Vaccine 37 (2019) 3730–3734

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

Is there any harm in administering extra-doses of vaccine to a person? Excess doses of vaccine reported to the Vaccine Adverse Event Reporting System (VAERS), 2007–2017

Pedro L. Moro [a,*], Jorge Arana [a], Paige L. Marquez [a], Carmen Ng [a], Faith Barash [b], Beth F. Hibbs [a], Maria Cano [a]

[a] Immunization Safety Office, Division of Healthcare Quality Promotion, National Center for Zoonotic and Emerging Infectious Diseases, Centers for Disease Control and Prevention, USA
[b] Center for Biologics Evaluation and Research (CBER), Food and Drug Administration (FDA), USA

ARTICLE INFO

Article history:
Received 23 January 2019
Received in revised form 12 April 2019
Accepted 16 April 2019
Available online 30 May 2019

Keywords:
Adverse event
Epidemiology
Excess dose
Extra dose
Surveillance
Vaccination errors
Vaccine safety

ABSTRACT

Background: The administration of an extra dose of a vaccine may occur due to a programmatic error (e.g., vaccination error) when there is need to provide one of the antigens of a combination vaccine not readily available as a single antigen, or when there is need to provide immunization in a person with uncertain vaccination histories (e.g., refugees). There is little data available on the safety of an extra dose of vaccine.
Objective: To assess for the presence of adverse events (AEs) most commonly reported following the administration of excess doses of vaccine in the Vaccine Adverse Event Reporting System (VAERS).
Methods: We searched VAERS for US reports where an excess dose of vaccine was administered to a person received from 1/1/2007 through 1/26/2018. We reviewed medical records for all serious reports and a random sample of non-serious reports. The most common AEs among reports of excess dose of vaccine administered were compared with the corresponding AEs for all vaccines reported to VAERS during the same period.
Results: Out of 366,815 total VAERS reports received, 5067 (1.4%) reported an excess dose of vaccine was administered; 3898 (76.9%) did not describe an adverse health event (AHE). The most common vaccines reported were trivalent inactivated influenza (15.4%), varicella (13.9%), hepatitis A (11.4%), and measles, mumps, rubella, varicella (11.1%). Among reports where only AHEs were reported, the most common were pyrexia (12.8%), injection site erythema (9.7%), injection site pain (8.9%), and headache (6.6%). The percentage of AHEs among these reports was comparable to all reports submitted to VAERS during the same study period.
Conclusion: More than three-fourths of reports of an excess dose of vaccine did not describe an AHE. Among reports where an AHE event was reported, we did not observe any unexpected conditions or clustering of AEs.

Published by Elsevier Ltd.

1. Introduction

Administration of an excess dose of a vaccine can occur under several scenarios: (1) administration of an excess dose of the same antigen due to a vaccination error (e.g., healthcare provider, documentation, or patient recall errors); (2) in the context of combination vaccines, such as when there is need to provide one of the antigens not readily available as a single antigen; (3) when there is a need to provide immunizations to individuals with uncertain vaccination histories, as in the case of special populations (e.g, refugees with missing records and unknown immune status). The Advisory Committee on Immunization Practices (ACIP) has specific recommendations regarding the administration of excess doses of vaccine [1] indicating that administration of excess antigens contained in a combination vaccine should be avoided in most situations. However, this may be justified if the excess antigen is not contraindicated, if the potential benefits to the patient outweigh the potential risk for adverse events (AEs) associated with the excess antigens, if the products that contain only the needed antigens are not readily available, and if there is better overall economic value if the direct and indirect costs of excess injections are taken into consideration. The ACIP recommendations state that an excess dose of many live-virus vaccines and *Haemophilus*

* Corresponding author at: Immunization Safety Office, Division Of Healthcare Quality Promotion, NCEZID, Centers for Disease Control and Prevention, 1600 Clifton Rd, MS D26, Atlanta, GA 30333, USA.
E-mail address: pmoro@cdc.gov (P.L. Moro).

https://doi.org/10.1016/j.vaccine.2019.04.088
0264-410X/Published by Elsevier Ltd.

influenzae or hepatitis B vaccine has not been found to be harmful [2,3], but the risk for an AE might increase when excess doses are administered at an earlier time than the recommended interval for certain vaccines [e.g., tetanus toxoid vaccines and pneumococcal polysaccharide vaccine (23-valent)] [4–8]. In some circumstances, the provider might prefer to use a combination vaccine to reduce the required number of injections. In such cases, the benefits and risks of administering the combination vaccine with an unneeded antigen should be carefully considered and discussed with the patient or parent. For most other vaccines in the immunization schedule, there is little if any information on AEs resulting from their excessive administration.

The objective of this study is to describe the characteristics of AEs associated with reports in VAERS where an excess dose of vaccine was administered.

2. Material & methods

2.1. VAERS

VAERS is a US national passive vaccine safety surveillance system created in 1990 and co-administered by the Centers for Disease Control and Prevention (CDC) and the Food and Drug Administration (FDA). It receives reports of AEs following vaccination but may also receive reports of vaccination errors not describing an AE [9]. VAERS accepts reports from vaccine manufacturers, healthcare providers, vaccine recipients and others. The VAERS report form collects information on age, sex, vaccines administered, dose and lot number, the AE experienced, and health history. Signs and symptoms of AEs are coded by trained personnel using the Medical Dictionary for Regulatory Activities (MedDRA), a clinically validated, internationally standardized terminology [10]. A VAERS report may be assigned one or more MedDRA preferred terms (PTs). A PT is a distinct descriptor for a symptom, sign, disease, diagnosis, therapeutic indication, investigation, medical error, surgical, or medical procedure, or medical, social, or family history characteristic [10], but PTs are not necessarily medically confirmed diagnoses. System Organ Class (SOC) is the highest level of the MedDRA hierarchy that provides the broadest classification for AEs (e.g., nervous system disorders) [11]. Reports are classified as serious or non-serious based on the Code of Federal Regulations (21-CFR) if one or more of the following are reported: death, life-threatening illness, hospitalization or prolongation of existing hospitalization, permanent disability, or a congenital anomaly/birth defect [12]. For serious reports, medical records are routinely requested and made available to VAERS personnel. Vaccine manufacturers are responsible for following up on serious reports or unexpected AEs submitted to them [9].

2.1.1. Search of reports

We searched the VAERS database for reports received for the analytic period January 1, 2007 through January 26, 2018 for: (1) reports containing any of the following MedDRA PTs: *accidental overdose, extra dose administered, incorrect dose administered, multiple drug overdose, overdose, incorrect dosage administered* and (2) reports containing the text string *"extra dose" "excess dose" "overdose"* or *"additional dose"* in the symptom, pre-existing and medical history variables. Excess dose of a vaccine was defined as greater than recommended volume, quantity, or dosage of a vaccine which may have been given on the same date or on separate dates. For example, a report of two doses of inactivated influenza vaccine for an adult patient on the same date or during the same influenza season were considered as excess doses. Pregnancy reports were searched using methods previously described [21].

2.1.2. Analysis of reports

We conducted descriptive analyses of reports by age, sex, vaccines administered, vaccines given in excess, type of administration error or reason for the excess dose, and the most common MedDRA PTs among reports where an adverse health event was described.

2.1.3. Clinical review

Investigators from CDC (PLM, JA) reviewed all serious reports and a simple random sample of non-serious reports and any available medical records to characterize AEs, if any. This review also sought to understand the circumstances under which an excess dose of vaccine was administered to identify opportunities for prevention. The main AE or diagnosis was classified using the MedDRA SOC [10]. Reports determined to be not related to an excess dose of a vaccine (e.g., overdose of a non-vaccine medication) were excluded.

Because VAERS is a routine, government-sponsored surveillance system that does not meet the definition of research, this investigation was not subject to institutional review board review or informed consent requirements.

3. Results

During the analytic period of this review, 366,815 total reports were submitted to VAERS. We detected 5067 reports of excess doses of vaccine administered. The proportions of reports of excess dose received increased from 0.8% in 2007 to a peak of 2.4% in 2015. The vaccine type most commonly associated with these reports (which also peaked during 2015) were inactivated influenza vaccines. Of the 5067 reports, 3898 (76.9%) did not describe an AE or any sign or symptom (Table 1). The most common reporters were vaccine manufacturers (3,168;62.5%). The most common vaccines reported were trivalent inactivated influenza, varicella, hepatitis A vaccines, and measles, mumps, rubella, varicella, vaccines (Table 2). The most frequent MedDRA PTs for all reports of excess dose of vaccine where an adverse health event was reported were systemic (e.g., fever) or local injection site reactions (Table 3).

3.1. Serious and non-serious reports

Clinical review of all available records for the 158 serious reports identified through the initial automated search strategy

Table 1
Characteristics of recipients of excess doses of vaccine reported to VAERS, January 2007—July 2017.

Characteristic	
Median age (range), years	11 (0–98)
	No (%)
Number of reports	5067
Serious	158 (3.1)
Reports with no adverse health event	3898 (76.9)
Female sex	1849 (36.5)
Male sex	1426 (28.1)
Unknown sex	1792 (35.4)
Age groups[a]	
0–11 months	438 (8.6)
1–6 years	1089 (21.5)
7–18 years	731 (14.4)
19–64 years	808 (16.0)
≥65 years	379 (7.5)
Type of reporter	
Manufacturer	3168 (62.5)
Provider	1180 (23.3)
Other	619 (12.2)
Parent/patient	100 (2.0)

[a] Age unknown in 1622 (32%).

Table 2
Most common vaccines administered in excess reported to VAERS, January 2007—July 2017 (N = 5067)[†].

Vaccine	N (%)
Trivalent inactivated influenza	778 (15.4)
Varicella	706 (13.9)
Hepatitis A	579 (11.4)
Measles, mumps, rubella, varicella	561 (11.1)
Varicella zoster	545 (10.8)
Hepatitis B	519 (10.2)
Quadrivalent human papilloma virus	374 (7.4)
Measles, mumps, rubella	359 (7.1)
Pneumococcal polysaccharide vaccine (23-valent)	299 (5.9)
Pneumococcal conjugate vaccine (13-valent)	280 (5.5)
Haemophilus influenzae type b conjugate vaccine	267 (5.3)
TdaP	226 (4.4)
DTaP	214 (4.2)
Quadrivalent inactivated influenza	191 (3.8)
DTaPHep B-IPV	189 (3.7)
Quadrivalent meningococcal conjugate vaccine	183 (3.6)
Inactivated polio vaccine	175 (3.4)
Ninevalent human papilloma virus	168 (3.3)
Rotavirus vaccine (pentavalent)	160 (3.2)

DTaP: Diphtheria and tetanus toxoids and acellular pertussis vaccine adsorbed.
Tdap: Tetanus toxoid, reduced diphtheria toxoid and acellular pertussis vaccine, adsorbed.
DTaPHep B-IPV: Diphtheria and tetanus toxoids and acellular pertussis adsorbed, hepatitis B and inactivated poliovirus vaccine.
[†] Reports may not be mutually exclusive.

Table 3
Adverse health events among reports where an excess dose of vaccine was administered, VAERS, January 2007–July 2017[†] (n = 1169).

Adverse health events	N (%)
Pyrexia	150 (12.8)
Injection site erythema	113 (9.7)
Injection site pain	104 (8.9)
Headache	77 (6.6)
Injection site swelling	76 (6.5)
Pain in extremity	75 (6.4)
Pain	69 (5.9)
Vomiting	61 (5.2)
Nausea	52 (4.4)
Dizziness	51 (4.4)
Fatigue	50 (4.3)
Cough	46 (3.9)

[†] Reports may not be mutually exclusive.

determined that 64 were cases involving an excess vaccine dose. Some of the false positives included reports with MedDRA PTs for incorrect dose administered, but not an excess dose when reviewed. Other false positives included MedDRA PTs for multiple drug overdose where a drug but not a vaccine was administered in excess. The SOCs most commonly reported among these excess dose serious reports were general disorders and administration site conditions (17), nervous system disorders (7), and immune system disorders (4) [Table 4a]. The most common vaccines given in excess among these serious reports were pneumococcal polysaccharide (13), influenza (10), hepatitis B (9), human papillomavirus (6) and herpes zoster (5). No specific pattern or cluster of AEs (e.g., injection site reactions) was found to occur with any of these vaccines given in excess.

We also reviewed a 6% random sample of non-serious reports (n = 279) (Table 4b). Most of these non-serious reports (245; 87.8%) did not describe an adverse health event. The most common vaccines for those reports with adverse health events (n = 34) were influenza (9), human papillomavirus (9), Pneumococcal polysaccharide vaccine (5), DTaP (5), herpes zoster (3), hepatitis A (2), hepatitis B (1). No cluster of AEs was observed for any of these vaccines. All reports were vaccination errors and the person giving the vaccine was not aware an excess dose of vaccine was being given. Most reports (~90%) did not describe the circumstances that led to administration of an excess dose of vaccine. However, in some reports the provider did not review the vaccination records; in other cases the patient did not recall having received the vaccine previously (e.g., influenza vaccine), and in other cases a child received an adult dose of the vaccine. In 127 (45.5%) of 279 non-serious reports an additional dose of vaccine was given on the same day. In 149 (53.4%), the excess dose of vaccine was given on a different date. In 10 reports, an adult vaccine formulation was given incorrectly to a child.

Table 4
Adverse events among serious reports and a random sample of non-serious reports of excess doses of vaccine reported to VAERS, January 1, 2007–July 2017.

4a. Serious reports after clinical review	
Adverse event (System Organ Class)	N (%)
General disorders and administration site conditions	17 (26.6)
Nervous system disorders	7 (10.9)
Immune system disorders	4 (6.3)
Infections and infestations	6 (9.4)
Psychiatric disorders	6 (9.4)
Metabolism and nutrition disorders	3 (4.7)
Gastrointestinal disorders	3 (4.7)
Cardiac disorders	3 (4.7)
Deaths[a]	4 (6.3)
No adverse health event reported[b]	4 (6.3)
Other[c]	7 (10.9)
Total	64
4b. Random sample of non-serious reports	
General disorders and administration site conditions	14 (5.0)
Nervous system disorders	7 (2.5)
Immune system disorders	6 (2.2)
Infections and infestations	2 (0.7)
Respiratory, thoracic and mediastinal disorders	2 (0.7)
Gastrointestinal disorders	1 (0.4)
Blood and lymphatic system disorders	1 (0.4)
Reproductive system and breast disorders	1 (0.4)
No adverse health event reported	245 (87.8)
Total	279

[a] Causes of death include: end-stage congestive heart failure, thrombosis, Sudden infant death syndrome and unknown cause.
[b] Report indicated patient was hospitalzed but did not report an adverse health event.
[c] The other includes two reports of an unspecified adverse event and one report each of injury, poisoning and procedural complications, blood and lymphatic system disorders, musculoskeletal and connective tissue disorders, respiratory, thoracic and mediastinal disorders, and vascular disorders.

Table 5
MedDRA[a] preferred terms most commonly reported among reports where an excess dose of vaccine was administered compared to the rest of the VAERS database, January 2007–July 2017[b].

MedDRA PT	Excess dose	VAERS database
	N = 1,169	N = 301,805
	N (%)	N (%)
Pyrexia	150 (12.8)	44,574 (14.8)
Injection site erythema	113 (9.7)	48,767 (16.2)
Injection site pain	104 (8.9)	33,183 (11.0)
Headache	77 (6.6)	24,455 (8.1)
Injection site swelling	76 (6.5)	36,419 (12.1)
Pain in extremity	75 (6.4)	24,375 (8.1)
Pain	69 (5.9)	29,143 (9.7)
Vomiting	61 (5.2)	16,824 (5.6)
Nausea	52 (4.4)	18,997 (6.3)
Dizziness	51 (4.4)	19,221 (6.4)
Fatigue	50 (4.3)	14,836 (4.9)
Cough	46 (3.9)	9487 (3.1)
Irritability	46 (3.9)	5707 (1.9)
Erythema	43 (3.7)	30,811 (10.2)
Rash	43 (3.7)	22,044 (7.3)

[a] MedDRA: Medical Dictionary for Regulatory Activities.
[b] Reports with no adverse health events reported were excluded.

Among 1169 reports of an excess dose of vaccine with an adverse health event, the 10 most common PTs were for local or systemic reactions and were comparable to the respective PTs in the entire VAERS database (Table 5).

3.2. Excess vaccine doses among pregnancy reports

We identified and reviewed 51 reports where an excess dose of a vaccine was given to a pregnant woman. Vaccines given in excess were inactivated influenza vaccine (33), Tdap (9), hepatitis B (1), human papilloma virus vaccine (6), and MMRII (2). In the latter two, the provider did not know the woman was pregnant. Most (38; 74.5%) reports did not describe an adverse health event. Among the 13 reports with an AE, some of the diagnoses included injection site reaction/arm soreness (10), scabies (1), headache/dysuria (1), and Taussig-Bing anomaly-infant-birth defect in a woman vaccinated with Tdap in the third trimester (1).

4. Discussion

This review of the VAERS database demonstrated that excess doses of vaccine were reported in 1.4% of all VAERS reports submitted during January 1, 2007 through January 26, 2018. The number of reports has been increasing over time and this increase parallels the general increase of most vaccination error reports in VAERS [14]. We noted that these reports occurred due to diverse vaccination errors, typically programmatic errors many of which should have been avoided by greater awareness of the administration instructions for the vaccines being administered or increased awareness of the immunization history of the patient.

There is some evidence that suggests there may be an increased risk of local reactions with repeated doses of certain vaccines such as DTaP. In pre-licensure studies of DTaP, large injection site reactions were observed to occur more frequently after the fifth dose of DTaP than after the previous four doses [15]. Similarly, for children vaccinated with a fourth dose of DTaP, which was the same DTaP received in the primary series, fever and injection site redness, swelling, and pain increased in prevalence compared with the third dose in the primary series [16]. The findings of this review seem reassuring since no adverse health events were reported in three-fourth of reports and among reports where an adverse health event was reported, injection site and systemic reactions were the most common conditions reported.

Some studies have shown an increased risk of AEs when tetanus-containing vaccines are given at short intervals. A clinical trial of 7156 children found that Tdap vaccine was well tolerated when given at intervals as short as 18 months from the prior tetanus-containing vaccine. However, the authors noted an increased risk of solicited reports of injection site swelling and erythema in children who received a tetanus-toxoid-containing vaccine more recently [17]. A retrospective cohort study of 436,828 Td vaccinations in the Vaccine Safety Datalink (VSD) found that medically attended local reactions, including cellulitis, were more common among persons who received a Td-containing vaccine within the preceding 5 years compared with a longer interval [18]. Another study of 4524 health-care workers vaccinated with Tdap during a pertussis outbreak in New England found that there was no difference in the rates of solicited moderate or severe injection site reactions, but there was an increase in redness, swelling, and subjective fever among patients who had received their prior Td-containing vaccine less than 2 years earlier [19].

An increased risk of AEs when administering tetanus-toxoid-containing vaccines within a short interval has been an area of concern now that ACIP recommends a dose of Tdap vaccine during every pregnancy irrespective of prior vaccination with a tetanus-toxoid-containing vaccine [20]. However, a recent study in the VSD found that among women who received Tdap vaccination during pregnancy, there was no increased risk of acute AEs or adverse birth outcomes for those who had been previously vaccinated within 2 years or 2–5 years compared with those who had been vaccinated more than 5 years prior [21].

In our review, we included pregnant women who had received a dose of vaccine in excess. Upon review of these pregnancy reports, we found that only a quarter of reports described an AE. The vaccines most commonly associated with these pregnancy reports were influenza or Tdap vaccines which are the two vaccines recommended for administration specifically during pregnancy. A previous review of maternal Tdap safety reports in VAERS described the nature of the vaccination errors where an excess dose of Tdap vaccine was given to a pregnant woman [13].

There are few other studies evaluating the safety of excess doses of any given vaccine. One recent report documented the administration of a five-fold higher dose of yellow fever vaccine to each of four persons in a military clinic [22]. Only one reported symptoms, which included abdominal pain and arm pain and which resolved following supportive intravenous fluid treatment. Three other studies in Brazil documented administration of a 10 to 25-fold overdose of 17-DD yellow fever vaccine among 64 individuals; only one person was hospitalized (for possible acute viscerotropism and eventually recovered) [23–25].

VAERS is the frontline surveillance system used to monitor the post-licensure safety of US vaccines. Strengths of VAERS include its broad national scope and timeliness [9]. VAERS can rapidly detect unexpected patterns and rare AEs that might represent potential safety signals that can be further evaluated in more robust data systems using population-based studies. VAERS is subject to the inherent limitations of passive surveillance system. Some of these limitations include over- or under-reporting, reporting biases, inconsistency in quality and completeness of reports, lack of denominator information, and lack of an unvaccinated comparison group [9]. For example, 63% of reports were submitted by vaccine manufacturers who are required by law to report to VAERS and this may introduce bias. Due to these limitations, we generally cannot assess if a vaccine caused an AE from VAERS data alone.

5. Conclusion

In this safety assessment of reports submitted to VAERS with excess doses of vaccine administered, we did not identify any new or unexpected safety issues. In some circumstances, querying patients about vaccination history especially with influenza vaccine, better awareness of specific vaccine recommendations, improved documentation in the medical record, and timely access to vaccination histories, may help prevent administration of excess doses of vaccines.

Disclaimer

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention or the Food and Drug Administration.

Declaration of interest

The authors declare that there are no conflict of interest.

Acknowledgments

We thank CDC's Immunization Safety Office staff whose work allowed this activity to be conducted.

Funding/Support

The study was implemented by the Centers for Disease Control and Prevention (CDC) and Food and Drug Administration (FDA). The only funds used were from CDC and FDA budgets. This study had no external sponsors.

References

[1] Kroger AT, Duchin J, Vázquez M. General Best Practice Guidelines for Immunization. Best Practices Guidance of the Advisory Committee on Immunization Practices (ACIP). [www.cdc.gov/vaccines/hcp/acip-recs/general-recs/downloads/general-recs.pdf]. Accessed on April 12, 2019.
[2] Midthun K, Horne AD, Goldenthal KL. Clinical safety evaluation of combination vaccines. Dev Biol Stand 1998;95:245–9.
[3] Pichichero ME, Blatter MM, Reisinger KS, et al. Impact of a birth dose of hepatitis B vaccine on the reactogenicity and immunogenicity of diphtheriatetanus-acellular pertussis-hepatitis B-inactivated poliovirus-Haemophilus influenzae type b combination vaccination. Pediatr Infect Dis J 2002;21(9):854–9. https://doi.org/10.1097/01.inf.0000027669.37444.24.
[4] CDC. Prevention of pneumococcal disease: recommendations of the Advisory Committee on Immunization Practices (ACIP). MMWR Recomm Rep 1997;46 (RR-8):1–24.
[5] CDC. Pertussis vaccination: use of acellular pertussis vaccines among infants and young children. Recommendations of the Advisory Committee on Immunization Practices (ACIP). MMWR Recomm Rep 1997;46(RR-7):1–25.
[6] DeStefano F, Goodman RA, Noble GR, McClary GD, Smith S, Broome CV. Simultaneous administration of influenza and pneumococcal vaccines. JAMA 1982;247(18):2551–4. https://doi.org/10.1001/jama.1982.03320430055032.
[7] Kretsinger K, Broder KR, Cortese MM, et al. Preventing tetanus, diphtheria, and pertussis among adults: use of tetanus toxoid, reduced diphtheria toxoid and acellular pertussis vaccine recommendations of the Advisory Committee on Immunization Practices (ACIP) and recommendation of ACIP, supported by the Healthcare Infection Control Practices Advisory Committee (HICPAC), for use of Tdap among health-care personnel. MMWR Recomm Rep 2006;55(RR-17):1–37.
[8] Broder KR, Cortese MM, Iskander JK, et al. Preventing tetanus, diphtheria, and pertussis among adolescents: use of tetanus toxoid, reduced diphtheria toxoid and acellular pertussis vaccines recommendations of the Advisory Committee on Immunization Practices (ACIP). MMWR Recomm Rep 2006;55(RR-3):1–34.
[9] Shimabukuro TT, Nguyen M, Martin D, DeStefano F. Safety monitoring in the Vaccine Adverse Event Reporting System (VAERS). Vaccine. 2015;33 (36):4398–405.
[10] Medical Dictionary for Regulatory Activities. Available at: http://www.meddramsso.com/. Accessed April 28, 2011.
[11] International Conference on Harmonisation of Technical Requirements for Registration of Pharmaceuticals. http://www.ich.org/products/meddra.html. Accesed on June 10, 2018.
[12] Food and Drug Administration. 21 CFR Part 600.80. Postmarketing reporting of adverse experiences. Fed Regist 1997;62:52252–3.
[13] Moro PL, Cragan J, Tepper N, Zheteyeva Y, Museru O, Lewis P, et al. Enhanced surveillance of tetanus toxoid, reduced diphtheria toxoid, and acellular pertussis (Tdap) vaccines in pregnancy in the Vaccine Adverse Event Reporting System (VAERS), 2011–2015. Vaccine 2016;34(20):2349–53.
[14] Hibbs BF, Moro PL, Lewis P, Miller ER, Shimabukuro TT. Vaccination errors reported to the Vaccine Adverse Event Reporting System, (VAERS) United States, 2000–2013. Vaccine 2015;33(28):3171–8.
[15] Pichichero ME, Edwards KM, Anderson EL, Rennels MB, Englund JA, Yerg DE, Blackwelder WC, Jansen DL, Meade BD. Safety and immunogenicity of six acellular pertussis vaccines and one whole-cell pertussis vaccine given as a fifth dose in four- to six-year-old children. Pediatrics 2000;105(1):e11.
[16] Pichichero ME, Deloria MA, Rennels MB, Anderson EL, Edwards KM, Decker MD, Englund JA, Steinhoff MC, Deforest A, Meade BD. A safety and immunogenicity comparison of 12 acellular pertussis vaccines and one whole-cell pertussis vaccine given as a fourth dose in 15- to 20-month-old children. Pediatrics 1997;100(5):772–88.
[17] Halperin SA, Sweet L, Baxendale D, et al. How soon after a prior tetanus-diphtheria vaccination can one give adult formulation tetanus-diphtheria-acellular pertussis vaccine? Pediatr Infect Dis J 2006;25(3):195–200.
[18] Jackson LA, Yu O, Belongia EA, et al. Frequency of medically attended adverse events following tetanus and diphtheria toxoid vaccine in adolescents and young adults: a Vaccine Safety Datalink study. BMC Infect Dis 2009;9:165.
[19] Talbot EA, Brown KH, Kirkland KB, Baughman AL, Halperin SA, Broder KR. The safety of immunizing with tetanus-diphtheria-acellular pertussis vaccine (Tdap) less than 2 years following previous tetanus vaccination: Experience during a mass vaccination campaign of health care personnel during a respiratory illness outbreak. Vaccine 2010;28(50):8001–7.
[20] Liang JL, Tiwari T, Moro P, Messonnier NE, Reingold A, Sawyer M, et al. Prevention of Pertussis, Tetanus, and Diphtheria with Vaccines in the United States: Recommendations of the Advisory Committee on Immunization Practices (ACIP). MMWR Recomm Rep 2018;67(2):1–44.
[21] Sukumaran L, McCarthy NL, Kharbanda EO, McNeil MM, Naleway AL, Klein NP, et al. Association of Tdap vaccination with acute events and adverse birth outcomes among pregnant women with prior tetanus-containing immunizations. JAMA 2015;314(15):1581–7.
[22] McNeil MM, Hibbs BF, Miller ER, Cano MV. Notes from the Field: Errors in Administration of an Excess Dosage of Yellow Fever Vaccine – United States, 2017. MMWR Morb Mortal Wkly Rep 2018;67(3):109–10.
[23] Rabello A, Orsini M, Disch J, Marcial T, Leal L, Freire S, Yamamura AM, Viana A. Low frequency of side effects following an incidental 25 times concentrated dose of yellow fever vaccine. Rev Soc Bras Med Trop 2002;35(2):177–80.
[24] Nishioka S, de A, Lomônaco Ade F. Overdose of yellow fever vaccine: a preventable error? Rev Soc Bras Med Trop 2002;35(5):541–2.
[25] Carneiro M, Lara Bda S, Schimidt B, Gais L. Overdose of yellow fever vaccine in the Southern region of Brazil. Rev Soc Bras Med Trop 2011;44(2):252–3.