Original Research

Safety of Tetanus Toxoid, Reduced Diphtheria Toxoid, and Acellular Pertussis and Influenza Vaccinations in Pregnancy

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OBJECTIVE: To evaluate the safety of coadministering tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis (Tdap) and influenza vaccines during pregnancy by comparing adverse events after concomitant and sequential vaccination.

METHODS: We conducted a retrospective cohort study of pregnant women aged 14–49 years in the Vaccine Safety Datalink from January 1, 2007, to November 15, 2013. We compared medically attended acute events (fever, any acute reaction) and adverse birth outcomes (preterm delivery, low birth weight, small for gestational age) in women receiving concomitant Tdap and influenza vaccination and women receiving sequential vaccination.

RESULTS: Among 36,844 pregnancies in which Tdap and influenza vaccines were administered, the vaccines were administered concomitantly in 8,464 (23%) pregnancies and sequentially in 28,380 (77%) pregnancies. Acute adverse events after vaccination were rare. We found no statistically significant increased risk of fever or any medically attended acute adverse event in pregnant women vaccinated concomitantly compared with sequentially. When analyzing women at 20 weeks of gestation or greater during periods of influenza vaccine administration, there were no differences in preterm delivery, low-birth-weight, or small-for-gestational-age neonates between women vaccinated concomitantly compared with sequentially in pregnancy.

CONCLUSION: Concomitant administration of Tdap and influenza vaccines during pregnancy was not associated with a higher risk of medically attended adverse acute outcomes or birth outcomes compared with sequential vaccination.

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Inactivated influenza vaccine is recommended at any time during pregnancy to protect pregnant women and their neonates from the complications of influenza infection,[1] and more recently, tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis (Tdap) vaccine

has been recommended during pregnancy with a preference for administration between 27 and 36 weeks of gestation to maximize maternal antibody response and transfer to the neonate.[2] The safety and benefits of influenza vaccination during pregnancy have been well studied.[3–6] Vaccination during pregnancy decreases morbidity in the pregnant women and also protects the neonates from disease caused by influenza infection. Recently, a few studies have shown that the Tdap vaccine is safe in pregnancy,[7–10] and others have shown effectiveness in decreasing the burden of pertussis in neonates.[11,12]

Studies evaluating the safety of coadministering Tdap and influenza vaccines in nonpregnant individuals have not found an increased risk of adverse events when compared with sequential vaccination.[13,14] Given the likelihood that concomitant vaccination will occur in pregnancies that overlap with the influenza season, and the potential for different responses to vaccinations in pregnant women compared with nonpregnant individuals,[15] we evaluated whether there was an increased risk of medically attended acute events or adverse birth outcomes when Tdap and influenza vaccines are administered concomitantly during pregnancy.

MATERIALS AND METHODS

We conducted a retrospective cohort study using data from the Vaccine Safety Datalink to assess the safety of concomitant Tdap and influenza vaccine administration in pregnancies ending in live births by evaluating medically attended acute events and adverse birth outcomes in women who received Tdap and influenza vaccines on the same day compared with different days (sequentially) in pregnancy.

The Vaccine Safety Datalink is a collaborative project between the Centers for Disease Control and Prevention and nine integrated health care organizations with an annual birth cohort of approximately 90,000 per year.[16] For this study, seven Vaccine Safety Datalink sites contributed data: Group Health Cooperative (Washington), Kaiser Permanente Northwest (Oregon) and (Washington), Kaiser Permanente Northern California (California), Southern California Kaiser Permanente (California), HealthPartners (Minnesota), Marshfield Clinic (Wisconsin), and Kaiser Permanente Colorado (Colorado).

We identified pregnancies ending in live births between January 1, 2007, and November 15, 2013, using a validated algorithm[17] used in prior Vaccine Safety Datalink pregnancy studies.[3,4] This pregnancy episode algorithm uses claims, administrative, and birth data to identify pregnancies and their associated outcomes and dates.

We included pregnant women aged 14–49 years who received Tdap and influenza vaccines during pregnancy and had continuous insurance coverage from 6 months before pregnancy to 6 weeks postpartum with no greater than a 30-day gap in enrollment. We excluded women who received any live vaccines in pregnancy, those with multiple gestations, and those with nonlive birth outcomes, including stillborn, spontaneous abortion, therapeutic abortion, trophoblastic disease, and ectopic pregnancy, because we did not access medical records to confirm these outcomes and their onset dates. Additionally, we excluded women who received more than one tetanus containing vaccine (including multiple Tdap vaccines) in the same pregnancy and women who received more than one influenza vaccine (seasonal influenza and H1N1 influenza or multiple seasonal influenza vaccines) on different days in the same pregnancy to limit our comparisons to women with a single influenza vaccination date and a single tetanus vaccination date. For example, a woman who received a seasonal influenza vaccine and an H1N1 influenza vaccine on the same day would be included in the cohort, but if she received these vaccines on different days, she would be excluded. Women may have received multiple vaccinations of the same strain during pregnancy in cases in which a pregnancy spanned two different influenza vaccination seasons (ie, February and September of the same calendar year) or in cases of health care provider error.

We identified Tdap and influenza vaccinations administered during pregnancy using electronic medical record and claims data. We defined a vaccine administered during pregnancy as one given from 7 days after the last menstrual period through 7 days before the pregnancy end date. We used these cutoffs to avoid inadvertently including vaccines that might have been given before pregnancy or in the postpartum period.[18]

We compared baseline characteristics between the two cohorts using χ^2 tests for categorical variables and t test for continuous variables. We used a log binomial regression analysis to calculate the relative risks for both rare (acute outcomes) and nonrare (birth outcomes) events. We identified all covariates and medically attended acute events using International Classification of Diseases, 9th Revision, Clinical Modification codes. We adjusted for differences in Vaccine Safety Datalink site and gestational age at Tdap vaccination as a linear covariate when comparing acute events. Additionally, we adjusted for maternal age, the presence of a maternal comorbidity (from 6 months before pregnancy through 30 days postpartum), the

presence of a pregnancy complication, season of delivery, prenatal care utilization,[19] and length of enrollment before pregnancy when comparing birth outcomes. We tested for effect modification by gestational age in weeks at Tdap vaccination for each outcome. All analyses were performed using SAS 9.3.

We compared medically attended acute outcomes (fever, limb pain, limb swelling, cellulitis, lymphadenitis, Arthus reaction, allergy, urticaria, and anaphylaxis) between concomitant and sequential vaccine recipients in the 0–3 and 0–7 days after Tdap and influenza vaccines. Outpatient diagnosis codes on the day of vaccination were excluded, because the diagnosis was likely present before the vaccination. We also compared the risk of incident Guillain-Barré syndrome occurring 1–42 days after vaccination. The day of vaccination was considered day 0. For the group of concomitant vaccine recipients, we examined events in three risk windows after vaccination (0–3, 0–7, and 1–42 days). For the group of sequentially vaccinated women, we examined each of the three windows after both Tdap and influenza vaccination dates. The time windows were allowed to overlap in women receiving vaccinations on separate days.

We compared the following birth outcomes between the groups: preterm delivery (defined as gestational age less than 37 weeks), low birth weight (birth weight less than 2,500 g), and small for gestational age (less than the 10th percentile for gestational age and sex).[20] We had initially planned to perform the analysis on the entire cohort; however, based on further evaluation examining the seasonal differences in influenza vaccine administration and differences in the gestational age at which Tdap vaccine is preferentially administered, we limited our analysis of adverse birth outcomes to women vaccinated during periods of peak influenza vaccine administration (September through January) and vaccinated at 20 weeks of gestation or greater. This allowed us to capture women who had an opportunity to be in either cohort, because they would be eligible for concomitant or sequential vaccination. Additionally, this would address biases associated with the seasonal differences in birth outcomes.[21] Finally, we limited our analysis of birth outcomes to women vaccinated before 37 weeks of gestation so as to not bias our results toward any protective effect of vaccination[22,23] and to pregnancies with known gestational age and birth weight recorded in the electronic health record or linked to the state birth registries.

We performed a priori power calculations and determined that we had 80% or higher power to detect relative risks of greater than 2 for all of our birth outcomes, even with the restricted cohort. However, our analyses for medically attended acute outcomes, which are rare, were underpowered. For this reason, we limited our analysis of acute outcomes to fever and any acute event (37,000 and 10,000 pregnancies needed in each cohort, respectively, to detect a relative risk of 2). We considered results to be statistically significant at an α error less than 0.05 using two-tailed tests. The study protocol was reviewed and approved by institutional review boards at Emory University, the Centers for Disease Control and Prevention, and the seven Vaccine Safety Datalink sites.

RESULTS

During our study period, we identified 633,542 total singleton pregnancies, 443,774 of which ended in live births (Fig. 1). Our final analytic cohorts for the analysis of acute events consisted of 8,464 (23%) pregnancies with concomitant Tdap and influenza vaccine administration and 28,380 (77%) pregnancies with sequential Tdap and influenza vaccine administration. When comparing baseline characteristics, the cohorts were similar in maternal age, enrollment in the health care plan before pregnancy, prenatal care utilization, comorbidities, and the receipt of other vaccinations during pregnancy. Most comparisons were statistically significantly different, but not necessarily clinically relevant, with the exception of gestational age at Tdap and influenza vaccination, which was 25 weeks of gestation (range 1–40 weeks) in the women vaccinated on the same day in pregnancy and 27 weeks of gestation (range 1–41 weeks) for Tdap vaccine and 19 weeks of gestation (range 1–40 weeks) for influenza vaccine for women vaccinated on different days ($P<.001$). Of women vaccinated on different days during pregnancy, the mean number of days between Tdap and influenza vaccines was 94 days with a median of 84 days. The study cohort size for birth outcomes was 4,554 (51%) pregnancies with concomitant Tdap and influenza vaccine administration and 4,440 (49%) with sequential Tdap and influenza vaccine administration. Distribution of baseline characteristics was similar to the full cohort (data not shown).

For the entire cohort of 36,844 vaccinated women, Tdap vaccine was most often administered later in pregnancy (37% in the second trimester, 56% in the third trimester), whereas influenza vaccine was administered relatively evenly throughout pregnancy (34% given in the first trimester, 34% in the second trimester, 32% in the third trimester). Women vaccinated with Tdap and influenza vaccines on different days received influenza vaccine earlier in pregnancy and Tdap vaccine later in pregnancy than women

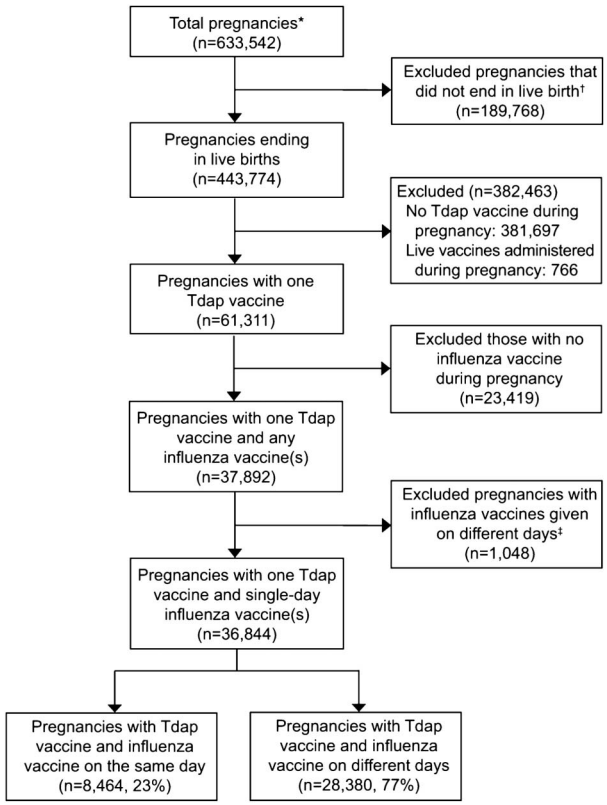

Fig. 1. Pregnant women in the Vaccine Safety Datalink vaccinated with tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis (Tdap) and influenza vaccines in pregnancy: 2007–2013. *Singleton pregnancies. †Nonlive birth includes stillborn, spontaneous abortion, therapeutic abortion, trophoblastic disease, ectopic pregnancy, and unknown outcomes. ‡Women were given either two seasonal influenza vaccinations or a seasonal influenza and H1N1 influenza vaccination on different days in pregnancy.
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vaccinated on the same day in pregnancy. The peak birth year was 2011 for women vaccinated with Tdap and influenza vaccines on the same day (36%) and 2013 for women vaccinated on different days (44%), likely representing changes to the Advisory Committee on Immunization Practices recommendations made emphasizing timing of Tdap vaccination after 2012. Very few vaccinations occurred in the years 2007–2009 (less than 2% of the cohort), when Tdap was not routinely recommended during pregnancy.

There were no differences between women receiving Tdap and influenza vaccines concomitantly compared with sequentially for medically attended fever and any acute event within 3 and 7 days after vaccination (Table 1). Overall, acute adverse events after vaccination were rare. There were no cases of Arthus reaction or Guillain Barrè syndrome after vaccination. There was no interaction between acute adverse events and gestational age at Tdap vaccination (data not shown).

In women who were vaccinated after 20 weeks of gestation during the period of peak influenza vaccination administration, there were no differences in the occurrence of preterm delivery, low-birth-weight, and small-for-gestational-age neonates for women receiving concomitant Tdap and influenza vaccines compared with women vaccinated sequentially (Table 2). There was no interaction between adverse birth outcomes and gestational age at time of Tdap vaccination (data not shown). As a post hoc descriptive analysis of the cohort used to evaluate birth outcomes, we found that, as expected, most deliveries were occurring in the winter months in both concomitantly and sequentially vaccinated women.

DISCUSSION

In our study of pregnant women receiving Tdap and influenza vaccines, we found no significant differences in the risk of medically attended acute outcomes between concomitant and sequential vaccination. Moreover, we found no differences in preterm delivery or low-birth-weight or small-for-gestational-age neonates when Tdap and influenza vaccines were coadministered at 20 weeks of gestation or later during peak influenza vaccine administration.

Our results are similar to randomized studies that have shown no difference in acute events after concomitant and sequential Tdap and influenza vaccination in nonpregnant individuals.[13,14] Both prior studies solicited adverse events from patients, although our study relied on diagnosis codes from medical visits.

Our study is similar to a Vaccine Safety Datalink study evaluating adverse obstetric events and birth outcomes after Tdap vaccine in pregnancy,[10] which included a cohort of pregnant women that overlapped with the women evaluated in our study. There are a few differences between the two studies. First, the prior study compared Tdap-vaccinated women with a cohort of unvaccinated women, whereas we compared two vaccinated cohorts receiving both Tdap and influenza vaccine. Additionally, that study adjusted for the exposure to influenza vaccine, whereas all of our women were exposed. Finally, the prior study used a time-dependent Cox model to evaluate preterm delivery, whereas we used a log binomial model to evaluate preterm delivery. Despite these differences, both studies have similar results, which provides additional reassurance of the safety of Tdap and influenza vaccine in pregnancy.

Table 1. Medically Attended Acute Outcomes After Tetanus Toxoid, Reduced Diphtheria Toxoid, and Acellular Pertussis and Influenza Vaccinations in Pregnancy

Outcome	Concomitant Tdap+Influenza (n=8,464)	Sequential Tdap+Influenza (n=28,380)*	Unadjusted Risk Difference (95% CI)	Unadjusted RR (95% CI)	Adjusted* RR (95% CI)	*P*
Fever (0–3 d)	2 (2.4)	9 (3.2)	−1 (−5 to 3)	0.75 (0.16–3.45)	0.69 (0.15–3.23)	.64
Fever (0–7 d)	3 (3.5)	12 (4.2)	−1 (−5 to 4)	0.84 (0.24–2.97)	1.60 (0.56–4.59)	.38
Any acute reaction (0–3 d)	11 (13.0)	32 (11.3)	2 (−7 to 10)	1.15 (0.58–2.29)	1.13 (0.57–2.27)	.72
Any acute reaction (0–7 d)	19 (22.4)	72 (25.4)	−3 (−15 to 9)	0.88 (0.53–1.47)	0.96 (0.58–1.61)	.88

Tdap, tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis; RR, relative risk; CI, confidence interval.
Data are n (rate per 10,000) unless otherwise specified.
* Adjusting for gestational age at Tdap vaccination in weeks and Vaccine Safety Datalink site.

One limitation to our study is that we analyzed only acute events in women who sought medical care. However, because pregnant women have frequent medical encounters, especially later in pregnancy, minor events may be more likely to be diagnosed and coded in pregnant women. The rarity of adverse events in our cohort may also be related to differences in the immune response that occurs during pregnancy to protect the fetus.[15] Such differences may result in pregnant women being less reactogenic in response to vaccines.

Another limitation is that we did not use chart review to determine if an adverse outcome was related to vaccination. However, this nondifferential misclassification bias should not affect our overall results. We also had two risk windows for women receiving sequential vaccination compared with one risk window for women receiving concomitant vaccination, which could have made the risk appear higher in the sequentially vaccinated women; however, this was not the case. We relied on birth weight and gestational age data from the electronic medical record and birth certificates. We believe them to be accurate based on prior validation work, which has shown a positive predictive value of greater than 90% between birth certificate and medical record data at the research sites included in this study.[24] We were unable to adjust for all potential confounders, including race and ethnicity, smoking status, and prior preterm delivery. Finally, we did not include long-term follow-up of the infants to monitor for any adverse events.

We observed there are both seasonal differences in influenza vaccine administration and differences in the gestational age at which Tdap vaccine is administered in pregnancy. In our cohort, influenza vaccine was primarily given during the months of September through January and was administered evenly throughout pregnancy. On the other hand, although Tdap vaccine can be given during any stage of pregnancy, the Advisory Committee on Immunization Practices gives preference to vaccination later in pregnancy. In our cohort, Tdap vaccine was generally administered during the second and third trimesters. Because of the combination of limited months of influenza vaccine administration and Tdap vaccine administration later in pregnancy, not all women were

Table 2. Birth Outcomes for Same Day Compared With Different Day Vaccination With Tetanus Toxoid, Reduced Diphtheria Toxoid, and Acellular Pertussis and Influenza in Pregnancy

Outcome	Concomitant Tdap+Influenza (n=4,554)	Squential Tdap+Influenza (n=4,440)	Unadjusted Risk Difference (95% CI)	Unadjusted RR (95% CI)	Adjusted* RR (95% CI)	*P*
Preterm delivery	333 (7.3)	295 (6.6)	0.7 (−0.4 to 1.7)	1.10 (0.95–1.28)	0.95 (0.82–1.11)	.52
Low birth weight	266 (5.8)	252 (5.7)	0.2 (−0.8 to 1.1)	1.03 (0.87–1.22)	0.92 (0.78–1.09)	.34
Small for gestational age	439 (9.6)	432 (9.7)	−0.1 (−1.3 to 1.1)	0.99 (0.87–1.12)	1.01 (0.88–1.15)	.92

Tdap, tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis; RR, relative risk; CI, confidence interval.
Data are n (%) unless otherwise specified.
* Adjusting for gestational age at Tdap vaccination in weeks, Vaccine Safety Datalink site, length of enrollment (months), prenatal care utilization index, maternal comorbidity, pregnancy complication, maternal age, seasonality of preterm delivery.

eligible for concomitant vaccination. For this reason, we limited our analysis of adverse birth outcomes to women vaccinated at 20 weeks of gestation or later during the months of September to January. This was important to avoid confounding related to seasonality of birth outcomes. Future studies are needed to evaluate nonlive birth outcomes such as stillbirth and spontaneous abortions.

We found no differences in medically attended acute events or adverse birth outcomes in pregnant women receiving concomitant or sequential vaccination with Tdap and influenza vaccines. Our findings should be reassuring to health care providers and pregnant women, especially for women who are later in their pregnancy during months of influenza vaccine administration and are most likely to receive concomitant vaccination.

REFERENCES

1. Centers for Disease Control and Prevention (CDC). Prevention and control of seasonal influenza with vaccines. Recommendations of the Advisory Committee on Immunization Practices–United States, 2013-2014. MMWR Recomm Rep 2013;62:1–43.
2. Centers for Disease Control and Prevention (CDC). Updated recommendations for use of tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine (Tdap) in pregnant women–Advisory Committee on Immunization Practices (ACIP). MMWR Morb Mortal Wkly Rep 2013;62:131–5.
3. Kharbanda EO, Vazquez-Benitez G, Lipkind H, Naleway A, Lee G, Nordin JD; Vaccine Safety Datalink Team. Inactivated influenza vaccine during pregnancy and risks for adverse obstetric events. Obstet Gynecol 2013;122:659–67.
4. Nordin JD, Kharbanda EO, Benitez GV, Nichol K, Lipkind H, Naleway A, et al. Maternal safety of trivalent inactivated influenza vaccine in pregnant women. Obstet Gynecol 2013;121:519–25.
5. Nordin JD, Kharbanda EO, Vazquez-Benitez G, Lipkind H, Lee GM, Naleway AL. Monovalent H1N1 influenza vaccine safety in pregnant women, risks for acute adverse events. Vaccine 2014;32:4985–92.
6. Richards JL, Hansen C, Bredfeldt C, Bednarczyk RA, Steinhoff MC, Adjaye-Gbewonyo D, et al. Neonatal outcomes after antenatal influenza immunization during the 2009 H1N1 influenza pandemic: impact on preterm birth, birth weight, and small for gestational age birth. Clin Infect Dis 2013;56:1216–22.
7. Munoz FM, Bond NH, Maccato M, Pinell P, Hammill HA, Swamy GK, et al. Safety and immunogenicity of tetanus diphtheria and acellular pertussis (Tdap) immunization during pregnancy in mothers and infants: a randomized clinical trial. JAMA 2014;311:1760–9.
8. Donegan K, King B, Bryan P. Safety of pertussis vaccination in pregnant women in UK: observational study. BMJ 2014; 349:g4219.
9. Shakib JH, Korgenski K, Sheng X, Varner MW, Pavia AT, Byington CL. Tetanus, diphtheria, acellular pertussis vaccine during pregnancy: pregnancy and infant health outcomes. J Pediatr 2013;163:1422–6.e1–4.
10. Kharbanda EO, Vazquez-Benitez G, Lipkind HS, Klein NP, Cheetham TC, Naleway A, et al. Evaluation of the association of maternal pertussis vaccination with obstetric events and birth outcomes. JAMA 2014;312:1897–904.
11. Amirthalingam G, Andrews N, Campbell H, Ribeiro S, Kara E, Donegan K, et al. Effectiveness of maternal pertussis vaccination in England: an observational study. Lancet 2014;384: 1521–8.
12. Dabrera G, Amirthalingam G, Andrews N, Campbell H, Ribeiro S, Kara E, et al. A case-control study to estimate the effectiveness of maternal pertussis vaccination in protecting newborn infants in England and Wales, 2012–2013. Clin Infect Dis 2015;60:333–7.
13. McNeil SA, Noya F, Dionne M, Predy G, Meekison W, Ojah C, et al. Comparison of the safety and immunogenicity of concomitant and sequential administration of an adult formulation tetanus and diphtheria toxoids adsorbed combined with acellular pertussis (Tdap) vaccine and trivalent inactivated influenza vaccine in adults. Vaccine 2007;25:3464–74.
14. Weston WM, Chandrashekar V, Friedland LR, Howe B. Safety and immunogenicity of a tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis vaccine when coadministered with influenza vaccine in adults. Hum Vaccin 2009;5:858–66.
15. Szekeres-Bartho J. Immunological relationship between the mother and the fetus. Int Rev Immunol 2002;21:471–95.
16. McNeil MM, Gee J, Weintraub ES, Belongia EA, Lee GM, Glanz JM, et al. The Vaccine Safety Datalink: successes and challenges monitoring vaccine safety. Vaccine 2014;32:5390–8.
17. Naleway AL, Gold R, Kurosky S, Riedlinger K, Henninger ML, Nordin JD, et al. Identifying pregnancy episodes, outcomes, and mother-infant pairs in the Vaccine Safety Datalink. Vaccine 2013;31:2898–903.
18. Kharbanda EO, Vazquez-Benitez G, Lipkind H, Naleway AL, Klein NP, Cheetham TC, et al. Receipt of pertussis vaccine during pregnancy across 7 Vaccine Safety Datalink Sites. Prev Med 2014;67:316–9.
19. Kotelchuck M. The Adequacy of Prenatal Care Utilization Index: its US distribution and association with low birthweight. Am J Public Health 1994;84:1486–9.
20. Oken E, Kleinman KP, Rich-Edwards J, Gillman MW. A nearly continuous measure of birth weight for gestational age using a United States national reference. BMC Pediatr 2003;3:6.
21. Lee SJ, Steer PJ, Filippi V. Seasonal patterns and preterm birth: a systematic review of the literature and an analysis in a London-based cohort. BJOG 2006;113:1280–8.
22. Pasternak B, Svanström H, Mølgaard-Nielsen D, Krause TG, Emborg HD, Melbye M, et al. Risk of adverse fetal outcomes following administration of a pandemic influenza A(H1N1) vaccine during pregnancy. JAMA 2012;308:165–74.
23. Kramer MS, Zhang X, Platt RW. Analyzing risks of adverse pregnancy outcomes. Am J Epidemiol 2014;179:361–7.
24. Andrade SE, Scott PE, Davis RL, Li DK, Getahun D, Cheetham TC, et al. Validity of health plan and birth certificate data for pregnancy research. Pharmacoepidemiol Drug Saf 2013;22:7–15.