)
Out of pocket	5.1	4.2	1.00 (0.81-1.24)	1.10 (0.86-1.40)
MATERNAL MEDICAL Factors				
Pre-pregnancy BMI				
Underweight (less than 18.5)	8.5	4.1	0.93 (0.79-1.11)	0.88 (0.73-1.07)
Normal (18.5-24.99)	47.8	4.4	1.00	1.00
Overweight/obese (25+)	43.8	4.7	1.09 (0.99-1.19)	1.05 (0.94-1.17)
Parity				
Primiparous	40.7	4.8	1.00	1.00
Multiparous	59.3	4.3	0.91 (0.83-1.00)	0.97 (0.87-1.08)
Fertility care prior to pregnancy				
Yes	16.1	5.3	1.24 (1.1-1.41)	1.12 (0.95-1.32)
No	83.9	4.3	1.00	1.00
History of type 1 or type 2 diabetes				
Yes	9.0	5.2	1.21 (1.04-1.41)	1.04 (0.84-1.29)
No	91.0	4.4	1.00	1.00
Gestational diabetes during index pregnancy				
Yes	17.9	5.3	1.26 (1.13-1.42)	1.18 (1.01-1.37)
No	82.1	4.3	1.00	1.00
Taken medications for hypertension 1 month before index pregnancy				
Yes	7.9	6.0	1.39 (1.18-1.64)	1.17 (0.96-1.42)

No	92.1	4.4	1.00	1.00
PRENATAL AND BIRTH RELATED FACTORS				
Type of prenatal care provider				
Obstetrician/Gynecologist	77.8	4.6	1.00	1.00
Family doctor or other doctor	11.7	4.7	1.04 (0.90-1.20)	0.84 (0.71-1.00)
Midwife or Other	10.5	3.8	0.82 (0.70-0.96)	0.80 (0.67-0.96)
Felt needed depression treatment during pregnancy				
Yes	10.8	5.3	1.13 (1.00-1.28)	1.05 (0.90-1.23)
No	89.2	4.4	1.00	1.00
Mode of delivery				
Vaginal	69.0	4.3	1.00	1.00
Caesarean	31.0	5.0	1.17 (1.06-1.29)	1.18 (1.05-1.32)
Gestational age at birth				
Preterm (<37 weeks)	9.1	4.9	1.12 (0.96-1.31)	0.98 (0.81-1.19)
Term (37-41 weeks)	88.3	4.4	1.00	1.00
Post-term (42 weeks or more)	2.6	6.3	1.37 (1.04-1.79)	1.01 (0.74-1.39)
Birthweight				
<2500g	7.8	5.3	1.24 (1.05-1.46)	1.16 (0.94-1.42)
2500-4000g	82.0	4.5	1.00	1.00
>4000g	10.2	4.1	0.90 (0.78-1.05)	0.84 (0.71-1.00)
Baby admitted to the intensive care unit after birth				
Yes	18.1	5.1	1.17 (1.04-1.32)	1.04 (0.89-1.22)
No	81.9	4.4	1.00	1.00

CHAPTER 3
Factors associated with the timing of the first prenatal ultrasound in Canada

Peri Abdullah, Christine Kurtz Landy, Hugh McCague, Alison Macpherson and Hala Tamim. Factors associated with the timing of the first prenatal ultrasound in Canada. BMC Pregnancy and Childbirth 2019, 19(1):164.

Abstract

Background
The aim of this study was to investigate the factors associated with the timing of the first prenatal ultrasound in Canada.

Methods
This was a secondary data analysis of the Maternity Experiences Survey, a cross-sectional survey covering different aspects of pregnancy, labour, birth and the post-partum period. Bivariate and multivariate multinomial logistic regressions were performed to assess the relationship between timing of first prenatal ultrasound and different independent variables.

Results
68.4% of Canadian women received an optimally timed first prenatal ultrasound, 27.4% received early ultrasounds and 4.3% received late ultrasound. The highest prevalence of early ultrasound was in Ontario (33.3%) and the lowest was in Manitoba (13.3%). The highest prevalence of late ultrasound was found in Manitoba (12.1%) and the lowest was in British Columbia and Ontario (3.5% each). The highest prevalence of optimal timing of first prenatal ultrasound was in Quebec (77%) and the lowest was in Ontario (63.2%). Factors influencing the timing of ultrasound included: *Early* – maternal age <20 (adjusted OR=0.54, 95%CI:0.34-0.84), alcohol use during pregnancy (adjusted OR=0.69, 95%CI:0.53-0.90), history of premature birth (adjusted OR = 1.41, 95%CI:1.06-1.89), multiparity (adjusted OR=0.67, 95%CI:0.57-0.78), born outside of Canada (adjusted OR=0.82, 95%CI:0.67-0.99), prenatal care in Newfoundland and Labrador (adjusted OR=1.66, 95%CI:1.20-1.30), Nova Scotia (adjusted OR=1.68, 95%CI:1.25-2.28), Ontario (adjusted OR=2.16, 95%CI:1.76-2.65), Saskatchewan (adjusted OR=1.50, 95%CI:1.05-2.14), Alberta (adjusted OR=1.37, 95%CI:1.05-1.77) British Columbia (adjusted OR=1.90, 95%CI:1.45-2.50) and Manitoba (adjusted OR=0.66, 95%CI:0.45-0.98) *Late* – unintended pregnancy (adjusted OR=1.89, 95%CI:1.38-2.59), born outside of Canada (adjusted OR=1.75, 95%CI:1.14-2.68), prenatal care in Manitoba (adjusted OR=2.88, 95%CI:1.64-5.05) and the Territories (adjusted OR=4.50, 95%CI:2.27-8.93). An interaction between history of miscarriage and having 'other' prenatal care provider significantly affected timing of ultrasound (adjusted OR=0.31, 95%CI:0.14-0.66).

Conclusions
Only 68% of Canadian women received an optimally timed prenatal ultrasound which was influenced by several factors including province of prenatal care, maternal age and country of birth, and an interaction effect between prenatal care provider and history of miscarriage. These findings establish a baseline of factors influencing the timing of prenatal ultrasound in Canada, which can be built upon by future studies.

Background

Ultrasound has been used in obstetrics since the 1950s and has become an essential part of current prenatal care [1]. The use of ultrasound in pregnancy can provide valuable information that can predict fetal outcomes and aid in the detection of cardiac [2], gastrointestinal [3], renal [4], and neural abnormalities [5] as well as chromosomal anomalies including Down's Syndrome [1]. Routine ultrasound in pregnancy is also useful for determination of multiple pregnancies and gestational age, and may be associated with a lower likelihood of inductions after 42 weeks [6]. Current recommendations by the Society of Obstetricians and Gynaecologists of Canada (SOGC) state that all pregnant women should be offered an ultrasound scan between 18-22 weeks to screen for fetal anomalies and to provide information about the placenta, gestational age and number of fetuses [7]. In addition, the SOGC recommends that all pregnant patients be offered an ultrasound scan between 11 and 14 weeks of pregnancy to confirm gestational age and viability as well as investigate the number of fetuses, early anatomical assessment and nuchal translucency [8].

Ultrasound can be used to detect a pregnancy as early as 5 weeks [9]. In early pregnancy, ultrasound is indicated for conditions such as: therapeutic abortions, threatened miscarriages and their complications, uncertain menstrual dates, twin pregnancies, abnormal pregnancies (e.g. ectopic, molar etc.) and pelvic masses [10]. However, since the early stages of pregnancy are so sensitive to any external changes [11], early prenatal ultrasound should be used with caution. In fact, using transvaginal ultrasound in early pregnancy has been associated with increased cell death rates in the developing human fetus [12]. Similarly, the use of Doppler ultrasound in early pregnancy has been associated with cell death in the liver of the rat fetus [13]. In addition, having an ultrasound too early might lead to misinterpretation and, consequently, unnecessary interventions that can harm an otherwise normal pregnancy [14].

Having the first prenatal ultrasound later in pregnancy can have a different set of consequences. First, the estimation of the gestational age of the fetus becomes increasingly less reliable as the pregnancy progresses [15,16], reaching a margin of error of more than 20 days in the third trimester [15]. This can have consequences when dealing with many situations including preterm labour and intrauterine growth restriction [15]. Moreover, generally speaking, presenting to obstetric care later in pregnancy can lead to adverse outcomes such as low birth weight, infant and neonatal mortality [17] and congenital malformations [18]. Finally, late access to prenatal care can result in missed opportunities of timely screening using diagnostic tests such as prenatal ultrasound [19].

Women who attend prenatal care later in pregnancy (after the first trimester) might miss the window of an optimally timed ultrasound. Differences in those who attend prenatal care late from those who attend early have been reported previously. It has been shown that late attenders (first prenatal visit after the first trimester) tend to be teenagers, unmarried, have had multiple pregnancies [20,21], non-European, have lower education and lower socio-economic status [21]. In Canada, inadequate prenatal care (prenatal care initiated after the 4th month of pregnancy, and having fewer prenatal care visits) was associated with being an immigrant, primiparity, smoking and alcohol use during pregnancy, and having a family doctor as the prenatal care provider [22]. In Manitoba, inadequate prenatal care (prenatal care between month 1 and 6 and having fewer than 8 prenatal care visits) was associated with young maternal age, being a single parent, having had 4 or more births and lower income [23].

Canada is the second largest country in the world by total area [24], however, it is sparsely populated with a total population of 37,314,442 [25]. Canada consists of 10 provinces and three territories. Approximately 86% of the population resides in four provinces, namely Quebec and Ontario in the east and Alberta and British Columbia in the west [25]. Average income is fairly equal across the provinces [26].The territories tend to be underserviced [27] with a lower socioeconomic status [28]. Canada has a publicly funded health care system. This means that obstetric care, including prenatal ultrasounds is publicly funded [29]. No studies have been found that addressed the factors associated with the timing of the first prenatal ultrasound in Canada or elsewhere. This is an important area to investigate because it can be used to better focus educational efforts and interventional efforts aimed at the optimization of prenatal ultrasound utilization in Canada. Moreover, findings from such an investigation may be used to help address issues such as over- and underutilization of prenatal ultrasound. The aim of this study is to investigate the factors associated with the timing of the first prenatal ultrasound in Canada using a national database, the Maternity Experiences Survey (MES).

Methods

This study was a secondary data analysis of the Maternity Experiences Survey (MES), a cross-sectional survey conducted following the 2006 Canadian Census of Population. The MES was the first national survey in Canada devoted to women's experiences of pregnancy, labour, birth and the postpartum period. The objective of this survey was to collect data from new mothers on perinatal health indicators such as: maternal health, prenatal care, labour and delivery, newborn health, breastfeeding, postpartum care, sources of information during pregnancy as well as overall experience. The MES was an initiative of the Canadian Perinatal Surveillance System of the Public Health Agency of Canada [30].

The target population for this survey was women who had given birth to a single baby in Canada between February 15 and May 15 of 2006 in Canada's 10 provinces, or between November 1, 2005 and February 1, 2006 in Canada's 3 territories. Participants were at least 15 years of age at the time of giving birth and had to have their baby spend at least one night per month with them.

Exclusion criteria included women who lived in collective dwellings or on First Nations reserves. The final sample included 6,421 women who had completed the survey and had given Statistics Canada consent to share their responses with the sponsor (Public Health Agency of Canada – Canadian Perinatal Surveillance System). Participation in the survey was voluntary with a response rate of 78%. In the provinces, data collection was conducted using a Computer Assisted Telephone Interview (CATI). In the territories, paper versions of the questionnaire were filled out during a personal interview if performing a CATI was not possible. The MES protocol has been reviewed by the Health Canada's Science Advisory Board and Research Ethics Board and the Federal Privacy Commissioner, and approved by the Statistics Canada's Policy Committee. Since this project was based on secondary data analysis of the MES, institutional ethics approval was not required. Detailed methodology of the MES has been described previously [30].

For this study, respondents who received prenatal care outside of Canada accounted for about 0.01% of the sample and were excluded. The outcome variable was 'timing of first ultrasound' and had three levels: early (defined as receiving the first prenatal ultrasound before 11 weeks of pregnancy), optimal (defined as receiving the first prenatal ultrasound between 11-22 weeks of pregnancy) and late (defined as receiving the first prenatal ultrasound after 22 weeks of pregnancy). These categories were chosen based on the SOGC recommendations that were in place at the time of the survey. In 2007, the SOGC recommendations for fetal aneuploidy stated that all pregnant women be offered prenatal screening test for fetal aneuploidy, some of which included a prenatal ultrasound between 11 and 14 weeks [31]. Similarly, this ultrasound was also recommended by the SOGC in 2003 to be offered as part of a comprehensive prenatal screening program [10]. The SOGC also recommended in 1999 that all pregnant patients be offered an ultrasound around 18-19 weeks to screen for structural anomalies [32]. However, in 2009 the SOGC recommended this ultrasound at 18-22 weeks [33]. In the present study the cut-off for the 'late' category was 22 weeks, which is in keeping with the recommendations that are closest to the time when the data were collected as well as current recommendations.

Information about this variable was collected from responses to the question "How many weeks pregnant were you when you had your first ultrasound?". The covariates assessed were grouped into several categories, the first of which is maternal factors which included: using fertility medications or procedures to get pregnant with the index pregnancy, health problems before pregnancy that warrant additional care during the index pregnancy , health problems during the index pregnancy that warrant additional care during pregnancy, pre-pregnancy Body Mass Index (BMI) and whether the pregnancy was intended. The latter was obtained from the question "thinking back to just before you became pregnant, would you say that you wanted to be pregnant...?" with the following responses: sooner, then, later and not at all. The first 2 were combined into 'intended' and the second 2 were combined into 'unintended'. The second category of covariates was behavioural risk factors and included: smoking during the last 3 months of pregnancy and alcohol use during pregnancy. The third category of covariates was reproductive history and included: parity (primiparous or multiparous), history of premature birth, history of ectopic and stillbirth (combined due to low counts), history of miscarriage and history of therapeutic abortion. The fourth category of covariates was prenatal and birth related factors and included: type of prenatal care provider, mode of delivery and birthweight. The final category of covariates was socio-demographic factors and included: maternal age, country of birth/Aboriginal status (included 3 categories: Canadian born, born outside of Canada, and Aboriginal – First Nations, Metis or Inuit), marital status (dichotomized to: with partner or with no partner), province of prenatal care, urban/rural residence, travel to another city for birth, education, employment during pregnancy and household income. The reference category for province of prenatal care was chosen to be Quebec due to its appropriate sample size and ease of interpretation of the results relative to the other provinces.

Statistical analysis

Multinomial logistic regression is an extension of simple logistic regression [34]. Unlike simple logistic regression, multinomial logistic regression allows for the analysis of outcomes that have more than two categories [34]. For this study, Chi square tests and bivariable multinomial logistic regression models were performed to assess the relationship of the covariates with the outcome variable at the bivariate level. Multivariable multinomial logistic regression was performed to assess the relationship between the independent variables and the outcome variable (reference category: 'optimal') while controlling for all of the covariates. This analysis produced adjusted Odds Ratios (OR) and 95% Confidence Intervals (95%CI). The significance level was set at alpha of 0.05. In addition, several potential interactions were investigated including: a) prenatal care provider x province of prenatal care b) prenatal care provider x urban/rural c) prenatal care provider x history of miscarriage d) prenatal care provider x history of stillbirth or ectopic e) prenatal care provider x having a condition before pregnancy requiring additional care and f) prenatal care provider x having a condition during pregnancy requiring additional care. A probability survey weight and 1000 bootstrap weights were provided by Statistics Canada and applied in order to obtain results that were nationally representative. The bootstrap weights take account of the complex design of the survey and provide more accurate estimates of variance [35]. All statistical tests were performed using Stata Statistical Software version 14 (StataCorp, College Station, TX).

Results

The total weighted sample size used was around 76,000. The percentage of Canadian women receiving an optimally timed first prenatal ultrasound was 68.4%, while 27.4% of women received early ultrasounds and 4.3% received late ultrasound (Figure 1). The province with the highest prevalence of optimal timing of first prenatal ultrasound was Quebec (77%), while the lowest prevalence of optimal timing of first prenatal ultrasound was found in Ontario (63.2%) (Figure 1). The province with the highest prevalence of early ultrasound was Ontario (33.3%) while the lowest prevalence of early ultrasound was found in Manitoba (13.3%) (Figure 1). Interestingly, Manitoba was also the province with the highest prevalence of late ultrasound (12.1%) (Figure 1). The provinces with the lowest prevalence of late ultrasound were British Columbia and Ontario (3.5% each) (Figure 1).

Table 1 shows the percentages and the unadjusted Odds Ratios (ORs) and 95% Confidence Intervals (95%CI) for timing of first prenatal ultrasound at the level of each of the covariates.

The maternal factors that were significantly associated with a higher likelihood of early first prenatal ultrasound were: fertility medications or procedures (adjusted OR = 3.47, 95%CI: 2.59-4.65), health problems before pregnancy (adjusted OR = 1.30, 95%CI: 1.09-1.56), health problems during pregnancy (adjusted OR = 1.27, 95%CI: 1.09-1.48) and underweight BMI (adjusted OR = 1.81, 95%CI:1.34-2.44) (Table 2). As for the 'late' category, women who had health problems before pregnancy were significantly less likely to have a late first prenatal ultrasound than those who did not have those problems (adjusted OR = 0.55, 95%CI: 0.31-0.97) (Table 2). In addition, women whose pregnancies were unintended were significantly more likely to undergo late first ultrasound than those with intended pregnancies (adjusted OR = 1.89, 95%CI: 1.38-2.59) (Table 2). No other maternal factors were significantly associated with late first prenatal ultrasound.

In terms of the behavioural risk factors, women who used alcohol during pregnancy were significantly less likely to receive early first prenatal ultrasounds than those who did not use alcohol (adjusted OR = 0.69, 95%CI: 0.53-0.90) (Table 2). No other behavioural risk factors were significantly associated with early or late first prenatal ultrasound.

As for reproductive history factors, history of premature birth was significantly associated with an increased likelihood of early first prenatal ultrasound (adjusted OR = 1.41, 95%CI: 1.06-1.89) (Table 2). Being multiparous was associated with a decreased likelihood of early first prenatal ultrasound (adjusted OR = 0.67, 95%CI: 0.57-0.78) (Table 2). The only interaction term that was found to be significant was that between prenatal care provider and whether the woman had a history of miscarriage. Taking this interaction term into account, having a history of miscarriage while seeing an OB/GYN (the reference category for care provider) was significantly associated with early first prenatal ultrasound (adjusted OR = 2.04, 95%CI: 1.65-2.54), whereas having a prenatal care provider other than a family doctor or an OB/GYN combined with having a history of miscarriage had significantly lower OR for early first prenatal ultrasound as compared to those who have had a history of miscarriage and were seeing an OB/GYN (adjusted OR = 0.31, 95%CI: 0.14-0.66) (Table 2). No other reproductive history factors were significantly associated with early or late first prenatal ultrasound.

The socio-demographic factors that were significantly associated with increased likelihood of early first prenatal ultrasound were a household income of 100,000 Canadian Dollars or more (adjusted OR = 1.41, 95%CI: 1.07-1.85) and province of prenatal care (Table 2). Women who received prenatal care in Newfoundland and Labrador (adjusted OR = 1.66, 95%CI: 1.20-1.30), Nova Scotia (adjusted OR = 1.68, 95%CI: 1.25-2.28), Ontario (adjusted OR = 2.16, 95%CI:

1.76-2.65), Saskatchewan (adjusted OR = 1.50, 95%CI: 1.05-2.14), Alberta (adjusted OR = 1.37, 95%CI: 1.095-1.77) and British Columbia (adjusted OR = 1.90, 95%CI: 1.45-2.50) were significantly more likely to receive early first prenatal ultrasound than those receiving their care in Quebec (Table 2). On the other hand, women who received their prenatal care in Manitoba were significantly less likely to receive early prenatal ultrasound (adjusted OR = 0.66, 95%CI: 0.45-0.98) (Table 2). The factors associated with a lower likelihood of early first prenatal ultrasound were being born outside of Canada (adjusted OR = 0.82, 95%CI: 0.67-0.99) and being under 20 years of age at the time of birth (adjusted OR = 0.54, 95%CI: 0.34-0.84) when compared to being Canadian born and being between 20-34 years of age at the time of birth, respectively (Table 2). Being born outside of Canada was also significantly associated with a higher likelihood of late first ultrasound than those born in Canada (adjusted OR = 1.75, 95%CI: 1.14-2.68) as was receiving prenatal care in Manitoba and the Territories (adjusted OR = 2.88, 95%CI: 1.64-5.05 and adjusted OR = 4.50, 95%CI: 2.27-8.93, respectively) than those receiving their care in Quebec (Table 2). The factors that were significantly associated with a lower likelihood of late first prenatal ultrasound were: living in an urban setting with a population size less than 30,000 (adjusted OR = 0.58, 95%CI: 0.35-0.98) when compared to urban population size of 500,000+, having a bachelor's degree (adjusted OR = 0.48, 95%CI: 0.29-0.80) when compared to women who had a high school education or less, and having travelled 80km or more to give birth (adjusted OR = 0.28, 95%CI: 0.12-0.65) when compared to women who did not travel for birth (Table 2).

Discussion

The results of this study indicate that only about 68% of Canadian women received an optimally timed prenatal ultrasound. Around 27% of Canadian women received early ultrasounds and this was influenced by a number of factors including: being younger, underweight, born outside of Canada, having a high household income and receiving prenatal care in Newfoundland and Labrador, Nova Scotia, Ontario, Saskatchewan, Alberta or British Columbia when compared with residing in Quebec. On the other hand, late ultrasound was performed in around 4% of Canadian women and was influenced by: being born outside of Canada, receiving prenatal care in Manitoba or the Territories and having an unintended pregnancy. The results of this study can be used to better direct national educational efforts about the optimal timing of the first prenatal ultrasound in low risk pregnancy. In addition, these results may be of use when addressing large scale issues such as over- and under-utilization of ultrasound in pregnancy.

Based on the present study, only 68% of Canadian women received optimally timed prenatal ultrasounds. This is concerning because both over- and under-utilization of prenatal ultrasound can be problematic. The obvious consequences of overutilization lie in the cost associated with performing these tests, which can burden the healthcare system if used excessively [36], while underutilization may lead to missed opportunities for screening [19].

This study has found that, after adjusting for confounders, multiple maternal factors were associated with a higher likelihood of early but not late first prenatal ultrasound. Women who used fertility procedures or medications for this pregnancy were significantly more likely to have an early prenatal ultrasound. These women generally undergo more testing than other women do and require multiple ultrasounds in early pregnancy to check embryonic growth and development [37]. Similarly, women who had pre-pregnancy or pregnancy conditions that warranted additional care during pregnancy may require earlier first prenatal ultrasounds than other women. In addition, underweight women were significantly more likely to have an early ultrasound. Obese women are more likely to access prenatal care late in pregnancy than non-obese women [19] and are generally more likely to avoid or delay screening tests [38,39] due to multiple factors including negative body image and to avoid weight loss advice [39], while underweight women are less likely to have late access to prenatal care [19]. In addition to this, underweight women have a higher likelihood of irregular menstruation [40] which may result in uncertain dates and, consequently, an earlier first prenatal ultrasound to establish gestational age. The present study also found that unintended pregnancy was significantly associated with increased likelihood of late ultrasound. This is in agreement with previous findings that women who have unintended pregnancies tend to have delayed prenatal care [41] and possibly miss the window of an optimally timed prenatal ultrasound.

After adjusting for covariates, the present study also found that women who used alcohol during pregnancy were less likely to undergo early first prenatal ultrasound than those who did not. This is consistent with previous studies that have found that substance use, including alcohol use, was associated with late access to prenatal care [22,23,42,43], which consequently makes them less likely to have early ultrasounds as opposed to optimal ultrasounds. A possible explanation of this is that these women may believe that their substance abuse has already harmed their baby irreversibly, leading them to delay prenatal care [44]. Another possible explanation, though no previous studies were found to support this, is that these women might not realize that they are pregnant early enough, leading to delayed prenatal care.

The present study found that reproductive history factors are significantly associated with timing of the first prenatal ultrasound, after adjusting for confounders. Multiparous women were less likely to receive early ultrasounds than primiparous women. This is consistent with previous studies in multiple countries including Canada, that have found that higher parity is associated with late or inadequate access to prenatal care [20,21,23,45,46]. Women who had positive previous pregnancies may feel more confident than women who are pregnant for the first time, and may not feel that accessing prenatal care early is of value [47,48]. On the other hand, women who have had negative experiences in their previous pregnancy may want to avoid or delay prenatal care [47]. Moreover, since these women most likely have children already, they may struggle with child care issues and time constraints leading to delayed prenatal care [47,48], and, consequently, leading to a lower likelihood of having early ultrasounds as opposed to optimally timed ones. The present study also found that women who had a history of preterm birth were significantly more likely to undergo early prenatal ultrasound. Although no specific recommendations have yet been set by the SOGC about the optimal timing of cervical length measurement using ultrasound [49], these women and their healthcare providers may opt for earlier ultrasounds to measure the cervix in hopes of avoiding preterm birth in this pregnancy. Interestingly, the present study also found an interaction effect between type of prenatal provider and having a history of a miscarriage. Specifically, women who received most of their care from and OB/GYN and had a history of miscarriage were at higher odds of receiving an early first ultrasound. In addition, among patients who had a history of miscarriage, women who were seeing healthcare providers other than OB/GYN or family doctor had significantly lower ORs for early ultrasound than those who received care from an OB/GYN. Midwives may be less reliant on ultrasound while caring for a patient [50], and may therefore not treat patients with a history of miscarriage with as many diagnostic tests as OB/GYNs do. In addition, in theory, women who had a history of a miscarriage may prefer to receive their care from an OB/GYN or family doctor, due to the fact that having a history of miscarriage may predispose women to a subsequent miscarriage [51]. This may mean that other healthcare providers may not see as many patients with a history of miscarriage as OB/GYN or family doctor. It is important to note here that it is not a specific recommendation of the SOGC that women with a history of miscarriage have earlier ultrasounds during subsequent pregnancies. However, these women and their prenatal care providers may be more anxious about the well-being of the baby and may, therefore, opt for earlier ultrasounds.

In terms of socio-demographic variables, the present study also found that women who were under 20 years of age were less likely to have an early ultrasound. This is consistent with findings that women who are under 20 years of age are more likely to have late access to prenatal care [19,52], which can reduce their likelihood of receiving earlier ultrasound compared to optimally timed ones. Teenage mothers may delay access to prenatal care due to not realising that they are pregnant [53], or due to fears of confirming that they are pregnant or the fear that someone else might subsequently discover their pregnancy [54]. Another finding of the present study is that women born outside of Canada were less likely to receive an early ultrasound and more likely to receive a late ultrasound. Previous studies in multiple countries including Canada have reported that foreign born mothers were more likely to have late access to prenatal care than mothers who were born in the country of reference [22,55–57]. This may be due to language barriers, fear of discrimination and lack of knowledge of the local healthcare system [58,59]. The present study also found differences between provinces with respect to timing of ultrasound. Patients receiving their prenatal care in Newfoundland and Labrador, Nova Scotia, Ontario, Saskatchewan, Alberta and British Columbia were more likely to receive early ultrasounds than those receiving their care in Quebec. The present study also found that receiving prenatal care in Manitoba was not only associated with a lower likelihood of early ultrasound but also with a higher likelihood of late ultrasound. These findings may be explained by the differences in prevalence of inadequate prenatal care between provinces; according to the MES, Quebec has a higher prevalence of inadequate prenatal care than multiple provinces including Newfoundland and Labrador, Nova

Scotia, Ontario, Saskatchewan, Alberta and British Columbia [22]. Quebec also has a lower prevalence of inadequate prenatal care than 2 of the Territories and Manitoba, although the difference between Quebec and Manitoba was small (22.3% and 22.5%, respectively) [22]. Moreover, women who receive their prenatal care in Ontario generally receive more ultrasounds during pregnancy than those in other provinces [50], which is consistent with the finding of the present study that the highest prevalence of early ultrasound was found in Ontario. Another factor contributing to these provincial differences can be the differences in wait times for ultrasound examinations in the Canadian provinces. In 2005 and 2006, Manitoba had higher ultrasound wait times than most of the other provinces followed by Quebec [60]. In 2006, it was reported that in Manitoba the wait time for an ultrasound was 8 weeks, followed by Quebec and Nova Scotia, (each reporting 6 week median wait times), with the other provinces reporting median wait times of 2-4.8 weeks [60]. As of 2018, the shortest wait time for an ultrasound was reported in Saskatchewan (1.1 weeks) and the longest was reported in Newfoundland and Labrador (10.5 weeks) [61]. Interestingly, some of the shortest wait times for an ultrasound were consistently found in Ontario (2 weeks) [60,61]. The present study also found that receiving prenatal care in the Territories was strongly associated with a higher likelihood of late prenatal ultrasound. The effect of wait times may be extrapolated to the Territories where access to prenatal care and diagnostic technology may be reduced. Another finding of the present study was that women living in an urban setting of a population of 30,000 or less and women who had to travel 80km or more to give birth were less likely to receive late ultrasounds. Although no specific findings from previous literature were found to support this, one explanation can be that in smaller settings, where large hospitals and centers are not available to provide all services, patients may have closer, more familiar relationships with their prenatal care providers making them more likely to access prenatal care and diagnostic testing at an optimal time. Education was a factor that influenced late ultrasound but not early ultrasound in the present study, where having a bachelor's degree was associated with a lower likelihood of having a late ultrasound when compared to high school education or less. Women with higher education tend to have more adequate access to prenatal care [46,52]. However, pregnant women with very high education may have more developed critical thinking skills allowing them to be more comfortable to question the practices of healthcare providers [46,62] and, therefore, may not be inclined to undergo testing as early as recommended. The present study also found that women who reported having a household income of 100,000 Canadian Dollars or more were more likely to receive early prenatal ultrasound. This is a surprising finding since medically necessary health care services are free to residents of Canada [63], making it less likely for Canadians to have financial barriers preventing access to prenatal care. However, this effect can be explained by taking into consideration the environmental and personal factors that influence women of different income brackets. The socio-ecological model of determinants of health services utilization proposed by Sword suggests that women of differing income brackets can have different personal, environmental and political influencers, ultimately leading to differing health services utilization patterns [64]. These differences can play a role even within a universally funded healthcare system and may make Canadian women of higher income more likely to prioritize their prenatal care when compared to lower income women, making them more likely to ask for and receive additional prenatal testing to 'make sure the baby is ok'. Moreover, higher income Canadian women may have more flexibility to take 'time off' to go to prenatal appointments than lower income women do, making them more likely to access prenatal services early in pregnancy.

The main limitation of this study is the cross-sectional design of the MES which may lead to reverse causality. In addition, the MES is over a decade old and the current Canadian population may have different characteristics than those captured by the MES. However, even though the MES is ‘old’, the information from this study can be valuable to establish a baseline of data pertaining to timing of prenatal ultrasound for future hypothesis generation. In addition, ‘old’ data can be valuable because, should there be newer data in the future, the results of this study can be used to investigate trends and changes over time in Canada. It is also important to note that the recommendations for prenatal ultrasound have not changed much since the time of the survey [10,31–33]. Another limitation is that with self-reported data there is always a potential for information bias either due to lack of recall or the temptation to present oneself favourably. Finally, not all of the possible confounding variables such as irregular menstrual cycles can be adjusted for either due to the lack of their availability in the MES or due to the power limitations within the regression model. Despite all the limitations mentioned above, the MES is the largest, most up to date Canada-wide database that covers information about timing of ultrasound and different aspects of the maternity experience, in addition to having a high response rate of 78%.

The findings of this study indicate only 68% of Canadian women receive an optimally timed prenatal ultrasound, and that the timing of prenatal ultrasound is influenced by numerous factors such as province of prenatal care, maternal age and country of birth. This study also found that having a history of a miscarriage combined with having a prenatal care provider other than an OB/GYN or family doctor was associated with a lower likelihood of early ultrasound. These findings establish a baseline of factors influencing the timing of prenatal ultrasound in Canada that can be built upon by future studies, which can investigate the relationship between type of prenatal care provider and province of prenatal care in a more up to date context, and perhaps focusing on provincial settings. In addition, these findings can help guide efforts to encourage the use of optimally timed prenatal ultrasounds by focusing education based on province, prenatal care provider, and patient characteristics. This will potentially address issues including under- and over-utilization of ultrasound in pregnancy.

The next chapter will explore prenatal ultrasound utilization as an exposure, rather than an outcome, and study its relationship with caesarean delivery.

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Table 1: Percentages and unadjusted Odds Ratios (OR) and 95% Confidence Intervals (95%CI) for timing of ultrasound at different independent variables. The Maternity Experiences Survey.

Variable	Overall %	Optimal	Early		Late	
		%	%	Unadjusted OR (95%CI)*	%	Unadjusted OR (95%CI)*
MATERNAL FACTORS						
Fertility medications or procedures						
Yes	4.7	42.6	55.2	3.49 (2.70-4.52)	2.2	0.81 (0.26-2.53)
No	95.3	69.8	25.9	1.00	4.4	1.00
Health problems before pregnancy						
Yes	15.3	63.8	33.7	1.40 (1.20-1.63)	2.5	0.57 (0.36-0.90)
No	84.7	69.2	26.1	1.00	4.6	1.00
Health Problems during pregnancy						
Yes	24.4	65.4	31.1	1.26 (1.15-1.44)	3.5	0.82 (0.60-1.12)
No	75.6	69.3	26.1	1.00	4.5	1.00
Pre-pregnancy BMI						
Underweight (less than 18.5)	6.1	59.3	36.5	1.63 (1.27-2.08)	4.2	1.17 (0.66-2.09)
Normal (18.5-24.99)	59.3	69.5	26.3	1.00	4.2	1.00
Overweight/obese (25+)	34.6	68.4	27.4	1.06 (0.93-1.20)	4.3	1.03 (0.77-1.36)
Intended pregnancy						
Unintended	27.1	66.7	26.3	0.98 (0.86-1.13)	7.1	2.24 (1.74-2.88)
Intended	73.0	69.1	27.7	1.00	3.3	1.00
BEHAVIOURAL RISK FACTORS						
Smoking during the last 3 months of pregnancy						
Yes	10.5	66.6	27.0	1.02 (0.84-1.23)	6.4	1.63 (1.18-2.27)
No	89.5	68.6	27.3	1.00	4.1	1.00
Alcohol during pregnancy						
Yes	10.5	75.6	20.1	0.64 (0.51-0.80)	4.3	0.88 (0.56-1.40)
No	89.6	67.6	28.1	1.00	4.3	1.00
REPRODUCTIVE HISTORY						

Parity						
Primiparous	45.5	65.7	30.8	1.00	3.5	1.00
Multiparous	54.5	70.7	24.4	0.73 (0.65-0.83)	5.0	1.32 (1.01-1.71)
History of premature birth						
Yes	5.8	64.0	32.9	1.30 (1.02-1.67)	3.1	0.80 (0.41-1.54)
No	94.2	68.8	27.1	1.00	4.2	1.00
History of ectopic pregnancy or stillbirth						
Yes	2.5	59.6	38.8	1.65 (1.18-2.32)	0.9	0.42 (0.15-1.12)
No	97.5	68.6	27.0	1.00	4.4	1.00
History of miscarriage						
Yes	22.1	60.9	36.6	1.72 (1.50-1.97)	2.5	0.61 (0.42-0.89)
No	77.9	70.5	24.7	1.00	4.8	1.00
History of therapeutic abortion						
Yes	11.8	69.4	26.3	0.94 (0.78-1.14)	4.3	0.98 (0.63-1.52)
No	88.2	68.2	27.5	1.00	4.3	1.00
PRENATAL AND BIRTH RELATED FACTORS						
Type of prenatal care provider						
OB/GYN	58.3	67.1	28.8	1.00	4.0	1.00
Family doctor/GP	34.4	70.3	25.2	0.84 (0.74-0.95)	4.5	1.07 (0.81-1.40)
Midwife and other†	7.3	68.5	26.1	0.89 (0.69-1.13)	5.4	1.30 (0.83-2.06)
Mode of delivery						
Vaginal	73.7	69.4	26.2	1.00	4.5	1.00
Caesarean	26.3	65.6	30.7	1.24 (1.09-1.41)	3.8	0.89 (0.66-1.21)
Birthweight						
<2500	5.1	60.7	35.0	1.45 (1.10-1.90)	4.3	1.15 (0.61-2.14)
2500-4000	82.4	68.5	27.2	1.00	4.3	1.00
>4000	12.6	70.6	24.8	0.89 (0.74-1.06)	4.6	1.05 (0.71-1.56)
SOCIO-DEMOGRAPHIC FACTORS						
Maternal age at delivery						
<20	3.0	66.0	22.3	0.86 (0.62-1.19)	11.7	2.89 (1.87-4.45)

20-34	79.5	68.7	27.1	1.00	4.2	1.00
35+	17.6	67.6	29.2	1.10 (0.94-1.28)	3.2	0.76 (0.52-1.11)
Country of birth/Aboriginal status						
Born in Canada	71.8	69.1	27.4	1.00	3.6	1.00
Born outside of Canada	24.0	66.7	27.2	1.03 (0.89-1.19)	6.1	1.77 (1.34-2.34)
Aboriginal	4.2	67.8	25.8	0.96 (0.72-1.28)	6.4	1.81 (1.10-2.96)
Marital status						
With partner	91.6	68.9	27.0	0.83 (0.68-1.01)	4.1	0.60 (0.41-0.87)
No Partner	8.4	63.6	30.1	1.00	6.4	1.00
Province of prenatal care						
Quebec	23.5	77.0	18.4	1.00	4.6	1.00
Newfoundland and Labrador	1.3	69.4	26.2	1.59 (1.20-2.09)	4.4	1.05 (0.58-1.90)
Prince Edward Island	0.4	76.8	15.8	0.86 (0.65-1.14)	7.4	1.62 (1.00-2.63)
Nova Scotia	2.2	68.4	27.8	1.71 (1.33-2.18)	3.8	0.93 (0.49-1.75)
New Brunswick	1.9	73.6	22.6	1.29 (0.96-1.72)	3.9	0.88 (0.49-1.59)
Ontario	39.3	63.2	33.3	2.21 (1.86-2.61)	3.5	0.93 (0.65-1.34)
Manitoba	3.5	74.7	13.3	0.75 (0.53-1.04)	12.1	2.70 (1.77-4.10)
Saskatchewan	3.1	70.9	25.3	1.49 (1.12-1.99)	3.9	0.91 (0.48-1.72)
Alberta	12.3	67.6	27.7	1.72 (1.40-2.12)	4.7	1.16 (0.73-1.86)
British Columbia	11.9	65.4	31.1	1.99 (1.59-2.49)	3.5	0.89 (0.52-1.51)
Territories	0.5	75.6	14.6	0.81 (0.62-1.06)	9.8	2.17 (1.47-3.22)
Urban/Rural						
Rural	17.8	71.3	24.6	0.83 (0.70-0.98)	4.2	0.81 (0.57-1.15)
Urban (<30,000)	17.0	70.2	26.4	0.91 (0.77-1.08)	3.4	0.66 (0.45-0.97)
Urban (30,000-99,000)	8.4	79.8	26.6	0.92 (0.73-1.15)	3.6	0.71 (0.42-1.21)
Urban (100,000-499,999)	11.6	65.4	29.9	1.10 (0.91-1.33)	4.7	0.99 (0.65-1.50)
Urban (500,000+)	45.1	67.3	27.9	1.00	4.9	1.00
Travelled to another city or town for birth						
Did not travel	75.3	68.3	27.3	1.00	4.4	1.00
<80km	20.7	68.7	27.2	0.99 (0.86-1.15)	4.2	0.93 (0.68-1.27)
80km+	4.0	67.7	30.2	1.12 (0.84-1.48)	2.1	0.48 (0.24-0.94)

Education						
High school or less	21.0	67.0	25.7	1.00	7.3	1.00
Post-secondary, below bachelor	43.6	68.6	27.2	1.03 (0.88-1.22)	4.1	0.55 (0.41-0.74)
Bachelor	25.7	69.6	27.7	1.04 (0.87-1.24)	2.7	0.35 (0.24-0.52)
Graduate	9.8	66.9	30.5	1.19 (0.94-1.50)	2.6	0.36 (0.20-0.66)
Employment during pregnancy						
Yes	78.7	69.0	27.4	0.98 (0.84-1.14)	3.6	0.48 (0.37-0.63)
No	21.3	66.2	26.8	1.00	7.1	1.00
Household income (Canadian Dollar)						
<30,000	17.0	68.0	25.7	1.00	6.2	1.00
30,000-<60,000	30.7	68.6	25.3	0.98 (0.81-1.17)	6.0	0.96 (0.70-1.32)
60,000-<100,000	32.2	72.6	24.8	0.90 (0.75-1.08)	2.6	0.39 (0.27-0.58)
100,000+	20.1	64.4	33.5	1.38 (1.12-1.69)	2.1	0.35 (0.21-0.58)

*Obtained using bivariable multinomial logistic regression models using 'Appropriate' as the reference category.
†Other includes: Nurse or nurse practitioner, other doctor (unspecified) or a response of 'other' to the question asking about the type healthcare provider that provided most of the respondent's prenatal care.

Table 2: Adjusted Odds Ratios (OR) and 95% Confidence Intervals (95%CI) obtained from a multivariable multinomial logistic regression model for timing of ultrasound at different independent variables. The Maternity Experiences Survey.

Variable	Early Adjusted OR (95%CI)*	Late Adjusted OR (95%CI)*
MATERNAL FACTORS		
Fertility medications or procedures		
Yes	3.47 (2.59-4.65)	1.39 (0.33-5.80)
Health problems before pregnancy		
Yes	1.30 (1.09-1.56)	0.55 (0.31-0.97)
Health Problems during pregnancy		
Yes	1.27 (1.09-1.48)	1.05 (0.73-1.50)
Pre-pregnancy BMI		
Underweight (less than 18.5)	1.81 (1.34-2.44)	0.87 (0.39-1.93)
Overweight/obese (25+)	1.06 (0.92-1.23)	0.99 (0.70-1.39)
Intended pregnancy		
Unintended	1.13 (0.96-1.34)	1.89 (1.38-2.59)
BEHAVIOURAL RISK FACTORS		
Smoking during the last 3 months of pregnancy		
Yes	0.97 (0.76-1.24)	1.00 (0.62-1.61)
Alcohol during pregnancy		
Yes	0.69 (0.53-0.90)	1.01 (0.57-1.79)
REPRODUCTIVE HISTORY		
Parity		
Multiparous	0.67 (0.57-0.78)	1.41 (0.97-2.05)
History of premature birth		
Yes	1.41 (1.06-1.89)	0.56 (0.24-1.32)
History of ectopic pregnancy or stillbirth		
Yes	1.50 (1.00-2.26)	0.40 (0.14-1.19)
History of miscarriage		
Yes	2.04 (1.65-2.54)	0.61 (0.33-1.11)

History of therapeutic abortion		
Yes	1.01 (0.81-1.25)	0.89 (0.54-1.47)
PRENATAL AND BIRTH RELATED FACTORS		
Type of prenatal care provider		
Family doctor/GP	0.94 (0.78-1.12)	1.26 (0.89-1.77)
Midwife and other†	1.16 (0.86-1.57)	1.71 (0.94-3.11)
Mode of delivery		
Caesarean	1.11 (0.95-1.29)	1.14 (0.81-1.62)
Birthweight		
<2500	1.25 (0.89-1.77)	0.76 (0.28-2.09)
>4000	0.90 (0.73-1.13)	0.96 (0.59-1.58)
SOCIO-DEMOGRAPHIC FACTORS		
Maternal age at delivery		
<20	0.54 (0.34-0.84)	1.11 (0.53-2.33)
35+	0.92 (0.76-1.12)	0.93 (0.61-1.42)
Country of birth/Aboriginal status		
Born outside of Canada	0.82 (0.67-0.99)	1.75 (1.14-2.68)
Aboriginal	0.83 (0.58-1.19)	0.59 (0.28-1.24)
Marital status		
With partner	0.80 (0.60-1.08)	0.92 (0.51-1.65)
Province of prenatal care		
Newfoundland and Labrador	1.66 (1.20-2.30)	1.25 (0.54-2.86)
Prince Edward Island	0.84 (0.60-1.18)	1.60 (0.85-3.01)
Nova Scotia	1.68 (1.25-2.28)	1.24 (0.57-2.70)
New Brunswick	1.29 (0.90-1.87)	1.14 (0.57-2.29)
Ontario	2.16 (1.76-2.65)	0.98 (0.63-1.54)
Manitoba	0.66 (0.45-0.98)	2.88 (1.64-5.05)
Saskatchewan	1.50 (1.05-2.14)	1.12 (0.53-2.36)
Alberta	1.37 (1.05-1.77)	1.55 (0.87-2.78)
British Columbia	1.90 (1.45-2.50)	0.84 (0.44-1.58)
Territories	1.01 (0.68-1.52)	4.50 (2.27-8.93)

Urban/Rural		
Rural	0.83 (0.66-1.03)	0.94 (0.57-1.57)
Urban (<30,000)	0.87 (0.70-1.07)	0.58 (0.35-0.98)
Urban (30,000-99,000)	0.94 (0.72-1.24)	0.93 (0.51-1.70)
Urban (100,000-499,999)	0.90 (0.71-1.13)	1.21 (0.69-2.14)
Travelled to another city or town for birth		
<80km	0.99 (0.83-1.19)	1.28 (0.88-1.86)
80km+	1.24 (0.87-1.75)	0.28 (0.12-0.65)
Education		
Post-secondary, below bachelor	0.96 (0.78-1.19)	0.74 (0.51-1.07)
Bachelor	0.98 (0.77-1.25)	0.48 (0.29-0.80)
Graduate	0.91 (0.68-1.22)	0.55 (0.27-1.10)
Employment during pregnancy		
Yes	0.96 (0.79-1.17)	0.83 (0.57-1.21)
Household income (Canadian Dollar)		
30,000-<60,000	1.02 (0.81-1.28)	1.37 (0.92-2.05)
60,000-<100,000	0.94 (0.74-1.21)	0.74 (0.45-1.24)
100,000+	1.41 (1.07-1.85)	0.74 (0.38-1.47)
INTERACTION: Prenatal care provider x History of miscarriage		
OB/GYN x No miscarriage	1.00	1.00
Family doctor x miscarriage	0.90 (0.64-1.25)	0.76 (0.29-1.98)
Midwife and other x miscarriage	0.31 (0.14-0.66)	1.51 (0.20-11.35)

*Obtained using a multivariable multinomial logistic regression model using ‘Optimal’ as the reference category.
†Other includes: Nurse or nurse practitioner, other doctor (unspecified) or a response of ‘other’ to the question asking about the type healthcare provider that provided most of the respondent’s prenatal care.

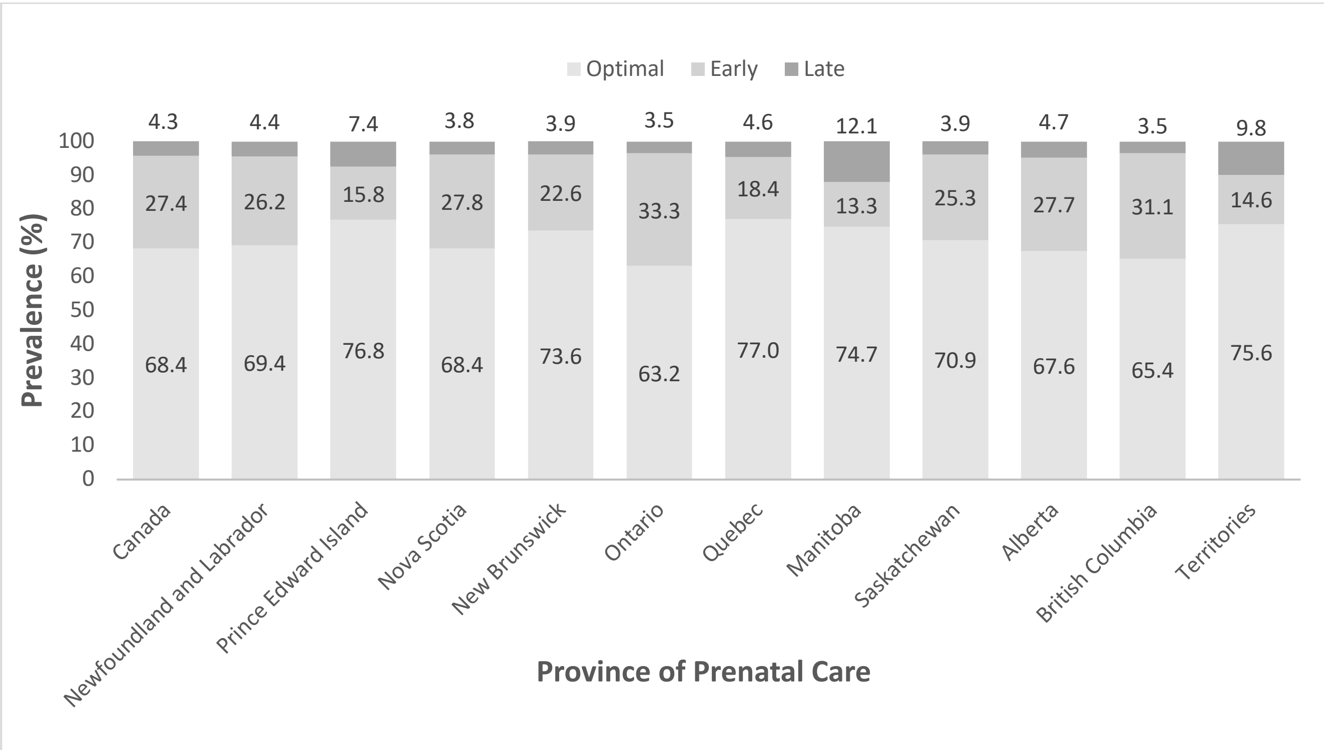

Figure 2: Prevalence of early, appropriate and late ultrasound in different regions of Canada. The Maternity Experiences Survey.

CHAPTER 4

Assessing the relationship between the number of prenatal ultrasounds and primary caesarean delivery: Findings from Canada and the USA

Abstract

Objective
To assess the relationship between the number of prenatal ultrasounds and primary Caesarean Delivery (CD) in Canada and the USA.

Methods
This study involved secondary data analysis of two national databases, Maternity Experiences Survey (Canada) and Listening To Mothers III survey (USA). Both surveys were cross-sectional covering pregnancy, labour, birth and post-partum. Women with CD history were excluded. The relationship between mode of delivery and number of ultrasounds was assessed using logistic regression adjusting for sociodemographic, medical and prenatal/birth related factors. A statistically significant interaction term between parity and the number of ultrasounds was added to the model.

Results
Prevalence of primary CD was 18.5% in Canada and 18.7% in the USA. Multiparas having >2 ultrasounds had significantly higher adjusted CD odds, which were up to 3.86 (95%CI:2.27-6.58) for 4 ultrasounds in Canada, and up to 4.68 (95%CI:2.31-9.46) for 4 ultrasounds in the USA. Canadian primiparas receiving >2 ultrasounds also had higher adjusted CD odds, up to 1.79 (95%CI:1.36-2.36) for 5+ ultrasounds.

Conclusion
Prenatal ultrasound was significantly associated with CD in Canadian and American multiparas and Canadian primiparas. These findings may serve as a baseline in Canada and the USA for future research to build upon.

Background

In 1985 a panel of reproductive health experts stated at a meeting organized by the World Health Organization (WHO) that "There is no justification for any region to have a rate [of caesarean delivery (CD)] higher than 10-15%" [1]. This was revisited in 2015 by the WHO which released an updated statement saying "At population level, caesarean section rates higher than 10% are not associated with reductions in maternal and newborn mortality rates" [1]. Despite these statements, CD rates have been steadily increasing globally, rising from 20% in 2000 to 28% in 2015 [2]. More recent statistics indicate that the Canadian CD rate was 28.8% in 2017-2018 [3] and the CD rate in the USA was 32% in 2017 [4]. Several factors have been associated with increased CD rates and these include: maternal request [5], higher socioeconomic status [6], higher education [7], increased Body Mass Index (BMI) [6,8–11], hypertension [9,12], multiple pregnancies [12], non-cephalic position [7,13], nulliparity [7,12], previous CD [7,9,12] and advanced maternal age [6,8,12,14,15].

This pattern of rising CD rates is alarming because CD has been associated with several adverse outcomes including: severe maternal morbidity [16,17] and mortality [17], antibiotic treatment of the mother after delivery [16], fetal mortality [17], admission of the baby to intensive care for more than 7 days [16,17], neonatal morbidity [18] and mortality [16] as well as increased risk of adverse outcomes in subsequent pregnancies [19]. In addition, CD is more costly than vaginal delivery [20], which can be an economic drain on the healthcare systems.

Little attention has been given to examining the impact of prenatal diagnostic testing, specifically prenatal ultrasound, on CD rates. In general, overutilization of diagnostic imaging can lead to increased medical interventions that are sometimes unnecessary [21]. In particular, the use of prenatal ultrasound in the third trimester of pregnancy can lead to increased prenatal interventions without a significant improvement in perinatal outcome [22]. This idea is supported by studies that showed that some findings detected by ultrasound such as nuchal cord and suspected macrosomia are associated with increased CD rates [23–25], even though there is insufficient evidence supporting CD as an intervention for these ultrasound findings [26–29]. In addition, a large randomized controlled trial showed that the routine use of ultrasound in pregnancy is not associated with improvements in perinatal outcome [30,31]. Nevertheless, the use of ultrasound in pregnancy can provide valuable information that can predict fetal outcomes and aid in the detection of cardiac [32], gastrointestinal [33], renal [34], and neural abnormalities [35] as well as chromosomal anomalies including Down's Syndrome [36]. Current recommendations by the Society of Obstetricians and Gynaecologists of Canada (SOGC) [37] and the American College of Obstetricians and Gynecologists (ACOG) [38] state that all pregnant women should be offered an ultrasound scan between 18-22 weeks to screen for fetal anomalies and to provide information about the placenta, gestational age and number of fetuses. In addition, both the SOGC [39] and ACOG [40] recommend that all pregnant patients be offered the option of having one of several prenatal screening tests for fetal aneuploidies, some of which include a first trimester ultrasound. Therefore, both the SOGC and ACOG recommend up to 2 prenatal ultrasounds. However, certain situations can put a pregnant women at risk which may lead to additional tests including ultrasounds, these situations include maternal obesity, twin pregnancies, and gestational diabetes [41]. It is worth noting that approximately 53% of Canadian women and 70% of American women received three or more ultrasounds during their pregnancy [26,42].

This relationship between prenatal ultrasound utilization and CD may be due to provider and/or patient anxiety, either pre-existing or induced by the ultrasound examination itself, which may lower the threshold for CD in these patients and providers in light of uncertain ultrasound findings. A small number of studies have investigated the relationship between prenatal ultrasound and CD. For instance, a study from China investigating this relationship as one of its main outcomes found that use of prenatal ultrasound was associated with increased odds of CD in rural Eastern China (OR = 1.32, 95%CI: 1.24-1.40) after adjusting for socioeconomic and clinical factors [14]. Moreover, having a late sonogram has been associated with increased likelihood of having a CD in nulliparous women [43]. Another study in Italy found that having more than 4 ultrasounds during a pregnancy when seeing a private OB/GYN was associated with increased CD rates after adjusting for clinical factors [44].

Investigating this relationship is important because it can increase the knowledge about factors that may have the potential to contribute to increased CD rates. It can also increase the knowledge about some of the outcomes that can potentially arise from increased use of ultrasound in pregnancy. Moreover, studying this relationship in different countries is crucial since, in theory, different countries will have differently trained physicians leading to different test ordering habits and/or different approaches to patient management in response to certain test results. The aim of this study was to investigate the relationship between the number of prenatal ultrasounds and primary CD rates in both Canada and the USA.

Methods

This study was performed using secondary analyses of data from the Maternity Experiences Survey (MES) and the Listening To Mothers III (LTM III). The MES was a cross-sectional survey of Canadian women living in all of the Canadian provinces and the territories. This survey was the first national effort devoted to women's experiences of pregnancy, labour, birth and the postpartum period. The MES was an initiative of the Canadian Perinatal Surveillance System of the Public Health Agency of Canada [45]. The target population for the MES was women who had given birth to a single baby in Canada between February 15 and May 15 of

2006 in Canada's 10 provinces, or between November 1, 2005 and February 1, 2006 in Canada's 3 territories. Participants were at least 15 years of age at the time of giving birth, who had their baby spend at least one night per month with them. Women who lived in collective dwellings or on First Nations communities were excluded. The final sample included 6,421 women who had completed the survey and had given Statistics Canada consent to share their responses with the sponsor (Public Health Agency of Canada – Canadian Perinatal Surveillance System). Participation in the survey was voluntary with a response rate of 78%. In the provinces, data collection was conducted using a Computer Assisted Telephone Interview (CATI). In the territories, paper versions of the questionnaire were filled out during a personal interview if performing a CATI was not possible. Detailed methodology of the MES has been described previously [45].

The LTM III was a national cross-sectional survey of women living in the USA, and collected information about pregnancy, labour, birth and the postpartum period. The LTM III was commissioned by Childbirth Connection, funded by the Kellogg Foundation and conducted by Harris Interactive® (a national market research firm). The target population for the LTM III survey was women who gave birth to a single baby in a hospital between July 1, 2011 and June 30, 2012, and who were: 18-45 years of age, whose baby was living at the time of the survey and who spoke English enough to complete the survey. The survey sample was drawn from the following panels: Harris Poll Online, Research Now/E-Rewards, GMI and Offerwise Hispanic. To recruit participants, an email invitation was sent to women from the panels mentioned above. The women were asked a series of screening questions to determine eligibility before accessing the survey. The final sample included 2,400 women whose data were analyzed in this study. Details of the LTM III methodology have been described previously [26,46].

For the purposes of this study, women in the MES sample who declared receiving most of their prenatal care outside of Canada or who declared having a prior caesarean section were excluded, bringing the MES sample size to 5577 women. In addition, women in the LTM III sample who declared having a prior caesarean section were excluded, bringing the LTM III sample size to 2059 women. The rate of Vaginal Birth After Caesarean (VBAC) was 19.9% (2004) in Canadian women [47] and 14% (2011/2012) in American Women [26]. Thus, the risk of caesarean on the index pregnancy was likely not driven by the number of prenatal ultrasounds during the index pregnancy, but rather by the woman's status as someone with a prior caesarean scar. Participation in MES and the LTM III was voluntary. The protocol of MES has been reviewed by the Health Canada's Science Advisory Board and Research Ethics Board and the Federal Privacy Commissioner, and approved by Statistics Canada's Policy Committee. All of the LTM surveys are in compliance with the code and standards of the Council of American Survey Research Organizations and the code of the National Council of Public Polls. Since this project was based on secondary data analysis of MES and the LTM III, institutional ethics approval and new participant consent was not required.

The outcome variable for both surveys was 'mode of delivery' and had 2 levels: vaginal delivery (reference category) and caesarean delivery. The question that was used to obtain information about this variable from the MES was: "Did you have a vaginal or caesarean birth for ^baby's name?". The question that was used to obtain information about the outcome variable from the LTM III was: "When you gave birth following your recent pregnancy, was your baby born … 1) Vaginally 2) by Cesarean".

The main independent variable was the 'number of prenatal ultrasounds' and had 4 levels: 2 or fewer, 3, 4, 5 or more. Information about this variable was obtained from the MES question

“How many ultrasounds did you have during your pregnancy with ^baby's name?” and the LTM III question “As best as you can remember, how many times did you have an ultrasound scan (sonogram) during your recent pregnancy?”.

Covariates for the MES included sociodemographic, medical history and prenatal and birth variables. The sociodemographic factors included: Maternal age at birth, country of birth (two categories: born in Canada or born outside of Canada), province of residence (1. Atlantic – Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland and Labrador. 2. Central – Ontario and Quebec. 3. Prairies – Saskatchewan, Manitoba and Alberta. 4. British Columbia. 5. The Territories – Northwest territories, Nunavut and Yukon), education, household income, employment during pregnancy and urban/rural residence. The medical history factors included: Pre-pregnancy BMI, parity, fertility care prior to index pregnancy, health problems before pregnancy warranting additional care during pregnancy (asked by the question: “Before your pregnancy, did you have any medical conditions or health problems that required you to take medication for more than 2 weeks, have special care, or extra tests during your pregnancy?”), health problems developed during pregnancy warranting additional care during pregnancy (asked by the question: “During your pregnancy, did you develop any new medical conditions or health problems that required you to take medication for more than 2 weeks, have special care, or extra tests?”), history of premature birth and history of stillbirth. The prenatal and birth factors included: Type of healthcare provider, stress 12 months prior to birth (asked by the question: “Thinking about the amount of stress in your life during the 12 months before ^baby's name was born, would you say that most days were...? 1. Not stressful 2. Somewhat stressful 3. Very stressful”. This was dichotomized into: ‘Yes’ which included women who responded with ‘somewhat stressful’ or ‘very stressful’; and ‘No’ which included women responding with ‘not stressful'), gestational age at delivery, birthweight and whether the baby was admitted to the intensive care unit immediately after birth.

Covariates for the LTM III were divided into several categories: Sociodemographic, medical history and prenatal and birth. The sociodemographic factors included: maternal age at birth, race, country of birth (two categories: USA born and born outside of the USA), region of residence grouped based on the United States Census region designations [48] (1. North East – Connecticut, Maine, Vermont, Rhode Island, New Hampshire, and Massachusetts, Pennsylvania, New York, and New Jersey, 2. Midwest – Wisconsin, Illinois, Michigan, Ohio, and Indiana, South and North Dakota, Iowa, Missouri, Kansas, Nebraska, and Minnesota, 3. South – District of Columbia, Texas, Louisiana, Oklahoma, and Arkansas, Tennessee, Mississippi, Alabama, and Kentucky, West Virginia, Georgia, Virginia, South and North Carolina, Maryland, Delaware, and Florida, and 4. West – Oregon, Hawaii, Alaska, California, and Washington, Wyoming, Montana, and Idaho, New Mexico, Utah, Arizona, Nevada, and Colorado), education, household income and source of payment for maternity care. The medical history factors included: Pre-pregnancy BMI, parity, fertility care prior to index pregnancy, history of type 1 or type 2 diabetes, gestational diabetes during the index pregnancy, and whether the woman took medication for hypertension one month before the index pregnancy. Prenatal and birth factors included: Type of prenatal provider, whether the women felt she needed treatment for depression (asked by the question "During your recent pregnancy, did you feel you needed any of the following services?" 1. Food stamps, WIC food vouchers, or money to buy food. 2. Treatment for depression. 3. Help to quit smoking. 4. Counseling for nutrition". This was dichotomized to: 'Yes' which included women responding with yes to 'treatment to depression'; and 'No' which included all other women), gestational age at birth, birthweight and whether the baby was admitted to the intensive care unit after birth.

Statistical analyses

To assess the bivariable relationship between the main independent variable and the covariates with the outcome, bivariable logistic regression models were performed. Two multivariable logistic regressions (one for each database) were performed to assess the relationship between the number of prenatal ultrasounds and CD while controlling for all of the covariates. This analysis produced adjusted Odds Ratios (OR) and 95% Confidence Intervals (95%CI). The significance level was set at an α of 0.05. An interaction term between parity and the number of prenatal ultrasounds was added to explore the relationship between ultrasound and CD for primiparous women compared to multiparous women. This interaction term was significant and, therefore, was kept in the model. For both surveys, the provided survey weights were applied to help ensure that the estimates were nationally representative. For the MES, bootstrap weights were also employed in order to account for the complex design of the survey. Goodness of fit was checked using the link test for model specification in Stata [49]. This test revealed no issues regarding model fit without weights as required in either of the datasets. Moreover, G*Power [50] was used to perform post-hoc achieved power analyses for both models which provided an estimated power of 0.995 for the MES sample and 0.973 for the LTM III sample. All statistical tests for the MES were performed using Stata Statistical Software version 14 (StataCorp, College Station, TX). All statistical tests for the LTM III were performed using IBM SPSS Statistics for Windows, version 24 (IBM Corp., Armnok, NY).

Results

The prevalence of primary CD in Canada and the USA was very similar, being18.5% in Canada and 18.7% in the USA. Table 1 shows the percentages, unadjusted ORs and 95%CIs, and adjusted ORs and 95%CIs for the Canadian sample. Table 2 shows the percentages, unadjusted ORs and 95%CIs, and adjusted ORs and 95%CIs for the American sample.

The number of prenatal ultrasounds received during pregnancy was significantly associated with increased odds of CD in multiparous women who received more than 2 ultrasounds in both samples compared to those who received 2 or fewer ultrasounds (Canadian – 3 ultrasounds: adjusted OR=2.03, 95%CI: 1.19-3.45; 4 ultrasounds: adjusted OR=3.86, 95%CI: 2.27-6.58; 5 or more ultrasounds: adjusted OR=3.63, 95%CI: 2.12-6.19. American – 3 ultrasounds: adjusted OR=2.09, 95%CI: 1.05-4.19; 4 ultrasounds: adjusted OR=4.68, 95%CI: 2.31-9.46; 5 or more ultrasounds: adjusted OR=3.29, 95%CI: 1.73-6.26) (Table 3). Primiparous women in Canada who received more than 2 ultrasounds were also at increased odds of receiving CD (3 ultrasounds: adjusted OR=1.50, 95%CI: 1.17-1.91; 4 ultrasounds: adjusted OR=1.36, 95%CI: 1.01-1.82; 5 or more ultrasounds: adjusted OR=1.79, 95%CI: 1.36-2.36) (Table 3). No significant relationship between the number of prenatal ultrasounds and CD was observed for primiparous women in the USA.

In Canadian women, increased odds of CD were seen in women who were 35 years of age or older, were overweight/obese, had their baby admitted to the intensive care unit after birth and had a baby weighing more than 4000g or less than 3500g (Table 1). In American women, increased odds of CD were seen in women who are 35 years of age or older, had other government programs paying for their maternity care (compared to Medicaid or CHIP), were overweight/obese, received fertility care prior to pregnancy, had their baby admitted to the intensive care unit after birth and who had a baby weighing more than 4000g at birth (Table 2).

The only factor associated with lower odds of CD in Canadian women was receiving prenatal care in the Territories (compared to the Atlantic provinces) (Table 1). Factors associated with lower CD odds in American women were maternal age lower than 20 years, paying 'out of pocket' for maternity care (compared to Medicaid or CHIP), having taken medications for hypertension one month prior to index pregnancy and receiving prenatal care from a family doctor (Table 2)

Discussion

The present study found that having more than 2 prenatal ultrasounds was associated with primary CD in both Canada and the USA, even after adjusting for several confounding variables. After adjusting for confounding factors, Canadian multiparous women with no history of CD had 2-3.9 times the odds of undergoing CD when they received more than 2 prenatal ultrasounds compared to receiving 2 or fewer ultrasounds. Moreover, Canadian primiparous women receiving more than 2 prenatal ultrasounds had 1.5-1.8 times the odds of CD compared to receiving 2 or fewer prenatal ultrasounds, after adjusting for confounding factors. In the USA, multiparous women with no history of CD were 2-4.7 times more likely to undergo CD when they received more than 2 prenatal ultrasounds compared to receiving 2 or fewer prenatal ultrasounds. The relationship between the number of prenatal ultrasounds and CD is expected in situations that warrant medical intervention such as additional prenatal ultrasounds and CD. However, such a relationship is of concern and significance in the context of additional ultrasounds that are not medically necessary. Though the results of this study are not completely free of confounding, they do increase the knowledge about the relationship between the number of prenatal ultrasounds and CD. These findings can serve as a baseline in Canada and the USA that future studies can build upon and delve deeper into.

It is worth noting that the healthcare systems in Canada and the USA are quite different [51]. Canada has universal healthcare insurance, where the Canadian government funds all medically necessary services for all taxpayers [51]. In contrast, the American government provides this coverage only to certain groups such as individuals with lower socioeconomic status, older adults and children [51]. This leaves a major portion of the population to either have no healthcare coverage or be covered by employer benefits or private insurance [51]. This is an important consideration when interpreting the findings of this study in these two countries.

In this study, efforts were made to make the samples used as low risk as possible for increased prenatal ultrasounds and CD by using databases that include only patients who had singleton pregnancies and by restricting the sample to women who have never had a CD prior to the index pregnancy. In addition, multiple factors such as birthweight, gestational age at birth, baby's stay in the intensive care unit and undergoing fertility treatments to get pregnant were adjusted for to account for as much confounding as possible. However, there are other situations that were not adjusted for in this study such as placental conditions, suspected intrauterine growth restriction and fetal position that may warrant an increased number of prenatal ultrasounds as well as CD.

With the above in mind, this study demonstrated a relationship between ultrasound and CD in multiparous women with no history of CD in both Canada and the USA. This same relationship was observed to a lesser extent in Canadian primiparous women but not in American primiparas. Multiparous women with no history of CD may be considered at lower risk for pregnancy/birth complications, and consequently, at lower risk for additional prenatal ultrasounds and CD than primiparous women because they have already experienced birth and have a 'proven pelvis'. Although the stronger association between the number of prenatal ultrasounds and CD in these women may be due to confounding by indication, this finding may be considered supportive of the theory that increased prenatal ultrasound utilization may be a contributing factor to the increased CD rates even in lower risk women. The difference in the observed relationship between ultrasound and CD in primiparous women in Canada and the USA may be due to differing practice philosophies and thresholds for intervention in both countries. This may also be due to differences in inclusion criteria in the two databases used in this study. This observed variation in the relationship between multiparas and primiparas in the context of ultrasound and CD needs to be further explored.

The association between the number of prenatal ultrasounds received during pregnancy and CD may be in part driven by characteristics of the healthcare provider. Previous studies have shown that fear of litigation and patient complaints may drive obstetricians to accept maternal requests for CD even when it is not medically necessary [52,53], and this effect may be compounded by increased malpractice premium amounts which can lead to increased CD rates in the USA [54–56]. Interestingly, fear of litigation has not been demonstrated to be a major influencer on CD rates in Canada [57]. In addition, provider characteristics such as older age and being full-time faculty practitioner were found to be associated with an increased CD rate in the USA [58] . In Canada, however, younger obstetricians were more comfortable with CD than older obstetricians and more strongly believed in its safety [59]. Moreover, it has been shown that certain personality attributes of the healthcare provider can affect whether a patient with a prior caesarean history will have a repeat CD or a Vaginal Birth After Caesarean (VBAC) [60]. Specifically, women were more likely to undergo VBAC if they were delivered by a physician with lower anxiety, higher tolerance for ambiguity and high proactive coping [60]. Therefore, providers with certain characteristics and personality traits may have a lower threshold for intervention with CD when faced with minor ultrasound findings. For example, anxious providers and/or patients may request a higher number of ultrasounds, which may consequently, reveal additional findings such a nuchal cord. A nuchal cord is not an indication for CD [27–29], however, to an anxious provider and/or patient it may be perceived as risky, making them more inclined to choose CD over vaginal delivery. In addition, prenatal ultrasound in itself may induce patient anxiety in anticipation of and during the ultrasound examination [61], or after the discovery of incidental findings [62]. This might make the patient more inclined to request potentially unnecessary intervention in the form of CD.

Other considerations potentially contributing to the relationship between the number of prenatal ultrasounds and CD are pay-for-performance models and societal expectations. Pay-for performance models of care are models that offer incentives to healthcare providers for meeting pre-defined targets of parameters of quality and efficacy [63]. Providers working within this model may, therefore, be more inclined to order additional tests and/or have a lower threshold for intervention in order to achieve targets. Considering societal expectations when interpreting the relationship between the number of prenatal ultrasounds and CD is also of importance. The use of prenatal ultrasound has proliferated significantly to the point of commercialization, which is reflected by the emergence of 'non-medical' or 'keepsake' ultrasounds [64]. This widespread availability of prenatal ultrasound may have led to an expectation among pregnant women and their families of receiving prenatal ultrasounds whenever they wanted them. These societal expectations may also contribute to increased CD rates, reflected by the emergence of CD on maternal request [65].

The present study showed that, after adjusting for confounding variables, maternal age of 35 years or more was associated with increased odds of CD in both the Canadian and the American samples. This is consistent with previous studies from various countries [6,8,12,14,15] and may be explained physiologically by myometrial incompetency and decreased oxytocin receptors in older women [15]. Other potential explanations for this relationship include close monitoring and lower threshold for obstetrical interventions in patients of advanced maternal age [15]. The present study also found that American women aged less than 20 years were at lower odds for CD, after adjusting for confounding variables. This is in agreement with previous reports [66–70] and may be due to better elasticity, myometrial function and lower cervical compliance [70]. In addition, this effect maybe due to the increased efforts of healthcare providers to avoid CD in teenage mothers [70]. Therefore, this relationship between younger maternal age and CD may not necessarily be due to lower rates of complications during pregnancy and birth in younger mothers, but rather due to the policy of the healthcare provider and the mother's opinion [69]. This may explain why this relationship was not observed in the Canadian sample. The only other sociodemographic factor that influenced Canadian women's odds of CD in this study was receiving most of their prenatal care in the Territories, which decreased the odds of CD compared to receiving prenatal care in the Atlantic provinces. This may be explained by decreased access to healthcare services in the Territories [71–74] and differing obstetrical philosophy and practice based on region [75]. The only other sociodemographic factor that influenced the odds of CD in the American sample was the source of payment for maternity care being a government program other than Medicaid or CHIP (increased the odds of CD) and 'out of pocket' payment (decreased the odds of CD). Medicaid and CHIP are government programs that are designed to provide basic healthcare coverage for people with lower income [76]. The other government programs include TriCare, Veterans Affairs and the Federal Employee Health Benefits program (FEHB). TriCare and FEHB both have different plans within the programs and can have more extended coverage than Medicaid and CHIP [77,78]. As for patients paying out of pocket being at lower odds for CD, these women may be more likely to opt for less expensive healthcare options, making them more likely to prefer vaginal birth [79].

In terms of maternal medical history, overweight/obese women in both samples were found to be at increased odds of CD compared to women of normal BMI, after adjusting for confounding variables. Being overweight/obese has been associated with CD in different parts of the world [6,8–11], a relationship that may be mediated by differing responses to oxytocin and increased risk of conditions such as cephalopelvic disproportion, meconium staining and cord accidents in the overweight/obese population [11]. In the present study, American women who received fertility care prior to pregnancy were also at higher odds of CD than those who did not, after adjusting for confounding variables. This relationship has been reported in the past [80,81] and may be due to the 'precious baby effect', in which obstetricians may lower their threshold for CD to prevent adverse outcomes, regardless of how unlikely, in patients who have received fertility treatment or procedures in order to conceive [82].

Finally, after adjusting for confounders, the prenatal and birth related factors that were associated with increased odds of CD in both samples were admission of the baby to the intensive care unit and baby's birthweight. These variables were included in the model to serve as proxy for complications arising during pregnancy that may act as confounders. Baby's stay in the intensive care unit has been shown in previous studies to be associated with increased CD rates [83,84]. Abnormalities detected by fetal heart monitoring may warrant CD [85] and can lead to the admission of the baby to the intensive care unit [86,87]. As for birthweight, the present study showed that a birthweight higher than 4000g was associated with increased CD odds in both samples, as was a birthweight under 2500g in the Canadian sample. This is consistent with previous studies that showed that birthweight extremes are associated with increased odds of CD [88,89]. The ACOG recommends that non-diabetic women with babies weighing more than 5000g, and women with gestational diabetes and babies larger than 4500g undergo CD [29,90]. As for the other end of the spectrum, smaller babies are more likely to assume a breech presentation [91], which is generally an indication for CD according to the ACOG and the SOGC [29,90,92].

The main limitation of this study is that it involved secondary data analyses of survey responses, and with self-reported data there is a potential of information bias in the form of lack of recall or the temptation to present oneself favourably. Another limitation of this study is data for the MES and LTM III were collected between 2005 and 2006 and between 2011 and 2012, respectively, and the characteristics of the current Canadian and American populations may be slightly different. It is important to note that the recommendations for prenatal ultrasound have not significantly changed since the time of the surveys [93–96], and even though the best practices regarding mode of delivery may have changed, the WHO recommendations regarding CD rates have remained the same [1]. Additionally, the MES and LTM III are the most recent national databases available that address maternity experiences in Canada and the USA, respectively. Moreover, both samples used in this study only included singleton pregnancies making our findings non-generalizable to multiple pregnancies. Finally, another major limitation of this study is that it was not possible to adjust for all of the medical indications that warrant both additional prenatal ultrasounds and CD that can confound the observed relationship, including placental issues and fetal position. It is worth noting that breech presentation and placental issues are of low incidence/prevalence; breech presentation accounts for approximately 3-5% of pregnancies [97], the prevalence of placenta previa in North America is 2.9 per 1000 pregnancies [98], prevalence of abruption in North America is 7-12 per 1000 pregnancies [99] and the incidence of placenta accreta, increta and percreta in the USA is 3 per 1000 pregnancies [100]. Postnatal and birth related variables (such as gestational age at birth, birthweight and intensive care unit admission) were used as proxy for complications arising during pregnancy that may confound the relationship between the number of prenatal ultrasounds and CD. Despite these limitations, this study was the first to investigate this important relationship in Canada and the USA on a national scale and provided important baseline information that can be built upon by future studies.

This study demonstrated, on a national scale, that more frequent prenatal ultrasounds are associated with increased odds for CD in both Canada and the USA. This is an important preliminary finding that needs to be replicated and further explored by future studies. Future studies can investigate the mechanisms underlying this relationship, such as further investigating provider characteristics that may mediate this effect and investigating the difference observed between multiparas and primiparas. Future studies can also aim to explore this relationship strictly in the context of medically unnecessary prenatal ultrasounds and CD, perhaps using clinical databases that might allow for excluding women with any known risk factors for additional CD and ultrasound or adjusting for these factors in the analysis.

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Table 1: Percentages, adjusted and unadjusted Odds Ratios (OR) and 95% Confidence Intervals (95%CI) for caesarean deliveries compared to vaginal deliveries in Canadian women with no history of prior caesarean deliveries (The Maternity Experiences Survey)

		Mode of delivery			
Variable	**Overall (n=5577) %**	**Vaginal**	**Caesarean**		
		%	**%**	**Unadjusted OR (95%CI)**	**Adjusted OR (95%CI)**
MAIN EXPOSURE					
Number of prenatal ultrasounds					
2 or fewer	47.5	87.3	12.8	1.00	1.00
3	23.2	79.6	20.4	1.76 (1.46-2.11)	2.03 (1.19-3.45)
4	13.7	74.9	25.1	2.29 (1.86-2.82)	3.86 (2.27-6.58)
5 or more	15.6	72.6	27.4	2.59 (2.12-3.15)	3.63 (2.12-6.19)
MATERNAL SOCIO-DEMOGRAPHIC FACTORS					
Age at birth					
<20	3.3	80.0	20.0	1.14 (0.83-1.56)	0.79 (0.50-1.24)
20-34	80.7	82.0	18.0	1.00	1.00
35+	16.0	79.2	20.8	1.19 (0.99-1.44)	1.71 (1.34-2.19)
Country of birth					
Canada	76.1	81.3	18.7	1.00	1.00
Other	23.9	81.9	18.1	0.96 (0.81-1.15)	1.05 (0.83-1.33)
Province of prenatal care					
Atlantic	5.8	80.6	19.4	1.00	1.00
Central	62.8	82.1	17.9	0.91 (0.76-1.09)	0.98 (0.76-1.25)
Prairies	19.1	81.4	18.6	0.95 (0.77-1.77)	1.19 (0.90-1.58)
British Columbia	11.7	78.4	21.6	1.14 (0.90-1.45)	1.37 (1.00-1.89)
Territories	0.5	90.4	9.6	0.44 (0.32-0.61)	0.59 (0.40-0.88)
Education					
High school or less	21.2	82.7	17.3	1.00	1.00
Post-secondary below bachelor	43.2	82.2	17.8	1.04 (0.86-1.29)	0.82 (0.64-1.06)
Bachelor	25.8	80.0	20.0	1.19 (0.97-1.47)	0.94 (0.70-1.25)
Graduate	9.9	79.5	20.5	1.24 (0.94-1.63)	0.86 (0.59-1.23)
Household income					

<$30,000	17.3	82.8	17.2	1.00	1.00
$30,000-<$60,000	30.9	81.5	18.5	1.09 (0.89-1.35)	1.14 (0.88-1.48)
$60,000-<$100,000	31.8	81.2	18.8	1.11 (0.90-1.37)	1.02 (0.77-1.34)
$100,000+	19.3	80.9	19.1	1.14 (0.90-1.44)	0.99 (0.72-1.34)
Employment during pregnancy					
Yes	79.7	80.0	20.0	1.68 (1.37-2.05)	1.05 (0.79-1.39)
No	20.3	87.1	14.0	1.00	1.00
Urban/Rural residence					
Rural	17.5	82.6	17.4	0.91 (0.75-1.11)	1.11 (0.86-1.43)
<30,000	17.1	82.9	17.1	0.89 (0.72-1.11)	0.93 (0.71-1.21)
30,000-99,999	8.3	81.9	18.1	0.96 (0.73-1.26)	0.97 (0.69-1.38)
100,000-499,999	11.8	78.4	21.6	1.19 (0.96-1.49)	1.09 (0.84-1.41)
500,000+	45.4	81.3	18.7	1.00	1.00
MATERNAL MEDICAL HISTORY					
Pre-pregnancy BMI					
Underweight (less than 18.5)	6.3	85.8	14.3	0.83 (0.59-1.17)	0.74 (0.48-1.15)
Normal (18.5-24.99)	60.3	83.4	16.6	1.00	1.00
Overweight/obese (25+)	33.4	77.0	23.0	1.50 (1.29-1.74)	1.74 (1.44-2.09)
Parity					
Primiparous	52.0	70.3	29.7	6.20 (5.17-7.44)	11.00 (7.53-16.08)
Multiparous	48.0	93.6	6.4	1.00	1.00
Fertility care prior to pregnancy					
Yes	5.0	70.6	29.4	1.91 (1.42-2.56)	1.35 (0.96-1.90)
No	95.0	82.1	17.9	1.00	1.00
Health problems before pregnancy					
Yes	14.8	77.7	23.3	1.32 (1.09-1.59)	1.11 (0.88-1.40)
No	85.2	82.1	17.9	1.00	1.00
Health problems during pregnancy					
Yes	24.6	79.6	20.5	1.18 (1.01-1.38)	0.94 (0.77-1.15)
No	75.5	82.1	17.9	1.00	1.00
History of premature birth					

Yes	4.4	91.8	8.2	0.38 (0.23-0.64)	1.29 (0.72-2.30)
No	95.6	81.1	18.9	1.00	1.00
History of stillbirth					
Yes	1.5	78.0	22.0	1.24 (0.70-2.21)	0.99 (0.49-2.00)
No	98.5	81.5	18.5	1.00	1.00
PRENATAL AND BIRTH RELATED FACTORS					
Type of prenatal care provider					
OB/GYN	57.3	80.5	19.5	1.00	1.00
Family doctor/GP or other doctor	35.1	83.7	16.3	0.80 (0.69-0.93)	0.87 (0.72-1.05)
Midwife or other	7.6	78.8	21.2	1.11 (0.85-1.45)	1.16 (0.83-1.63)
Stress 12 months before birth					
Yes	56.4	82.1	17.9	0.90 (0.78-1.05)	0.88 (0.74-1.06)
No	43.6	80.6	19.4	1.00	1.00
Gestational age at birth					
Preterm (<37 weeks)	6.2	72.6	27.4	1.74 (1.33-2.28)	0.92 (0.61-1.39)
Term (37-41 weeks)	92.5	82.2	17.8	1.00	1.00
Post-term (42 weeks or more)	1.4	76.2	23.8	1.44 (0.81-2.58)	0.75 (0.38-1.50)
Birthweight					
<2500g	5.2	68.0	32.0	2.32 (1.76-3.07)	1.99 (1.27-3.11)
2500-4000g	82.6	83.2	16.8	1.00	1.00
>4000g	12.2	75.8	24.3	1.58 (1.30-1.93)	1.99 (1.56-2.55)
Baby admitted to the intensive care unit after birth					
Yes	12.5	68.6	31.4	2.29 (1.90-2.77)	1.65 (1.28-2.12)
No	87.5	83.4	16.6	1.00	1.00
Interaction: Number of ultrasounds x parity					
2 or fewer ultrasounds x multiparous					1.00
3 ultrasounds x primiparous	-	-	-	-	0.74 (0.41-1.33)
4 ultrasounds x primiparous	-	-	-	-	0.35 (0.19-0.64)
5+ ultrasounds x primiparous	-	-	-	-	0.49 (0.27-0.90)

Table 2: Percentages, adjusted and unadjusted Odds Ratios (OR) and 95% Confidence Intervals (95%CI) for caesarean deliveries compared to vaginal deliveries in American women with no history of prior caesarean deliveries (The Listening To Mothers III Survey)

		Mode of Delivery			
Variable	Overall (n=2059) %	Vaginal	Caesarean		
		%	%	Unadjusted OR (95%CI)	Adjusted OR (95%CI)
MAIN EXPOSURE VARIABLE					
Number of prenatal ultrasounds					
2 or fewer	31.4	86.2	13.8	1.00	1.00
3	22.6	82.9	17.1	1.30 (0.93-1.82)	2.09 (1.05-4.19)
4	13.0	78.5	21.5	1.71 (1.18-2.50)	4.68 (2.31-9.46)
5 or more	32.9	76.4	23.6	1.94 (1.45-2.61)	3.29 (1.73-6.26)
MATERNAL SOCIO-DEMOGRAPHIC FACTORS					
Age at birth					
<20	8.3	85.9	14.1	0.69 (0.44-1.10)	0.37 (0.19-0.72)
20-34	78.5	81.2	18.8	1.00	1.00
35+	13.2	78.8	21.2	1.16 (0.84-1.60)	1.61 (1.07-2.42)
Race					
White	54.8	80.3	19.7	1.00	1.00
African American	15.5	84.8	15.2	0.73 (0.52-1.04)	0.74 (0.48-1.13)
Hispanic	22.7	80.0	20.0	1.03 (0.78-1.35)	0.98 (0.68-1.43)
Other	7.0	84.7	15.3	0.74 (0.45-1.20)	0.67 (0.37-1.20)
Country of birth					
USA	93.6	81.6	18.4	1.00	1.00
Other	6.4	76.2	23.8	1.41 (0.92-2.15)	1.49 (0.86-2.58)
Region of Residence					
Northeast	15.6	77.9	22.1	1.05 (0.82-1.66)	1.06 (0.68-1.65)
Midwest	22.9	85.8	14.2	0.67 (0.47-0.96)	0.87 (0.57-1.32)
South	38.8	80.6	19.4	0.99 (0.73-1.32)	0.84 (0.58-1.21)
West	22.7	80.3	19.7	1.00	1.00
Education					
High school or less	41.9	81.7	18.3	1.00	1.00

Some college	29.1	82.0	18.0	0.98 (0.74-1.29)	0.98 (0.69-1.40)
College graduate or higher	29.0	80.1	19.9	1.10 (0.84-1.45)	0.98 (0.66-1.47)
Household income					
$29,400 or less	29.2	81.2	18.8	1.00	1.00
$29,401-$60,000	31.9	81.4	18.6	0.98 (0.73-1.33)	1.05 (0.71-1.55)
$60,001-$98,200	23.9	82.3	17.7	0.93 (0.67-1.29)	0.89 (0.56-1.42)
>$98,200	15.1	78.8	21.2	1.16 (0.81-1.66)	1.16 (0.69-1.93)
Source of payment for maternity care					
Medicaid or CHIP	38.1	81.3	18.7	1.00	1.00
Other government program	9.1	74.0	26.0	1.54 (1.05-2.27)	1.96 (1.22-3.17)
Private insurance	46.9	81.7	18.3	0.97 (0.76-1.25)	0.96 (0.66-1.39)
Out of pocket	5.8	88.3	11.7	0.56 (0.30-1.04)	0.46 (0.21-0.98)
MATERNAL MEDICAL HISTORY					
Pre-pregnancy BMI					
Underweight (less than 18.5)	8.8	85.5	14.5	0.98 (0.62-1.55)	0.88 (0.51-1.52)
Normal (18.5-24.99)	50.5	85.4	14.6	1.00	1.00
Overweight/obese (25+)	40.7	75.3	24.8	1.92 (1.51-2.43)	1.99 (1.49-2.66)
Parity					
Primiparous	49.7	74.7	25.3	2.44 (1.92-3.10)	8.19 (4.38-15.30)
Multiparous	50.3	87.8	12.2	1.00	1.00
Fertility care prior to pregnancy					
Yes	17.6	76.2	23.8	1.49 (1.12-1.98)	1.58 (1.06-2.37)
No	82.4	82.8	17.2	1.00	1.00
History of type 1 or type 2 diabetes					
Yes	8.8	80.9	19.1	1.01 (0.68-1.51)	0.80 (0.42-1.52)
No	91.2	81.3	18.7	1.00	1.00
Gestational diabetes during index pregnancy					
Yes	17.5	77.6	22.4	1.31 (0.99-1.74)	0.81 (0.53-1.24)
No	82.5	82.1	17.9	1.00	1.00
Taken medications for hypertension 1 month before index pregnancy					

Yes	7.9	84.4	15.6	0.78 (0.50-1.23)	0.56 (0.31-0.99)
No	92.1	80.9	19.1	1.00	1.00
PRENATAL AND BIRTH RELATED FACTORS					
Type of prenatal care provider					
Obstetrician/Gynecologist	75.7	80.6	19.4	1.00	1.00
Family doctor or other doctor	13.2	85.0	15.0	0.73 (0.51-1.05)	0.60 (0.37-0.98)
Midwife or Other	11.0	81.1	18.9	0.97 (0.68-1.40)	0.98 (0.62-1.57)
Felt needed depression treatment during pregnancy					
Yes	15.5	75.0	25.0	1.56 (1.17-2.08)	1.16 (0.78-1.74)
No	84.5	82.4	17.6	1.00	1.00
Gestational age at birth					
Preterm (<37 weeks)	7.8	69.5	30.5	2.03 (1.41-2.92)	1.42 (0.83-2.44)
Term (37-41 weeks)	89.2	82.3	17.7	1.00	1.00
Post-term (42 weeks or more)	3.0	82.8	17.2	0.99 (0.50-1.96)	1.71 (0.77-3.79)
Birthweight					
<2500g	7.9	76.6	23.4	1.43 (0.97-2.12)	1.00 (0.58-1.71)
2500-4000g	82.6	82.3	17.7	1.00	1.00
>4000g	9.5	76.5	23.5	1.45 (1.01-2.08)	1.77 (1.13-2.77)
Baby admitted to the intensive care unit after birth					
Yes	18.5	71.0	29.0	2.19 (1.68-2.86)	2.03 (1.37-3.00)
No	81.5	84.2	15.8	1.00	1.00
Interaction: Number of prenatal ultrasounds x parity					
2 or fewer ultrasounds x multiparous					1.00
3 ultrasounds x primiparous	-	-	-	-	0.31 (0.13-0.74)
4 ultrasounds x primiparous	-	-	-	-	0.20 (0.08-0.49)
5 or more ultrasounds x primiparous	-	-	-	-	0.33 (0.15-0.72)

Table 3: Adjusted Odds Ratios (OR) and 95% Confidence Intervals (95%CI) for Caesarean Delivery (CD) in primiparous women and multiparous women with no history of CD. The Maternity Experiences Survey (MES, Canada) and the Listening To Mothers III survey (LTM III, USA).

	Canada (MES)		**USA (LTM III)**	
	Adjusted OR (95%CI) for CD in primiparous women[a]	**Adjusted OR (95%CI) for CD in multiparous women[a]**	**Adjusted OR (95%CI) for CD in primiparous women[b]**	**Adjusted OR (95%CI) for CD in multiparous women[b]**
Number of prenatal ultrasounds				
2 or fewer	1.00	1.00	1.00	1.00
3	1.50 (1.17-1.91)	2.03 (1.19-3.45)	0.65 (0.39-1.09)	2.09 (1.05-4.19)
4	1.36 (1.01-1.82)	3.86 (2.27-6.58)	0.92 (0.51-1.67)	4.68 (2.31-9.46)
5 or more	1.79 (1.36-2.36)	3.63 (2.12-6.19)	1.10 (0.71-1.69)	3.29 (1.73-6.26)

[a] Adjusted for: maternal age, country of birth, province of prenatal care, education, household income, employment during pregnancy, urban/rural residence, pre-pregnancy BMI, parity, fertility care prior to pregnancy, health problems before pregnancy, health problems during pregnancy, history of premature birth, history of stillbirth, type of prenatal care provider, stress 12 months prior to birth, gestational age at birth, birthweight and admission of baby to the intensive care unit

[b]Adjusted for: maternal age, race, country of birth, region of residence, education, household income, source of payment for maternity care, pre-pregnancy BMI, parity, fertility care prior to pregnancy, history of type 1 or type 2 diabetes, gestational diabetes during index pregnancy, medications for hypertension 1 month prior to index pregnancy, type of prenatal care provider, patient feeling the need for depression treatment during pregnancy, gestational age at birth, birthweight and admission of baby to the intensive care unit.

CHAPTER 5

Dissertation discussion

Summary

Guided by the conceptual framework of 'medical overuse' devised by Morgan et al [1], the studies of this dissertation aimed to shed light on some factors that are associated with prenatal ultrasound utilization. Using two national databases, namely the MES and the LTM III, the studies of this dissertation explored different aspects of prenatal ultrasound utilization: 1) how prenatal ultrasound utilization is influenced by having single or multiple prenatal care providers, 2) factors associated with the timing of the first prenatal ultrasound, and 3) the relationship between prenatal ultrasound and mode of delivery. No significant relationship was found between having single or multiple prenatal care providers and the number of prenatal ultrasounds. Several factors were found to influence the timing of the first prenatal ultrasound including maternal, socioeconomic, reproductive history related and prenatal and birth related factors. Finally, having an increased number of prenatal ultrasounds was associated with increased odds for CD. These findings provided an epidemiological overview of prenatal ultrasound utilization in Canada and the USA and may inform efforts aimed at optimizing the utilization of prenatal ultrasound, as well as raise awareness about relationships that have not been adequately explored thus far.

Addressing the utilization of prenatal ultrasounds

As with any other medical test, optimizing the utilization of prenatal ultrasound requires extensive investigation into the elements contributing to its misuse. The studies of this dissertation are not without limitations, and confounding may still play a role making it difficult to purely investigate 'overutilization' of prenatal ultrasound in these samples. Nevertheless, these studies have identified factors associated with prenatal ultrasound utilization, which have the potential to contribute to or result from overutilization or underutilization.

<u>Factors with potential to contribute to overutilization or underutilization</u>

The first study of this dissertation "the relationship between single versus multiple prenatal care providers and the number of ultrasounds received during pregnancy: Findings from the Listening To Mothers III survey" did not find a significant relationship between having single or multiple prenatal care providers and the number ultrasounds received during pregnancy. This may indicate that models of care that involve multiple prenatal care providers in the USA do offer informational continuity allowing for seamless transition between providers seeing the same woman. It is important to note that this association may look different in different settings and using different databases. Alternatively, the non-significance may be explained by other factors that may have rendered the overall relationship between having single versus multiple prenatal care providers and the number of prenatal ultrasounds non-significant. These include: the different combinations of provider types, whether the patient was cared for under the shared care model, the total number of prenatal care providers and the timing of when the new providers join a woman's prenatal care. It is important, therefore, to assess this relationship while accounting for these factors and this can be explored by future studies. Though the association between continuity of care and medical overuse has generally been underexplored, the studies that did attempt to assess this relationship in medical disciplines other than obstetrics show that receiving care from single rather than multiple healthcare providers can lead to a lower frequency of unnecessary diagnostic testing and intervention [2,3]. This study also identified factors that were associated with an increased number of prenatal ultrasounds including African American race, gestational diabetes and caesarean delivery. It also identified factors that were associated with a decreased number of prenatal ultrasounds including receiving care from a midwife or a family doctor.

The second study of this dissertation “factors associated with the timing of prenatal ultrasound in Canada” demonstrated that several sociodemographic factors such as maternal age, province of prenatal care and country of birth influence the timing of the first prenatal ultrasound in Canada, even after adjusting for several confounders. The timing of prenatal ultrasound is tied to its overutilization and underutilization because when a woman has her first prenatal ultrasound too early in the pregnancy, she will likely receive a minimum of 3 prenatal ultrasounds (if she received the recommended 2 ultrasounds as well). Having a prenatal ultrasound that is too early may also set the trend of additional ultrasounds for the rest of the pregnancy. Contrarily, if a woman has her first ultrasound too late in her pregnancy she will likely receive a lower total number of prenatal ultrasounds simply because there is not enough time left in the pregnancy to receive additional ultrasounds. Though the timing of the first prenatal ultrasound has not been studied before, previous studies investigating access to prenatal care demonstrated similar findings. To name a few, women presenting early to prenatal care and who receive an early first prenatal ultrasound tend to be older than 20 years [4–6], underweight [5,6], not alcohol users [6–10] and primiparous [6,9,11–14]. Late presenters to prenatal care and those who receive late prenatal ultrasounds tend to have unintended pregnancies [6,15], be foreign born [6,10,16–18] and receive prenatal care in Manitoba [6,10].

The two studies of this dissertation described above tackle the heading ‘identify the factors promoting overuse’ and subheading ‘identify the most important drivers of overuse’ from Morgan et al’s research agenda [1].

Potential adverse outcome of overutilization

The third study of this dissertation “assessing the relationship between the number of prenatal ultrasounds and primary caesarean delivery: Findings from Canada and the USA” demonstrated an association between prenatal ultrasound utilization and primary CD which, in the context of unnecessary prenatal ultrasounds, may be considered as an adverse outcome of overutilization. The findings of this study are consistent with the very few other studies that explored this relationship in different settings either as a main objective or as a secondary finding [19–22], urging the need to explore this relationship in more depth. This study tackles the heading ‘measure the effect of overuse’ and the subheading ‘measure the impact of overuse’ from Morgan et al’s research agenda [1].

The use of technology in healthcare

While this dissertation addressed numerous patient related factors that may be associated with prenatal ultrasound utilization, it did not assess many environmental factors, namely those pertaining to the advances in healthcare technology. These are important to consider when looking at the ‘big picture’ of prenatal ultrasound utilization. The increasing advances in technology in healthcare have lead to what is called a “technological imperative”, a term first coined in the 1960s that implies that medical practitioners are obliged to provide the best care that is technologically possible [23,24]. As such, the use of technology has dominated healthcare leading to a culture of “if it exists, we must use it” [24–26]. This has become a common mindset not only in healthcare providers, but in patients as well. Nowadays, patients are more educated about, and aware of the technological advances in healthcare than ever before, and often demand the latest technological advances for their care [25,26]. In the context of prenatal ultrasounds, pregnant women view ultrasound scans as an important part of their care and often demand additional scans during the course of their pregnancy [27,28]. These demands are further nurtured and encouraged by the proliferation of commercial, non-medical (also known as 'keepsake') prenatal ultrasound, which further propagates the effects of the "technological imperative" in prenatal care [29,30]. Therefore, there seems to be a culture of technology uptake among patients and healthcare providers alike, which may directly or indirectly lead to increased utilization of prenatal ultrasound.

Comment on prenatal ultrasound safety

Although the use of diagnostic ultrasound has generally been deemed safe [31], several potential adverse outcomes have been associated with the use of prenatal ultrasound including tissue heating [32,33], low birth weight (in animals) [34,35] and a higher likelihood not being right-handed [36]. There has also been a report of increased exposure to endocrine disrupting chemicals related to the gel used to facilitate the ultrasound exam in pregnant women [37]. It is important to note that the evidence supporting these associations is still scarce, however, the scarcity of evidence to support associations with adverse outcomes should not imply safety. In addition, most of the studies investigating the safety of prenatal ultrasound are more than 20 years old [38], and the acoustic outputs of ultrasound machines are increasing over time which can augment these effects or produce new ones [38–40]. Moreover, higher acoustic intensities can be produced in some situations commonly encountered during pregnancy such as doppler scanning, structures with low perfusion (such as the embryo) and scanning with a full bladder that has an anteroposterior length of >5cm [40]. Therefore, the SOGC continues to recommend the use of prenatal ultrasound under the As Low As Reasonably Achievable (ALARA) principle [38].

Strengths and limitations

The main limitation of the studies of this dissertation is that they involve secondary data analyses of survey responses. Both surveys used (The MES and the LTM III) are cross-sectional in design which may introduce reverse causality. Additionally, self-reported data can introduce information bias in the form of lack of recall or the participants' temptation to present themselves favourably. Moreover, the MES was collected in 2005/2006 and the LTM III data was collected in 2011/2012, and the current characteristics of the Canadian and American populations may be different compared to those at the time of data collection. However, up to my knowledge, these surveys are the only/most recent national databases available that provided details about various aspects of pregnancy, particularly, prenatal ultrasound. Finally, with these surveys, I was also limited with the available variables and may have, therefore, missed several potential confounders. For example, I was not able to control for placental issues and fetal presentation. It is important to note that breech presentation accounts for about 3-5% of pregnancies [41], the prevalence of placenta previa in North America is 2.9 per 1000 pregnancies [42], prevalence of abruption in North America is 7-12 per 1000 pregnancies [43] and the incidence of placenta accreta, increta and percreta in the USA is 3 per 1000 pregnancies [44]. To address the lack of variables that may have played a role in the analyses, birth related factors such as mode of delivery (for objectives 1 and 2), gestational age at birth, birthweight and admission to the intensive care unit were used as proxy for conditions complicating pregnancies that may confound the relationships explored. Moreover, we were not able to address other factors such as different combinations of prenatal care providers, the total number of prenatal care providers, timing of when a new provider joins prenatal care and whether a shared-care model was used during prenatal care. All of these factors were not available in the surveys used in this dissertation and may confound the investigated relationships.

Despite the above limitations, these studies utilized two nationally representative databases making the findings of these studies generalizable to pregnant women in Canada and the USA. Moreover, these studies tackled an underexplored field and contributed to filling some of the knowledge gaps in this area.

Implications and future directions

Despite its clinical and economic implications, prenatal ultrasound utilization as a field has not been extensively assessed. These studies raise awareness about some of the factors that are associated with prenatal ultrasound utilization in Canada and the USA, and may encourage researchers to delve deeper into the epidemiology of prenatal ultrasounds using different settings, databases and research techniques. These studies also establish a baseline of factors related to prenatal ultrasound utilization in Canada and the USA that future studies can build upon. The findings of this dissertation are preliminary and need to be replicated and further explored before any significant action aimed at reducing overutilization can take place. Nevertheless, when taken within the context of unnecessary ultrasounds, the findings of this dissertation may help optimize the utilization of prenatal ultrasound in Canada and the USA, perhaps by informing efforts aimed at decreasing overutilization and/or by educating prenatal care providers about the potential adverse outcomes (i.e. CD) that may arise from it.

Future studies can aim to replicate these findings and/or explore these relationships in different regions of the world, since differences in obstetrical practice philosophies and cultural variations may influence them. Future studies can also investigate these relationships using different databases that may allow for better control over confounding variables, to truly isolate 'overutilization' and study the factors that may play a role in it. Provider characteristics and their influence on prenatal ultrasound utilization is also an area that can be targeted by future studies. Moreover, the mechanisms mediating the effect of parity on the relationship between prenatal ultrasound utilization and caesarean delivery need further study. Future studies can also investigate the relationship between single/multiple prenatal care providers and prenatal ultrasound utilization using a more reliable measure of the number of prenatal care providers. Finally, the relationship between single versus multiple providers and the number of prenatal ultrasounds can be further explored while accounting for the different provider combinations, shared-care model versus switching providers, the total number of providers and the timing of when a provider joins prenatal care.

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APPENDIX A

Factors that put a pregnancy at risk

This list was compiled based on information provided by the National Institute of Child Health and Human Development (a part of the National Institutes of Health in the USA) [1], the Mayo clinic [2] and the Merck Manuals [3].

Existing Health Conditions

- High blood pressure
- Polycystic ovary syndrome
- Heart disease
- Diabetes
- Kidney disease
- Autoimmune disease
- Breathing problems
- Blood disorders
- Thyroid disease
- Multiple abdominal surgeries
- Infertility
- Obesity
- HIV/AIDS
- Psychiatric illness
- Advanced maternal age
- Teen pregnancy
- First-time pregnancy after age 35

Lifestyle Factors

- Alcohol use
- Cigarette smoking
- Illegal drugs
- Group B streptococcal information

Previous Pregnancy conditions

- Multiple previous caesarean sections or uterine surgeries
- Stillbirth
- Rh incompatibility
- Late abortion
- Post-term pregnancy
- Preterm newborn
- Intrauterine growth restriction
- Abnormal fetal position
- Polyhydraminios
- Previous brachial plexus injury
- Preterm premature rupture of membranes

- Conditions of Pregnancy
- Multiple gestation
- Gestational diabetes
- Preeclampsia and eclampsia
- Placental abnormalities
- Abnormal presentation
- Fetal bradycardia and tachycardia
- Fetal weight < 2.5 Kg or > 4 Kg
- Fetal acidosis

Current pregnancy complications

- Placental abnormalities
- Fetal growth restriction
- Rh sensitization
- Multiple gestation

Anatomic abnormalities

- Uterine malformation
- Incompetent cervix

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APPENDIX B

Indications for prenatal ultrasound

This list was compiled based on information from Obtained from the American Institute of Ultrasound in Medicine in 2013 [1].

First-trimester ultrasound:

- Confirmation of the presence of an intrauterine pregnancy
- Evaluation of a suspected ectopic pregnancy
- Defining the cause of vaginal bleeding
- Evaluation of pelvic pain
- Estimation of gestational (menstrual) age
- Diagnosis or evaluation of multiple gestations
- Confirmation of cardiac activity
- Imaging as an adjunct to chorionic villus sampling, embryo transfer, and localization and removal of an intrauterine device
- Assessing for certain fetal anomalies, such as anencephaly, in high-risk patients
- Evaluation of maternal pelvic masses and/or uterine abnormalities
- Measuring the nuchal translucency when part of a screening program for fetal aneuploidy
- Evaluation of a suspected hydatidiform mole.

- Second- and third-trimester ultrasound:
    - Screening for fetal anomalies
    - Evaluation of fetal anatomy
    - Estimation of gestational (menstrual) age
    - Evaluation of fetal growth
    - Evaluation of vaginal bleeding
    - Evaluation of abdominal or pelvic pain
    - Evaluation of cervical insufficiency
    - Determination of fetal presentation
    - Evaluation of suspected multiple gestation
    - Adjunct to amniocentesis or other procedure
    - Evaluation of a significant discrepancy between uterine size and clinical dates
    - Evaluation of a pelvic mass
    - Evaluation of a suspected hydatidiform mole
    - Adjunct to cervical cerclage placement
    - Suspected ectopic pregnancy
    - Suspected fetal death
    - Suspected uterine abnormalities
    - Evaluation of fetal well-being
    - Suspected amniotic fluid abnormalities
    - Suspected placental abruption

- Adjunct to external cephalic version
- Evaluation of premature rupture of membranes and/or premature labor
- Evaluation of abnormal biochemical markers
- Follow-up evaluation of a fetal anomaly
- Follow-up evaluation of placental location for suspected placenta previa
- History of previous congenital anomaly
- Evaluation of the fetal condition in late registrants for prenatal care
- Assessment for findings that may increase the risk for aneuploidy

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