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Predictors of tetanus, diphtheria, acellular pertussis and influenza vaccination during pregnancy among full-term deliveries in a medically underserved population

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ABSTRACT

Objective: To evaluate predictors of vaccination among women who received tetanus, diphtheria, and acellular pertussis vaccination (Tdap), influenza vaccination, and Tdap and influenza vaccinations.
Study Design: In a retrospective cohort study of all full-term (≥37 weeks gestation) deliveries between July 1, 2016 and June 30, 2018 at a single, safety-net institution, we used multinomial logistic regression models to compare predictors of vaccination among women who received Tdap only, influenza only, and both Tdap and influenza vaccines.
Results: Among 3132 full-term deliveries, women were primarily non-Hispanic black (67.5%), between the ages of 21–34 (65.3%), and multiparous (76.0%). The rates of only influenza or Tdap vaccination were 10.3% and 21.6%, respectively; 43.3% of women received both vaccines, and 24.9% of women did not receive either vaccine. In the adjusted models, Hispanic ethnicity was positively associated with receipt of all types of vaccination and non-Spanish language interpreter use was positively associated with receipt of Tdap vaccination and Tdap and influenza vaccination. A parity of greater than three and inadequate and unknown prenatal care adequacy were negative predictors of all types of vaccination. Pre-existing hypertension was negatively associated with Tdap vaccination, and HIV-positive status was negatively associated with influenza vaccination and Tdap and influenza vaccination.
Conclusion: Compared to the national rate of both Tdap and influenza vaccination (32.8%), a higher proportion of women received both vaccines in our study population. Vaccine uptake may be affected by race/ethnicity, use of interpreter services, parity, pre-existing comorbidities, and prenatal care adequacy. The lower rate of influenza vaccination compared to Tdap vaccination suggests that other factors, such as vaccine hesitancy and mistrust, may be differentially impacting influenza vaccination uptake in our predominantly minority population. Future provider and public health approaches to vaccine promotion should incorporate culturally appropriate strategies that address vaccine-related beliefs and misconceptions.

1. Background

Pregnant women and their infants have an elevated risk of developing pertussis and severe influenza infection compared to the general population [1–3]. The highest rates of hospitalization and death due to pertussis are among newborns under two months of age, before they are able to get vaccinated [1]. Annual surveillance reports since 2000 show that among pertussis cases, 80% of hospitalizations and 90% of deaths occur in infants under one [4]. Further, during recent outbreaks, attack rates among newborns less than six months of age were almost twenty times higher than attack rates among the general population [5]. Pregnant women with influenza have higher rates of hospital admissions [6,7] and are more likely to be admitted to intensive care units compared to non-pregnant women [8–10].

The Centers for Disease Control and Prevention (CDC) and American College of Obstetricians and Gynecologists (ACOG) both recommend that women receive the Tdap vaccine between 27 and 36 weeks gestation of each pregnancy to provide optimal

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protection to newborns [11]. However, Tdap vaccination rates remain low- in 2016, only 48.8% of pregnant patients with a live birth had received the Tdap vaccination during their pregnancy [2]. Influenza vaccination rates also remained low at 35.6% in 2017 [12], despite the recommendation by both CDC [13] and ACOG [14] for routine influenza vaccination of pregnant women during all trimesters.

Even though the timing for Tdap vaccination is more restrictive than the influenza vaccination, Tdap vaccination rates are marginally higher than those of influenza vaccination. Some prior studies attribute the lower rate of influenza uptake to greater distrust in the influenza vaccine as a result of skepticism surrounding vaccine efficacy, especially among African American mothers [15–17]. Pregnant women may also be more likely to refuse influenza vaccination [17] due to the perception that the influenza vaccine provides self-protection, while the Tdap vaccine protects the baby [18]. Additionally, influenza vaccination rates may be lower due to misconceptions surrounding the safety and side-effects of the vaccine [17,19], and low perceived susceptibility to influenza [19].

Other factors associated with Tdap and influenza vaccine refusal in pregnancy include young maternal age [15,20], absence of public insurance [21], black race [15,16,19,20,22], and lack of provider recommendation [17,20,23]. A recent study has also suggested that pregnant women are more likely to accept the Tdap vaccine if they had already received the influenza vaccine [24].

Several studies have looked at predictors of influenza and Tdap vaccinations separately, however, none have systematically compared differences in predictors of receipt of either or both of the vaccines, particularly in a predominantly non-Hispanic black population with high levels of medical mistrust. The objectives of the current study are to determine the predictors of Tdap vaccination, influenza vaccination, and both Tdap and influenza vaccination in a medically underserved population of women at Grady Memorial Hospital. Our primary hypothesis is that the influenza vaccination rate in our population will be lower than the rate of Tdap vaccination because of differences in perceptions of Tdap and influenza vaccinations.

2. Materials and methods

We conducted a retrospective cohort study of pregnant women who delivered at Grady Memorial Hospital under the supervision of Emory University clinicians. Grady Memorial Hospital is a large public hospital in Atlanta, Georgia that offers medical care to a diverse patient population, including many individuals who are indigent, underinsured, or uninsured [25]. All women who delivered between July 1, 2016 and June 30, 2018 were included.

Two data sources were used to identify all women with deliveries during the study period- the Emory Medical Care Foundation database and a delivery record maintained in the labor and delivery suite. Delivery was defined as the birth of one or more fetuses after 20 weeks of gestation, regardless of the viability of the fetus. Medical record numbers corresponding to a patient without a delivery, deliveries outside of the study period, and deliveries attended by non-Emory University providers at Grady Memorial Hospital were excluded.

Medical charts for identified patients were each reviewed for demographic information, including age, race, ethnicity, language and use of interpretive services, insurance status, education, and zip code of residence. Clinical characteristics including history of chronic diseases, parity, and prior obstetrical history were abstracted. Information about all clinical encounters in the current pregnancy (e.g. prenatal care visits, triage visits, hospital admissions) and prenatal care adequacy were also recorded. Prenatal care adequacy was defined using the Kotelchuck Index or Adequacy of Prenatal Care Utilization (APNCU) Index [26,27]. Prenatal care was defined as "unknown" if patients received some or all prenatal care outside of Grady Health System, which prohibited quantification of adequacy of care with the Kotelchuck index. Study data were collected and managed using Research Electronic Data Capture (REDCap) electronic data capture tools hosted at Emory University [28].

Influenza vaccination was defined as electronically documented receipt of influenza vaccine that occurred from twelve months before delivery to the delivery date. This time period was chosen to capture both women who received an influenza vaccine before pregnancy for the season in which they were pregnant and women who received the vaccine while pregnant. Receipt of influenza vaccine was captured in the EHR in three ways: vaccines given within Grady Health System, vaccines received in the state of Georgia reported to the Georgia Registry of Immunization Transactions and Services, and vaccines self-reported by patients to their prenatal care provider documented in a prenatal care note. Tdap vaccination was defined as electronically documented receipt of Tdap vaccine during 27–36 weeks of gestation. Tdap vaccinations occurring before pregnancy, outside of the vaccination window, or immediately after delivery were documented as 'no Tdap' because of current CDC and ACOG recommendations for timing of the vaccine [13,14]. Receipt of Tdap vaccine was captured in the EHR in two ways: vaccines given within Grady Health System and vaccines received in the state of Georgia reported to the Georgia Registry of Immunization Transactions and Services.

The rate of influenza vaccination in the pregnant population was calculated by dividing the number of influenza vaccinations in our sample by the number of deliveries after 37 weeks of gestation. The rate of Tdap vaccination in the pregnant population was calculated by dividing the number of Tdap vaccinations in our sample by the number of deliveries after 37 weeks of gestation. Deliveries prior to 37 weeks of gestation were excluded from analysis in order to allow all women the opportunity to receive vaccination during the recommended vaccination window [29].

To identify predictors of prenatal Tdap only, influenza only, and both Tdap and influenza vaccination, multinomial logistic regression models were used to estimate unadjusted and adjusted odds ratios (aOR), as well as corresponding 95% confidence intervals (CIs). Binomial logistic regression models were used to estimate adjusted odds ratios and 95% CIs for the association between influenza vaccination (predictor) and Tdap (outcome). All models were adjusted for maternal age, smoking during pregnancy, race/ethnicity, parity, prenatal care adequacy, and prior history of chronic medical conditions (asthma, HIV, diabetes, hypertension, obesity). These factors were selected *a priori* for inclusion as they have been previously identified in the literature as predictors of maternal vaccination. P values of < 0.05 were considered statistically significant. Multicollinearity of the predictors was assessed using variation inflation factor and tolerance. Statistical analyses were conducted using Statistical Analysis Software (SAS) (SAS Institute Inc., Cary, NC), version 9.4.

The study was approved by the institutional review board at Emory University and the Grady Research Oversight Committee.

3. Results

From July 1, 2016 to June 30, 2018, we identified 3723 women with a delivery to Emory providers at Grady Memorial Hospital. Our final analytic cohort for the analysis of vaccination predictors consisted of 3132 women with a delivery after 37 weeks of gestation. As shown in Table 1, approximately 65% of our sample were between the ages of 21–34, 67% were non-Hispanic black, and 76% were multiparous. Among the women who were reported

Table 1
Demographic and clinical characteristic cs of pregnancies for full-term deliveries, July 1, 2016 – June 30, 2018.

	Total study population n = 3132	No Tdap or Flu vaccines n = 780 (24.90%)	Flu only n = 321 (10.25%)	Tdap only n = 676 (21.58%)	Both Flu & Tdap vaccines n = 1,355 (43.26%)
Age at delivery					
<21	631 (20.15)	183 (23.46)	67 (20.87%)	140 (20.71)	241 (17.79)
21–34	2044 (65.26)	492 (63.08)	213 (66.36)	432 (63.91)	907 (66.94)
>34	457 (14.59)	105 (13.46)	41 (12.77)	104 (15.38)	207 (15.28)
Race/ethnicity					
Non-Hispanic white	81 (2.62)	27 (3.52)	11 (3.45)	14 (2.09)	29 (2.16)
Non-Hispanic black	2089 (67.45)	615 (80.08)	226 (70.85)	471 (70.30)	777 (57.99)
Non-Hispanic other	198 (6.38)	32 (4.17)	14 (4.39)	44 (6.57)	108 (8.06)
Hispanic	729 (23.54)	94 (12.24)	68 (21.32)	141 (21.04)	426 (31.79)
Interpreter Use					
None	2362 (75.42)	675 (86.54)	253 (78.82)	506 (74.85)	928 (68.49)
Spanish	506 (16.16)	60 (7.69)	43 (13.40)	105 (15.53)	298 (21.99)
Other language	264 (8.43)	45 (5.77)	25 (7.79)	65 (9.62)	129 (9.52)
Parity					
0	750 (23.95)	185 (23.75)	84 (26.17)	171 (25.30)	310 (22.88)
1	236 (7.54)	40 (5.13)	27 (8.41)	62 (9.17)	107 (7.90)
2	775 (24.75)	179 (22.98)	77 (23.99)	160 (23.67)	359 (26.49)
3 or more	1370 (43.76)	375 (48.14)	133 (41.43)	283 (41.86)	579 (42.73)
Chronic medical conditions					
Hypertension	229 (7.31)	59 (7.56)	22 (6.85)	37 (5.47)	111 (8.19)
Diabetes Mellitus	65 (2.08)	11 (1.41)	8 (2.49)	8 (1.18)	38 (2.80)
Asthma	274 (8.75)	82 (10.51)	32 (9.97)	54 (7.99)	106 (7.82)
HIV+	63 (2.01)	21 (2.69)	3 (0.93)	14 (2.07)	25 (1.85)
Tobacco use in pregnancy	313 (10.23)	113 (14.75)	33 (10.58)	63 (9.50)	104 (7.89)
Prenatal care					
Unknown	468 (14.97)	280 (36.04)	50 (15.63)	71 (10.50)	67 (4.95)
Inadequate	1344 (42.98)	379 (48.78)	142 (44.38)	306 (45.27)	517 (38.18)
Intermediate	515 (16.47)	56 (7.21)	53 (16.56)	114 (16.86)	292 (21.57)
Adequate	638 (20.40)	52 (6.69)	59 (18.44)	150 (22.19)	377 (27.84)
Adequate plus	162 (5.18)	10 (1.29)	16 (5.00)	35 (5.18)	101 (7.46)
Primary insurance type					
Self-pay	199 (6.35)	75 (9.62)	23 (7.17)	37 (5.47)	64 (4.72)
Medicare/Medicaid	2771 (88.47)	659 (84.49)	285 (88.79)	607 (89.79)	1220 (90.04)
Commercial	162 (5.17)	46 (5.90)	13 (4.05)	32 (4.73)	71 (5.24)

Influenza vaccination was defined as documented administration of influenza vaccine in the Grady Health System EHR, the Georgia Registry of Immunization Transactions and Services, or self-reported receipt of influenza vaccine within the time frame of twelve months before delivery and the delivery date. Tdap vaccination was defined as documented administration of influenza vaccine in the Grady Health System HER or the Georgia Registry of Immunization Transactions and Services between 27 and 36 weeks gestation. Data are unadjusted odd ratio (95% confidence interval), and adjusted odds ratio (95% confidence interval. Other, non-Hispanic race/ethnicity includes Asian, Hawaiian/other Pacific Islander, Native American, and multiracial.

being born outside of the United States, Mexico, Guatemala, and Ethiopia were the most common countries of origin (data not shown). Approximately 23% of the study population were Hispanic, and Spanish was the most common language requiring an interpreter. Very few women had history of diabetes mellitus and HIV, while approximately 7% had hypertension and 9% had a history of asthma. Ten percent of women reported using tobacco products during pregnancy. Medicare and Medicaid were the payers for the majority of deliveries (88%).

In our study population, the total rates of only influenza vaccination or Tdap vaccination were 10.3% and 21.6%, respectively; the overall rate of Tdap vaccination (64.9%) was higher than the overall rate of influenza vaccination (53.5%). The rate of both Tdap and influenza vaccination was 43.3%, and 24.9% of women did not receive Tdap or influenza vaccines. Among non-Hispanic black women, 29.4% did not receive Tdap or influenza vaccination.

In adjusted multivariable regression analyses, women who received the influenza vaccine were 3.6 (95% CI: 3.0–4.3) times more likely to also receive the Tdap vaccine (data not shown). As shown in Table 2, Hispanic race/ethnicity was generally associated with increased odds of influenza vaccination and Tdap vaccination. Non-Hispanic other race/ethnicity was positively associated with receipt of both Tdap and influenza vaccinations. Women who used interpreter services for a language other than Spanish had significantly higher odds of Tdap vaccination only and both Tdap and influenza vaccination. A parity greater than three was negatively associated with receipt of antenatal Tdap and influenza vaccination. HIV+ status was negatively associated with influenza vaccination only and both Tdap and influenza vaccination. Women who had pre-existing hypertension had significantly lower odds of Tdap vaccination only. Women with inadequate prenatal care and women with unknown prenatal care adequacy had lower odds of antenatal influenza and Tdap vaccination. No statistically significant linear relationships between predictors were detected.

4. Discussion

The rate of both antenatal Tdap and influenza vaccination (43.3%) in our study population was higher than the national rate reported by the CDC in the 2017–2018 influenza season, which was roughly 32.8%. This higher rate of vaccination may be related to practices in place at Grady including universal provider recommendation of Tdap and influenza vaccination with standing orders, maintaining clinic stock of both vaccines, and provision of both vaccinations at no additional cost to patients.

Our finding that Hispanic ethnicity was associated with increased odds of antenatal Tdap vaccination builds upon previously reported data which found that women who accepted the Tdap vaccine were more likely to be Hispanic, compared to non-Hispanic black and white women [30]. Conversely, a retrospective cohort study of pregnant women enrolled in Medicaid found that

Table 2
Relative odds of Tdap and Influenza immunization during pregnancy for full-term deliveries by selected demographic characteristics, clinical characteristics, prenatal care adequacy, and insurance status.

	Flu unadjusted odds ratio (95% CI)	Tdap unadjusted odds ratio (95% CI)	Tdap & Flu unadjusted odds ratio (95% CI)	Flu adjusted odds ratio (95% CI)	Tdap adjusted odds ratio (95% CI)	Tdap & Flu adjusted odds ratio (95% CI)
Age at delivery						
<21	0.85 (0.61–1.17)	0.87 (0.68–1.13)	0.71 (0.57–0.89)	0.72 (0.49–1.06)	0.80 (0.59–1.08)	0.76 (0.58–1.01)
21–34	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
>34	0.90 (0.61–1.34)	1.13 (0.84–1.52)	1.07 (0.83–1.39)	1.02 (0.67–1.55)	1.25 (0.90–1.74)	0.99 (0.73–1.34)
Race/ethnicity						
Non-Hispanic white	1.11 (0.54–2.27)	0.68 (0.35–1.31)	0.85 (0.50–1.45)	1.28 (0.59–2.76)	0.85 (0.43–1.72)	1.16 (0.64–2.13)
Non-Hispanic black	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
Non-Hispanic other	1.19 (0.62–2.27)	1.80 (1.21–2.88)	2.67 (1.78–4.02)	0.97 (0.47–1.99)	1.30 (0.76–2.24)	1.85 (1.13–3.02)
Hispanic	1.97 (1.39–2.79)	1.96 (1.47–2.61)	3.59 (2.80–4.59)	1.75 (1.18–2.60)	1.50 (1.08–2.09)	2.76 (2.06–3.70)
Interpreter Use						
None	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
Spanish	1.91 (1.26–2.90)	2.33 (1.67–3.27)	3.61 (2.69–4.85)	1.03 (0.55–1.91)	1.53 (0.91–2.58)	1.44 (0.91–2.28)
Other language	1.48 (0.89–2.47)	1.93 (1.30–2.87)	2.09 (1.46–2.97)	1.34 (0.78–2.30)	1.67 (1.09–2.57)	1.88 (1.26–2.79)
Parity						
0	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
1	1.49 (0.86–2.56)	1.68 (1.07–2.62)	1.60 (1.06–2.39)	1.20 (0.67–2.17)	1.37 (0.84–2.23)	1.35 (0.86–2.14)
2	0.95 (0.65–1.37)	0.97 (0.72–1.30)	1.20 (0.93–1.55)	0.87 (0.58–1.29)	0.82 (0.59–1.13)	1.07 (0.80–1.43)
3 or more	0.78 (0.56–1.08)	0.82 (0.63–1.06)	0.92 (0.74–1.15)	0.64 (0.44–0.95)	0.65 (0.48–0.89)	0.73 (0.55–0.97)
Chronic Medical Conditions						
Hypertension	0.90 (0.54–1.50)	0.71 (0.46–1.08)	1.09 (0.79–1.52)	0.69 (0.40–1.20)	0.53 (0.33–0.86)	0.83 (0.56–1.23)
Diabetes Mellitus	1.79 (0.71–4.48)	0.84 (0.33–2.09)	2.02 (1.03–3.97)	2.01 (0.76–5.32)	0.93 (0.35–2.48)	1.85 (0.84–4.08)
Asthma	0.94 (0.61–1.45)	0.74 (0.52–1.06)	0.72 (0.53–0.98)	1.04 (0.66–1.63)	0.79 (0.53–1.16)	0.89 (0.63–1.25)
HIV	0.34 (0.10–1.15)	0.76 (0.39–1.52)	0.68 (0.38–1.22)	0.24 (0.07–0.85)	0.49 (0.24–1.04)	0.43 (0.22–0.85)
Tobacco use in pregnancy	0.68 (0.45–1.03)	0.61 (0.44–0.84)	0.50 (0.37–0.66)	0.85 (0.55–1.31)	0.78 (0.55–1.12)	0.75 (0.54–1.03)
Prenatal care						
Unknown	0.16 (0.10–0.25)	0.09 (0.06–0.13)	0.03 (0.02–0.05)	0.15 (0.09–0.24)	0.09 (0.06–0.13)	0.04 (0.02–0.05)
Inadequate	0.33 (0.22–0.50)	0.28 (0.20–0.40)	0.19 (0.14–0.26)	0.35 (0.23–0.53)	0.30 (0.21–0.43)	0.20 (0.15–0.29)
Intermediate	0.83 (0.49–1.42)	0.71 (0.45–1.11)	0.72 (0.48–1.08)	0.83 (0.48–1.42)	0.68 (0.43–1.07)	0.72 (0.47–1.09)
Adequate	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*
Adequate plus	1.41 (0.60–3.38)	1.21 (0.56–2.62)	1.39 (0.68–2.84)	1.45 (0.59–3.59)	1.40 (0.63–3.10)	1.40 (0.67–2.91)
Primary Insurance						
Self-pay	1.09 (0.50–2.35)	0.71 (0.39–1.29)	0.55 (0.34–0.91)	1.53 (0.68–3.40)	0.97 (0.51–1.84)	0.97 (0.55–1.73)
Medicaid/ Medicare	1.53 (0.81–2.88)	1.32 (0.83–2.11)	1.20 (0.82–1.76)	1.42 (0.74–2.73)	1.24 (0.75–2.04)	1.17 (0.74–1.83)
Private	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*	*Ref*

Influenza vaccination was defined as documented administration of influenza vaccine in the Grady Health System EHR, the Georgia Registry of Immunization Transactions and Services, or self-reported receipt of influenza vaccine within the time frame of twelve months before delivery and the delivery date. Tdap vaccination was defined as documented administration of influenza vaccine in the Grady Health System HER or the Georgia Registry of Immunization Transactions and Services between 27 and 36 weeks gestation.
Data are unadjusted odd ratio (95% confidence interval), and adjusted odds ratio (95% confidence interval. Other, non-Hispanic race/ethnicity includes Asian, Hawaiian/other Pacific Islander, Native American, and multiracial.

there were no significant differences in rates of Tdap between non-Hispanic white and Hispanic women [31]. However, this study included infants delivered prior to 36 weeks gestation, which limits its direct comparison to our study findings. Additionally, our study population is primarily African American women with only a small subset of white women, making direct comparison difficult due to community-level differences that can contribute to differing rates of vaccination.

We also examined use of interpreter services in our study population because prior research has demonstrated that the language barriers, indicated by the need for interpreter services, have varying effects on access to healthcare across race and ethnicity groups [32–34]. Our finding that use of non-Spanish language interpreter services was positively associated with Tdap vaccination only and Tdap and influenza vaccinations is novel. This builds upon prior studies that have demonstrated that interpreter use during a medical visit is associated with greater acceptance of provider recommendations [34]. Although one prior study in an Australia found that antenatal vaccination rates are higher among English and Spanish speaking women, and English as a second language negatively predicted antenatal vaccination, this study was conducted in an Australian population that was majority Caucasian, therefore limiting a direct comparison to our study results [35]. Our findings likely reflect the large immigrant and foreign-born population seeking prenatal care at Grady [25].

According to a 2018 retrospective cross-sectional study, patients who were willing to get the influenza vaccine were more open to receiving other preventive vaccinations [24]; our results provide further support for this finding. Even with a much smaller vaccination window for Tdap, between 27 and 36 weeks of gestation, rates of Tdap vaccination in our study population were much higher than influenza vaccination. This could be due to differences in vaccine hesitancy related to the two vaccines.

Specifically, there is some evidence that women perceive the influenza vaccine as being unsafe during pregnancy [19] and may be more willing to receive the Tdap vaccine than the influenza vaccine [17] because pertussis is perceived as more serious during pregnancy [1]. Additionally, there may be a tendency by providers

to emphasize the importance of influenza vaccination for maternal protection while Tdap vaccination is promoted primarily for infant protection [18]. This, combined with the perception that pertussis poses a greater risk to the baby, may explain greater uptake of Tdap vaccination [18].

Furthermore, prior research on trust and maternal vaccination has shown that people are less likely to trust in the influenza vaccine [17] than the Tdap vaccine [16] because of skepticism surrounding the efficacy of the influenza vaccine [16,17,19]. Although provider recommendations can be an important influencing factor for patients to accept vaccines [17], level of trust in healthcare providers also differs by race and ethnicity [16]. Prior studies have found that, compared with non-Hispanic white patients, non-Hispanic black patients are more skeptical of vaccinations, especially the influenza vaccine [36], and their own healthcare providers [37]. African Americans may have greater medical distrust as a result of personal and historical experiences of discrimination and racial biases [16]. While recommending influenza vaccination during pregnancy, healthcare providers should be conscious of vaccine hesitancy, and address misinformation and negative perceptions about the influenza vaccination in culturally appropriate ways [37–39].

A key limitation of our study was that we were unable to determine prenatal care adequacy for roughly 15% of the patients in our population because these women received prenatal care from providers outside of Grady Health System. We found that these women had significantly lower vaccination rates compared to women with adequate prenatal care. It is possible that transferring prenatal care might be a unique negative predictor of antenatal vaccination and/or women who received care at multiple sites might be less likely to receive adequate prenatal care; however, there is currently a gap in the literature to support these hypotheses. Other limitations of our study include that interpretation of provider offer of vaccination was limited by documentation in EHR. Additionally, due to the nature of our data, we were not able to examine or control for social determinants of health that were not regularly documented in the EHR.

Strengths of our study include examining a large cohort of medically underserved pregnant patients where the majority are insured by Medicaid and Medicare. We were also able to account for influenza vaccination in three distinct ways, including EHR documentation, Georgia Registry of Immunization Transactions and Services documentation, and self-report of vaccination. Additionally, we sought to reduce the potential for immortal time bias by excluding deliveries prior to 37 weeks of gestation. Antenatal Tdap vaccination studies are susceptible to immortal time bias as a result of the recommendation window for the vaccine. Although most studies include all births after 20 weeks in their analysis, Tdap vaccination is not offered until 27–36 weeks, and pregnancies must reach the vaccination window of 27–36 weeks in order to receive the vaccine. The time before Tdap vaccination is "immortal" because women that deliver prior to 27–36 weeks would not have been offered the Tdap vaccination [29].

The disparity in influenza versus Tdap coverage in our medically underserved population suggests that other factors, such as vaccine hesitancy and mistrust, may be differentially impacting influenza vaccination uptake and that culturally appropriate strategies for addressing vaccine hesitancy are needed. Given that attending regular prenatal care visits increases the likelihood that vaccinations are offered or recommended by the provider and accepted by the patient, barriers to accessing adequate prenatal care-including transportation, insurance status, and lack of social support, should continue to be examined and addressed, especially among medically underserved patient populations [40,41].

Counseling, recommending, and offering vaccinations should be prioritized by providers at prenatal care visits in order to lower the impact of barriers among women with infrequent prenatal care visits. Providers should consider using presumptive messaging when offering vaccinations, rather than participatory messaging, because presumptive messaging has been associated with increased acceptance of vaccination [42]. Presumptive messaging, such as saying 'you are due for your influenza vaccination today,' biases patient answers towards vaccination by assuming acceptance of the vaccination [42]. Additionally, in cases where patients initially refuse vaccination providers should provide counseling with information and reassurance about antenatal vaccination [42,43]. All approaches to increasing antenatal vaccination should be considered with input from public health program stakeholders and prenatal care providers in order to identify and overcome barriers to vaccination among pregnant women [25].

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2019.08.044.

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