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Milestones in the History of Vaccination

1870	1884	1885	1887	1900
Louis Pasteur creates the first live attenuated bacterial vaccine (chicken cholera)	Pasteur creates the first live attenuated viral vaccine (rabies)	Pasteur first uses rabies vaccine in a human	Institut Pasteur established	Paul Ehrlich formulates receptor theory of immunity

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Milestones in the History of Vaccination

1901	1909	1919	1923	1926
First Nobel Prize in Medicine to von Behring for diphtheria antitoxin	Theobald Smith discovers a method for inactivating diphtheria toxin	Calmette and Guerin create BCG, the first live attenuated bacterial vaccine for humans	First whole-cell pertussis vaccine tested Gaston Ramon develops diphtheria toxoid	Ramon and Christian Zoeller develop tetanus toxoid

Milestones in the History of Vaccination

1927	1931	1936	1948	1954
Yellow fever virus isolated	Goodpasture describes a technique for viral culture in hens' eggs	Thomas Francis and Thomas Magill develop the first inactivated influenza vaccine	John Enders and colleagues isolate Lansing Type II poliovirus in human cell line	Enders and Peebles isolate measles virus Francis Field Trial of inactivated polio vaccine

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Milestones in the History of Vaccination

1955	1961	1963	1965	1966
Inactivated polio vaccine licensed	Human diploid cell line developed	Measles vaccine licensed Trivalent oral polio vaccine licensed	Bifurcated needle for smallpox vaccine licensed	World Health Assembly calls for global smallpox eradication

Milestones in the History of Vaccination

1967	1969	1971	1977	1979
Maurice Hilleman develops Jeryl Lynn strain of mumps virus	Stanley Plotkin develops RA27/3 strain of rubella vaccine virus	MMR vaccine licensed	Last indigenous case of smallpox (Somalia)	Last wild poliovirus transmission in the U.S.

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Milestones in the History of Vaccination

1981	1983	1986	1989	1990
First hepatitis B vaccine licensed	Smallpox vaccine withdrawn from civilian market	First recombinant vaccine licensed (hepatitis B) National Childhood Vaccine Injury Act	Two-dose measles vaccine recommendation	First polysaccharide conjugate vaccine licensed (*Haemophilus influenzae* type b)

Milestones in the History of Vaccination

1994	1995	1996	1997	1998
Polio elimination certified in the Americas Vaccines for Children program begins	Varicella vaccine licensed Hepatitis A vaccine licensed First harmonized childhood immunization schedule published	Acellular pertussis vaccine licensed for infants	Sequential polio vaccination recommended	First rotavirus vaccine licensed

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APPENDICES

A Schedules and Recommendations

B Vaccines

C Vaccine Storage and Handling

D Vaccine Administration

1999	2000	2003	2004	2004
Exclusive use of inactivated polio vaccine recommended Rotavirus vaccine withdrawn	Pneumococcal conjugate vaccine licensed for infants	Live attenuated influenza vaccine licensed	Inactivated influenza vaccine recommended for all children 6–23 months of age	Indigenous transmission of rubella virus interrupted

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Milestones in the History of Vaccination

2005	2005	2006	2006	2006
Acellular pertussis vaccines licensed for adolescents and adults	MMR-varicella (MMRV) licensed	Second generation rotavirus vaccine licensed	First human papillomavirus vaccine licensed	First herpes zoster vaccine licensed

Vaccines and Related Products Distributed in the United States

Vaccine/Biologic	Brand Name	Manufacturer	Type	How Supplied
Diphtheria, Tetanus, acellular Pertussis	Infanrix®	GlaxoSmithKline	Inactivated	single-dose vial or syringe
Diphtheria, Tetanus, acellular Pertussis	Tripedia®	sanofi-pasteur	Inactivated	single-dose vial
Diphtheria, Tetanus, acellular Pertussis	Daptacel®	sanofi-pasteur	Inactivated	single-dose vial
Diphtheria, Tetanus, acellular Pertussis + Hib	TriHIBit®	sanofi-pasteur	Inactivated	single-dose vial
Diphtheria, Tetanus, acellular Pertussis +Hep B + IPV	Pediarix®	GlaxoSmithKline	Inactivated	single-dose vial or syringe
Diphtheria, Tetanus, acellular Pertussis + Hib + IPV	Pentacel®	sanofi-pasteur	Inactivated	single-dose vial
Diphtheria, Tetanus, acellular Pertussis + IPV	Kinrix®	GlaxoSmithKline	Inactivated	single-dose vial or syringe
Diphtheria, Tetanus (DT; ped <7yrs, P-free)	generic	sanofi-pasteur	Inactivated	single-dose vial
Tetanus, diphtheria, adsorbed (Td; >7yrs, P-free)	Decavac®	sanofi-pasteur	Inactivated	single-dose syringe
Tetanus, diphtheria, adsorbed (Td; >7yrs)	generic	Mass Biologic Labs	Inactivated	15-dose vial
Tetanus, diphtheria, acellular Pertussis (Tdap; 10-64 yrs)	Boostrix®	GlaxoSmithKline	Inactivated	single-dose vial or syringe
Tetanus, diphtheria, acellular Pertussis (Tdap; 11-64 yrs)	Adacel™	sanofi-pasteur	Inactivated	single-dose vial
Tetanus toxoid (TT; >7 yrs) adsorbed	generic	sanofi-pasteur	Inactivated	10-dose vial
Tetanus toxoid (TT; adult booster use only)	generic	sanofi-pasteur	Inactivated	15-dose vial
Tetanus immune globulin (TIG)	HyperTET™	Talecris	Human immunoglobulin	single-dose syringe
Haemophilus influenzae type b (PRP-T)	ActHIB®	sanofi-pasteur	Inactivated	single-dose vial
Haemophilus influenzae type b (HbOC)	HibTITER®	Wyeth	Inactivated	single-dose vial
Haemophilus influenzae type b (PRP-OMP)	PedvaxHIB®	Merck	Inactivated	single-dose vial
Haemophilus influenzae type b (PRP-OMP) + Hep B	Comvax®	Merck	Inactivated	single-dose vial
Hepatitis A: ped/adol & adult formulations	Havrix®	GlaxoSmithKline	Inactivated	single-dose vial or syringe
Hepatitis A: ped/adol & adult formulations	Vaqta®	Merck	Inactivated	single-dose vial or syringe
Hepatitis A immune globulin	GamaSTAN™	Talecris	Human immunoglobulin	2 mL and 10 mL vials
Hepatitis B: ped/adol & adult formulations	Engerix-B®	GlaxoSmithKline	Inactivated	single-dose vial or syringe
Hepatitis B: ped/adol & adult formulations	Recombivax HB®	Merck	Inactivated	single-dose vial
Hepatitis B dialysis formulation	Recombivax HB®	Merck	Inactivated	single-dose vial
Hepatitis B immune globulin (HBIG)	HyperHEP B™	Talecris	Human immunoglobulin	1 mL syringe, 1 mL or 5 mL vial
Hepatitis B immune globulin (HBIG): ped formulation	HyperHEP B™	Talecris	Human immunoglobulin	single-dose 0.5 mL neonatal syringe
Hepatitis B immune globulin (HBIG)	Nabi-HB®	Nabi	Human immunoglobulin	single-dose vial
Hepatitis A & B: adult formulation	Twinrix®	GlaxoSmithKline	Inactivated	single-dose vial or syringe
Human papillomavirus (HPV)	Gardasil®	Merck	Inactivated	single-dose vial or syringe
Influenza (trivalent inactivated influenza vaccine [TIV])	Fluarix®	GlaxoSmithKline	Inactivated	10 single-dose syringes
Influenza (live attenuated influenza vaccine [LAIV])	FluMist®	Medimmune	Live, intranasal	10 single-use sprayers
Influenza (TIV)	Afluria®	CSL Biotherapies	Inactivated	single-dose syringe & 10-dose vial
Influenza (TIV)	Fluvirin®	Novartis	Inactivated	single-dose syringe & 10-dose vial
Influenza (TIV)	Fluzone®	sanofi-pasteur	Inactivated	10-dose vial
Influenza (TIV; >36 mos; no preservative)	Fluzone®	sanofi-pasteur	Inactivated	single-dose syringe (0.5 mL)
Influenza (TIV; ped 6-35 mos; no preservative)	Fluzone®	sanofi-pasteur	Inactivated	single-dose syringe (0.25 mL)
Influenza (TIV; >18 yrs)	FluLaval™	GlaxoSmithKline	Inactivated	10-dose vial
Measles, Mumps, Rubella (MMR)	M-M-R II®	Merck	Live, attenuated	single-dose vial
Measles, Mumps, Rubella + Varicella (MMRV)	ProQuad®	Merck	Live, attenuated	single-dose vial
Meningococcal conjugate (A/C/Y/W-135)	Menactra®	sanofi pasteur	Inactivated	single-dose vial
Meningococcal polysaccharide (A/C/Y/W-135)	Menomune®	sanofi pasteur	Inactivated	single-dose vial
Pneumococcal conjugate, 7-valent	Prevnar®	Wyeth	Inactivated	single-dose vial
Pneumococcal polysaccharide, 23-valent	Pneumovax 23®	Merck	Inactivated	single-dose vial or 5-dose vial
Polio (IPV)	IPOL®	sanofi pasteur	Inactivated	single-dose syringe or 10-dose vial
Rotavirus	RotaTeq®	Merck	Live, oral	single-dose tube
Rotavirus	Rotarix®	GlaxoSmithKline	Live, oral	single-dose tube
Varicella	Varivax®	Merck	Live, attenuated	single-dose vial
Varicella Zoster Immune Globulin (VZIG) (IND)	VariZIG™	Cangene	Human Immunoglobulin	125-U vial
Zoster	Zostavax®	Merck	Live, attenuated	single-dose vial
Anthrax, adsorbed	BioThrax™	BioPort	Inactivated	multi-dose vial
Japanese encephalitis	JE-VAX®	sanofi pasteur	Inactivated	single-dose vial
Rabies	Imovax®	sanofi pasteur	Inactivated	single-dose vial
Rabies	RabAvert®	Novartis	Inactivated	single-dose vial
Rabies Immune Globulin (RIG)	Imogam Rabies-HT®	sanofi-pasteur	Human immunoglobulin	2 mL and 10 mL vials
Rabies Immune Globulin (RIG)	HyperRAB™	Talecris	Human immunoglobulin	2 mL and 10 mL vials
Typhoid VI polysaccharide	Typhim Vi®	sanofi-pasteur	Inactivated	single-dose syringe and 20-dose vial
Typhoid, live oral Ty21a	Vivotif®	Berna	Live, attenuated	4-capsule package
Yellow Fever	YF-Vax®	sanofi-pasteur	Live, attenuated	single- and 5-dose vial

Diphtheria

Diphtheria is an acute, toxin-mediated disease caused by the bacterium *Corynebacterium diphtheriae*. The name of the disease is derived from the Greek *diphthera*, meaning leather hide. The disease was described in the 5th century BCE by Hippocrates, and epidemics were described in the 6th century AD by Aetius. The bacterium was first observed in diphtheritic membranes by Klebs in 1883 and cultivated by Löffler in 1884. Antitoxin was invented in the late 19th century, and toxoid was developed in the 1920s.

Diphtheria

- Greek *diphthera* (leather hide)
- Recognized by Hippocrates in 5th century BCE
- Epidemics described in 6th century
- *C. diphtheriae* described by Klebs in 1883
- Toxoid developed in 1920s

Corynebacterium diphtheriae

C. diphtheriae is an aerobic gram-positive bacillus. Toxin production (toxigenicity) occurs only when the bacillus is itself infected (lysogenized) by a specific virus (bacteriophage) carrying the genetic information for the toxin (tox gene). Only toxigenic strains can cause severe disease.

Culture of the organism requires selective media containing tellurite. If isolated, the organism must be distinguished in the laboratory from other *Corynebacterium* species that normally inhabit the nasopharynx and skin (e.g., diphtheroids).

C. diphtheriae has three biotypes—gravis, intermedius, and mitis. The most severe disease is associated with the gravis biotype, but any strain may produce toxin. All isolates of *C. diphtheriae* should be tested by the laboratory for toxigenicity.

Corynebacterium diphtheriae

- Aerobic gram-positive bacillus
- Toxin production occurs only when *C. diphtheriae* infected by virus (phage) carrying tox gene
- If isolated, must be distinguished from normal diphtheroid

Pathogenesis

Susceptible persons may acquire toxigenic diphtheria bacilli in the nasopharynx. The organism produces a toxin that inhibits cellular protein synthesis and is responsible for local tissue destruction and membrane formation. The toxin produced at the site of the membrane is absorbed into the bloodstream and then distributed to the tissues of the body. The toxin is responsible for the major complications of myocarditis and neuritis and can also cause low platelet counts (thrombocytopenia) and protein in the urine (proteinuria).

Clinical disease associated with non-toxin-producing strains is generally milder. While rare severe cases have been reported, these may actually have been caused by toxigenic strains that were not detected because of inadequate culture sampling.

Clinical Features

The incubation period of diphtheria is 2–5 days (range, 1–10 days).

Disease can involve almost any mucous membrane. For clinical purposes, it is convenient to classify diphtheria into a number of manifestations, depending on the site of disease.

Diphtheria Clinical Features

- Incubation period 2-5 days (range, 1-10 days)
- May involve any mucous membrane
- Classified based on site of infection
  - –anterior nasal
  - –pharyngeal and tonsillar
  - –laryngeal
  - –cutaneous
  - –ocular
  - –genital

Diphtheria

Pharyngeal and Tonsillar Diphtheria

- Insidious onset of exudative pharyngitis
- Exudate spreads within 2-3 days and may form adherent membrane
- Membrane may cause respiratory obstruction
- Fever usually not high but patient appears toxic

Anterior Nasal Diphtheria

The onset of anterior nasal diphtheria is indistinguishable from that of the common cold and is usually characterized by a mucopurulent nasal discharge (containing both mucus and pus) which may become blood-tinged. A white membrane usually forms on the nasal septum. The disease is usually fairly mild because of apparent poor systemic absorption of toxin in this location, and it can be terminated rapidly by antitoxin and antibiotic therapy.

Pharyngeal and Tonsillar Diphtheria

The most common sites of diphtheria infection are the pharynx and the tonsils. Infection at these sites is usually associated with substantial systemic absorption of toxin. The onset of pharyngitis is insidious. Early symptoms include malaise, sore throat, anorexia, and low-grade fever. Within 2–3 days, a bluish-white membrane forms and extends, varying in size from covering a small patch on the tonsils to covering most of the soft palate. Often by the time a physician is contacted, the membrane is greyish-green, or black if bleeding has occurred. There is a minimal amount of mucosal erythema surrounding the membrane. The membrane is adherent to the tissue, and forcible attempts to remove it cause bleeding. Extensive membrane formation may result in respiratory obstruction.

The patient may recover at this point; or if enough toxin is absorbed, develop severe prostration, striking pallor, rapid pulse, stupor, and coma, and may even die within 6 to 10 days. Fever is usually not high, even though the patient may appear quite toxic. Patients with severe disease may develop marked edema of the submandibular areas and the anterior neck along with lymphadenopathy, giving a characteristic "bullneck" appearance.

Laryngeal Diphtheria

Laryngeal diphtheria can be either an extension of the pharyngeal form or can only involve this site. Symptoms include fever, hoarseness, and a barking cough. The membrane can lead to airway obstruction, coma, and death.

Cutaneous (Skin) Diphtheria

In the United States, cutaneous diphtheria has been most often associated with homeless persons. Skin infections are quite common in the tropics and are probably responsible for the high levels of natural immunity found in these populations. Skin infections may be manifested by a scaling rash or by ulcers with clearly demarcated edges and membrane, but any chronic skin lesion may harbor *C. diphtheriae* along with other organisms. Generally, the organisms isolated

from recent cases in the United States were nontoxigenic. The severity of the skin disease with toxigenic strains appears to be less than in other forms of infection with toxigenic strains. Skin diseases associated with nontoxigenic strains are no longer reported to the National Notifiable Diseases Surveillance System in the United States.

Other sites of involvement include the mucous membranes of the conjunctiva and vulvovaginal area, as well as the external auditory canal.

Complications

Most complications of diphtheria, including death, are attributable to effects of the toxin. The severity of the disease and complications are generally related to the extent of local disease. The toxin, when absorbed, affects organs and tissues distant from the site of invasion. The most frequent complications of diphtheria are myocarditis and neuritis.

Diphtheria Complications

- Most attributable to toxin
- Severity generally related to extent of local disease
- Most common complications are myocarditis and neuritis
- Death occurs in 5%-10%

Myocarditis may present as abnormal cardiac rhythms and can occur early in the course of the illness or weeks later, and can lead to heart failure. If myocarditis occurs early, it is often fatal.

Neuritis most often affects motor nerves and usually resolves completely. Paralysis of the soft palate is most frequent during the third week of illness. Paralysis of eye muscles, limbs, and diaphragm can occur after the fifth week. Secondary pneumonia and respiratory failure may result from diaphragmatic paralysis.

Other complications include otitis media and respiratory insufficiency due to airway obstruction, especially in infants.

Death

The overall case-fatality rate for diphtheria is 5%–10%, with higher death rates (up to 20%) among persons younger than 5 and older than 40 years of age. The case-fatality rate for diphtheria has changed very little during the last 50 years.

Laboratory Diagnosis

Diagnosis of diphtheria is usually made on the basis of clinical presentation since it is imperative to begin presumptive therapy quickly.

Culture of the lesion is done to confirm the diagnosis. It is critical to take a swab of the pharyngeal area, especially any discolored areas, ulcerations, and tonsillar crypts. Culture medium containing tellurite is preferred because it provides a selective advantage for the growth of this organism.

A blood agar plate is also inoculated for detection of hemolytic streptococcus. If diphtheria bacilli are isolated, they must be tested for toxin production.

Gram stain and Kenyon stain of material from the membrane itself can be helpful when trying to confirm the clinical diagnosis. The Gram stain may show multiple club-shaped forms that look like Chinese characters. Other *Corynebacterium* species (diphtheroids) that can normally inhabit the throat may confuse the interpretation of direct stain. However, treatment should be started if clinical diphtheria is suggested, even in the absence of a diagnostic Gram stain.

In the event that prior antibiotic therapy may have impeded a positive culture in a suspect diphtheria case, two sources of evidence can aid in presumptive diagnosis: 1) isolation of *C. diphtheriae* from cultures of specimens from close contacts, or 2) a low nonprotective diphtheria antibody titer (less than 0.1 IU) in serum obtained prior to antitoxin administration. This is done by commercial laboratories and requires several days. To isolate *C. diphtheriae* from carriers, it is best to inoculate a Löffler or Pai slant with the throat swab. After an incubation period of 18–24 hours, growth from the slant is used to inoculate a medium containing tellurite.

Medical Management

Diphtheria Antitoxin

Diphtheria antitoxin, produced in horses, was first used in the United States in 1891. It is no longer indicated for prophylaxis of contacts of diphtheria patients, only for the treatment of diphtheria. Since 1997, diphtheria antitoxin has been available only from CDC, and only through an Investigational New Drug (IND) protocol.

Diphtheria Antitoxin

- Produced in horses
- First used in the U.S. in 1891
- Used only for treatment of diphtheria
- Neutralizes only unbound toxin

Antitoxin will not neutralize toxin that is already fixed to tissues, but it will neutralize circulating (unbound) toxin and will prevent progression of disease. The patient must be tested for sensitivity before antitoxin is given. Consultation on the use of diphtheria antitoxin is available through the duty officer at the CDC during office hours (8:00 a.m.–4:30 p.m. ET) at 404-639-3158, or at all other times through CDC's Emergency Operations Center at 770-488-7100.

Persons with suspected diphtheria should be given antibiotics and antitoxin in adequate dosage and placed in isolation after the provisional clinical diagnosis is made and appropriate cultures are obtained. Respiratory support and airway maintenance should also be administered as needed.

Antibiotics

Treatment with erythromycin orally or by injection (40 mg/kg/day; maximum, 2 gm/day) for 14 days, or procaine penicillin G daily, intramuscularly (300,000 U/day for those weighing 10 kg or less, and 600,000 U/day for those weighing more than 10 kg) for 14 days. The disease is usually not contagious 48 hours after antibiotics are instituted. Elimination of the organism should be documented by two consecutive negative cultures after therapy is completed.

Preventive Measures

For close contacts, especially household contacts, a diphtheria booster, appropriate for age, should be given. Contacts should also receive antibiotics—benzathine penicillin G (600,000 units for persons younger than 6 years old and 1,200,000 units for those 6 years old and older) or a 7- to 10-day course of oral erythromycin, (40 mg/kg/day for children and 1 g/day for adults). For compliance reasons, if surveillance of contacts cannot be maintained, they should receive benzathine penicillin G. Identified carriers in the community should also receive antibiotics. Maintain close surveillance and begin antitoxin at the first signs of illness.

Contacts of cutaneous diphtheria should be treated as described above; however, if the strain is shown to be nontoxigenic, investigation of contacts can be discontinued.

Epidemiology

Occurrence

Diphtheria occurs worldwide, but clinical cases are more prevalent in temperate zones. In the United States during the pretoxoid era, the highest incidence was in the Southeast during the winter. More recently, highest incidence rates have been in states with significant populations of Native Americans. No geographic concentration of cases is currently observed in the United States.

Diphtheria Epidemiology

• Reservoir	Human carriers Usually asymptomatic
• Transmission	Respiratory Skin and fomites rarely
• Temporal pattern	Winter and spring
• Communicability	Up to several weeks without antibiotics

Reservoir

Human carriers are the reservoir for *C. diphtheriae* and are usually asymptomatic. In outbreaks, high percentages of children are found to be transient carriers.

Transmission

Transmission is most often person-to-person spread from the respiratory tract. Rarely, transmission may occur from skin lesions or articles soiled with discharges from lesions of infected persons (fomites).

Diphtheria

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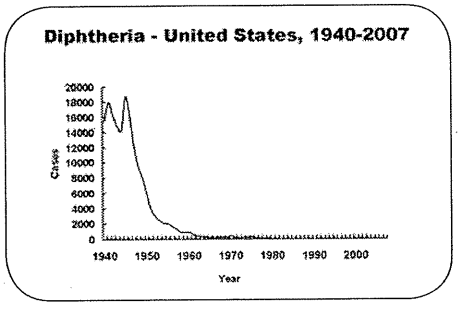

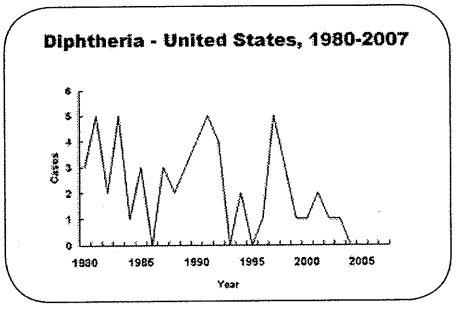

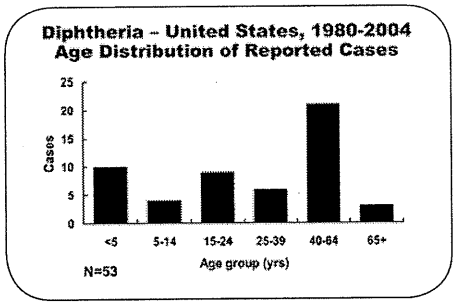

Temporal Pattern

In temperate areas, diphtheria most frequently occurs during winter and spring.

Communicability

Transmission may occur as long as virulent bacilli are present in discharges and lesions. The time is variable, but organisms usually persist 2 weeks or less, and seldom more than 4 weeks, without antibiotics. Chronic carriers may shed organisms for 6 months or more. Effective antibiotic therapy promptly terminates shedding.

Secular Trends in the United States

Diphtheria was once a major cause of morbidity and mortality among children. In England and Wales during the 1930s, diphtheria was among the top three causes of death for children younger than 15 years of age.

In the 1920s in the United States, 100,000–200,000 cases of diphtheria (140–150 cases per 100,000 population) and 13,000–15,000 deaths were reported each year. In 1921, a total of 206,000 cases and 15,520 deaths were reported. The number of cases gradually declined to about 19,000 cases in 1945 (15 per 100,000 population). A more rapid decrease began with the widespread use of toxoid in the late 1940s.

From 1970 to 1979, an average of 196 cases per year were reported. This included a high proportion of cutaneous cases from an outbreak in Washington State. Beginning in 1980, all cases with nontoxigenic cutaneous isolates were excluded from reporting. Diphtheria was seen most frequently in Native Americans and persons in lower socio-economic strata.

From 1980 through 2004, 57 cases of diphtheria were reported in the United States, an average of 2 or 3 per year (range, 0–5 cases per year). Only 5 cases have been reported since 2000.

Of 53 reported cases with known patient age since 1980, 31 (58%) were in persons 20 years of age or older; 44% of cases were among persons 40 years of age or older. Most cases have occurred in unimmunized or inadequately immunized persons. The current age distribution of cases corroborates the finding of inadequate levels of circulating antitoxin in many adults (up to 60% with less than protective levels).

Although diphtheria disease is rare in the United States, it appears that *Corynebacterium diphtheriae* continues to circulate in areas of the country with previously endemic diphtheria. In 1996, 10 isolates of *C. diphtheriae* were obtained from persons in an Native American community in South Dakota. Eight of these isolates were toxigenic.

None of the infected persons had classic diphtheria disease, although five had either pharyngitis or tonsillitis. The presence of toxigenic *C. diphtheriae* in this community is a good reminder for providers not to let down their guard against this organism.

Diphtheria continues to occur in other parts of the world. A major epidemic of diphtheria occurred in countries of the former Soviet Union beginning in 1990. By 1994, the epidemic had affected all 15 Newly Independent States (NIS). More than 157,000 cases and more than 5,000 deaths were reported. In the 6 years from 1990 through 1995, the NIS accounted for more than 90% of all diphtheria cases reported to the World Health Organization from the entire world. In some NIS countries, up to 80% of the epidemic diphtheria cases have been among adults. The outbreak and the age distribution of cases are believed to be due to several factors, including a lack of routine immunization of adults in these countries.

Diphtheria Toxoid

Characteristics

Beginning in the early 1900s, prophylaxis was attempted with toxin–antitoxin mixtures. Toxoid was developed around 1921 but was not widely used until the early 1930s. It was incorporated with tetanus toxoid and pertussis vaccine and became routinely used in the 1940s.

Diphtheria toxoid is produced by growing toxigenic *C. diphtheriae* in liquid medium. The filtrate is incubated with formaldehyde to convert toxin to toxoid and is then adsorbed onto an aluminum salt.

Single-antigen diphtheria toxoid is not available. Diphtheria toxoid is available combined with tetanus toxoid as pediatric diphtheria-tetanus toxoid (DT) or adult tetanus-diphtheria (Td), and with both tetanus toxoid and acellular pertussis vaccine as DTaP and Tdap. Diphtheria toxoid is also available as combined DTaP-HepB-IPV (Pediarix) and DTaP-IPV/Hib (Pentacel—see Chapter 14 for more information. Pediatric formulations (DT and DTaP) contain a similar amount of tetanus toxoid as adult Td, but contain 3 to 4 times as much diphtheria toxoid. Children younger than 7 years of age should receive either DTaP or pediatric DT. Persons 7 years of age or older should receive the adult formulation (adult Td), even if they have not completed a series of DTaP or pediatric DT. Two brands of Tdap are available—Boostrix (approved for persons 10 through 64 years of age) and Adacel (approved for persons 11 through 64 years of age). DTaP and Tdap vaccines do not contain thimerosal as a preservative.

DTaP, DT, Td and Tdap

	Diphtheria	Tetanus
DTaP, DT	7-8 Lf units	5-12.5 Lf units
Td, Tdap (adult)	2-2.5 Lf units	5 Lf units

DTaP and pediatric DT used through age 6 years. Adult Td for persons 7 years and older. Tdap for persons 10–64 years

Diphtheria Toxoid

- Formalin-inactivated diphtheria toxin
- Schedule: Three or four doses + booster
- Efficacy: Approximately 95%
- Duration: Approximately 10 years
- Should be administered with tetanus toxoid as DTaP, DT, Td, or Tdap

Diphtheria

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Routine DTaP Primary Vaccination Schedule

Dose	Age	Interval
Primary 1	2 months	---
Primary 2	4 months	4 weeks
Primary 3	6 months	4 weeks
Primary 4	15-18 months	6 months

Children Who Receive DT

- The number of doses of DT needed to complete the series depends on the child's age at the first dose:
  - —if first dose given at younger than 12 months of age, 4 doses are recommended
  - —if first dose given at 12 months or older, 3 doses complete the primary series

Routine DTaP Schedule for Children Younger Than 7 Years of Age

Booster Doses

- 4 through 6 years of age, before entering school
- 11 or 12 years of age if 5 years since last dose (Tdap)
- Every 10 years thereafter (Td)

Routine Td Schedule for Unvaccinated Persons 7 Years of Age and Older

Dose*	Interval
Primary 1	---
Primary 2	4 weeks
Primary 3	6 to 12 months

Booster dose every 10 years

*ACIP recommends that one of these doses (preferably the first) be administered as Tdap

Immunogenicity and Vaccine Efficacy

After a primary series of three properly spaced diphtheria toxoid doses in adults or four doses in infants, a protective level of antitoxin (defined as greater than 0.1 IU of antitoxin/mL) is reached in more than 95%. Diphtheria toxoid has been estimated to have a clinical efficacy of 97%.

Vaccination Schedule and Use

DTaP (diphtheria and tetanus toxoids and acellular pertussis vaccine) is the vaccine of choice for children 6 weeks through 6 years of age. The usual schedule is a primary series of 4 doses at 2,4,6, and 15–18 months of age. The first, second, and third doses of DTaP should be separated by a minimum of 4 weeks. The fourth dose should follow the third dose by no less than 6 months, and should not be administered before 12 months of age.

If a child has a valid contraindication to pertussis vaccine, pediatric DT should be used to complete the vaccination series. If the child was younger than 12 months old when the first dose of DT was administered (as DTP, DTaP, or DT), the child should receive a total of four primary DT doses. If the child was 12 months of age or older at the time the first dose of DT was administered, three doses (third dose 6–12 months after the second) completes the primary DT series.

If the fourth dose of DT, DTP or DTaP is administered before the fourth birthday, a booster (fifth) dose is recommended at 4 through 6 years of age. The fifth dose is not required if the fourth dose was given on or after the fourth birthday.

Because of waning antitoxin titers, most persons have antitoxin levels below the optimal level 10 years after the last dose. Tetanus toxoid should be given with diphtheria toxoid as Td every 10 years. The first booster dose may be given at 11 or 12 years of age if at least 5 years have elapsed since the last dose of DTP, DTaP, or DT. ACIP recommends this dose be administered as Tdap. If a dose is given sooner as part of wound management, the next booster is not needed for 10 years thereafter. More frequent boosters are not indicated and have been reported to result in an increased incidence and severity of local adverse reactions.

Td is the vaccine of choice for children 7 years and older and for adults. A primary series is three or four doses, depending on whether the person has received prior doses of diphtheria-containing vaccine and the age these doses were administered. The number of doses recommended for children who received one or more doses of DTP, DTaP, or DT before age 7 years is discussed above. For unvaccinated persons 7 years and older (including persons who cannot

document prior vaccination), the primary series is three doses. The first two doses should be separated by at least 4 weeks, and the third dose given 6 to 12 months after the second. For persons 10 years and older ACIP recommends that one of these doses (preferably the first) be administered as Tdap. A booster dose of Td should be given every 10 years. Tdap is approved for a single dose at this time (i.e., it should not be used for all the doses of Td in a previously unvaccinated person 7 years or older). Refer to the pertussis chapter for more information about Tdap.

Interruption of the recommended schedule or delay of subsequent doses does not reduce the response to the vaccine when the series is finally completed. There is no need to restart a series regardless of the time elapsed between doses.

Diphtheria disease might not confer immunity. Persons recovering from diphtheria should begin or complete active immunization with diphtheria toxoid during convalescence.

Contraindications and Precautions to Vaccination

Persons with a history of a severe allergic reaction (anaphylaxis) to a vaccine component or following a prior dose should not receive additional doses of diphtheria toxoid. Diphtheria toxoid should be deferred for those persons who have moderate or severe acute illness, but persons with minor illness may be vaccinated. Immunosuppression and pregnancy are not contraindications to receiving diphtheria toxoid. See pertussis chapter for additional information on contraindications and precautions to Tdap.

Diphtheria and Tetanus Toxoids Contraindications and Precautions

- Severe allergic reaction to vaccine component or following a prior dose
- Moderate or severe acute illness

Adverse Reactions Following Vaccination

Local reactions, generally erythema and induration with or without tenderness, are common after the administration of vaccines containing diphtheria toxoid. Local reactions are usually self-limited and require no therapy. A nodule may be palpable at the injection site for several weeks. Abscess at the site of injection has been reported. Fever and other systemic symptoms are not common.

Exaggerated local (Arthus-type) reactions are occasionally reported following receipt of a diphtheria- or tetanus-containing vaccine. These reactions present as extensive painful swelling, often from shoulder to elbow. They generally begin 2–8 hours after injections and are reported most often in adults, particularly those who have received frequent doses of diphtheria or tetanus toxoid. Persons experiencing these severe reactions usually have very high serum antitoxin levels; they should not be given

Diphtheria and Tetanus Toxoids Adverse Reactions

- Local reactions (erythema, induration)
- Fever and systemic symptoms not common
- Exaggerated local reactions (Arthus-type)
- Severe systemic reactions rare

further routine or emergency booster doses of Td more frequently than every 10 years. Less severe local reactions may occur in persons who have multiple prior boosters.

Rarely, severe systemic reactions such as generalized urticaria, anaphylaxis, or neurologic complications have been reported following administration of diphtheria toxoid.

Vaccine Storage and Handling

All diphtheria-toxoid-containing vaccines should be stored continuously at 35°–46°F (2°–8°C). Freezing reduces the potency of the tetanus component. Vaccine exposed to freezing temperature should never be administered.

Suspect Case Investigation and Control

Immediate action on all highly suspect cases (including cutaneous) is warranted until they are shown not to be caused by toxigenic *C. diphtheriae*. The following action should also be taken for any toxigenic *C. diphtheriae* carriers who are detected.

1. Contact state health department or CDC.
2. Obtain appropriate cultures and preliminary clinical and epidemiologic information (including vaccine history).
3. Begin early presumptive treatment with antibiotics and antitoxin. Impose strict isolation until at least two cultures are negative 24 hours after antibiotics were discontinued.
4. Identify close contacts, especially household members and other persons directly exposed to oral secretions of the patient. Culture all close contacts, regardless of their immunization status. Ideally, culture should be from both throat and nasal swabs. After culture, all contacts should receive antibiotic prophylaxis. Inadequately immunized contacts should receive DTaP/DT/Td/Tdap boosters. If fewer than three doses of diphtheria toxoid have been given, or vaccination history is unknown, an immediate dose of diphtheria toxoid should be given and the primary series completed according to the current schedule. If more than 5 years have elapsed since administration of diphtheria toxoid-containing vaccine, a booster dose should be given. If the most recent dose was within 5 years, no booster is required (see the ACIP's 1991 Diphtheria, Tetanus, and Pertussis: *Recommendations for Vaccine Use and Other Preventive Measures* for schedule for children younger than 7 years of age). Unimmunized contacts should start a course of DTaP/DT/Td vaccine and be monitored closely for symptoms of diphtheria for 7 days.
5. Treat any confirmed carrier with an adequate course of antibiotic, and repeat cultures at a minimum of 2 weeks