

Changing Epidemiology of Pertussis in the United States: Increasing Reported Incidence Among Adolescents and Adults, 1990–1996

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Since 1990, the reported incidence of pertussis has increased in the United States with peaks occurring every 3–4 years. On the basis of analysis of pertussis cases reported to the Centers for Disease Control and Prevention, the incidence remained stable among children aged younger than 5 years, most of whom were protected by vaccination. In contrast to 1990–1993, during 1994–1996, the average incidence among persons aged 5–9 years, 10–19 years, and 20 years or older increased 40%, 106%, and 93%, respectively. Since 1990, 14 states reported pertussis incidences of ≥ 2 cases per 100,000 population during at least 4 years between 1990 and 1996; seven of these states also reported that a high proportion of cases occurred in persons aged 10 years or older. Analysis of national data on pertussis did not provide sufficient information to fully elucidate the relative importance of multiple possible explanations for the increase in the incidence of pertussis in adolescents and adults. Improvement in diagnosis and reporting of pertussis in this age group, particularly in some states, is an important factor contributing to the overall increase.

Pertussis, a disease caused by the bacterium *Bordetella pertussis* and characterized by a paroxysmal cough phase lasting several weeks, continues to be an important cause of morbidity in the United States. A dramatic decline in the incidence of disease was observed following the widespread use of whole-cell pertussis vaccines in the mid-1940s. However, since the early 1980s, the reported incidence of pertussis has been increasing, with peaks continuing to occur every 3–4 years (figure 1) [1]. Large outbreaks were reported in Cincinnati and Chicago in 1993 and in Idaho, Massachusetts, and Vermont in 1996 [2–4]. In 1996, 7,796 cases of pertussis were reported, the highest number of pertussis cases reported since 1967.

This increase in the reported incidence of pertussis occurred in a period when the rate of vaccination coverage among pre-school-aged children reached its highest levels in the United States. The rate of vaccination coverage with at least three doses of diphtheria and tetanus toxoids and whole-cell pertussis vaccine (DTP) increased from 61% in 1991 to 95% in 1995 and 1996 [5]. The rate of vaccination coverage with at least four doses of DTP was 81% in 1996, compared with 59% in 1992. During the same period, in two randomized, controlled trials conducted in Europe, the efficacy of one of the whole-

cell pertussis vaccines widely used in the United States was found to be low (36% and 48%) [6, 7]. However, our recent calculations of the effectiveness of the pertussis vaccination program in the United States, which were made by using the screening method, indicated that the overall effectiveness of three doses of pertussis vaccine against clinical disease was 82% (95% CI, 79%–85%) [8]. The screening method utilizes data from the national disease surveillance and data on vaccination coverage and provides a crude measure of vaccine effectiveness. In this investigation, we were unable to determine what proportion of children had received vaccine that was shown to have a lower efficacy in the European trials, because surveillance and coverage data did not have information about vaccine manufacturers.

Although, in general, pertussis vaccines are highly effective against pertussis disease, immunity following vaccination appears to wane over time [9–11]. Waning immunity plays an important role in the occurrence of pertussis in older age groups. Another possible reason for the increase in the reported incidence of pertussis could be increased diagnosis and reporting of cases. Last, a combination of all of the factors listed above could play a role in the increase. Herein, the epidemiology of pertussis in the United States during 1990–1996 that was based on national surveillance data is described, and possible reasons for the increased reported incidence of pertussis in recent years and the change in age distribution of reported cases are discussed.

Methods

Pertussis is a notifiable disease in every state in the United States. Cases are reported by physicians, laboratories, hospital infection control personnel, and other health care professionals

Received 26 August 1998; revised 22 January 1999.

This work was presented in part at the 37th Interscience Conference on Antimicrobial Agents and Chemotherapy held in Toronto on 28 September–1 October 1997 and at the International Conference on Emerging Infectious Diseases held in Atlanta on 8–11 March 1998.

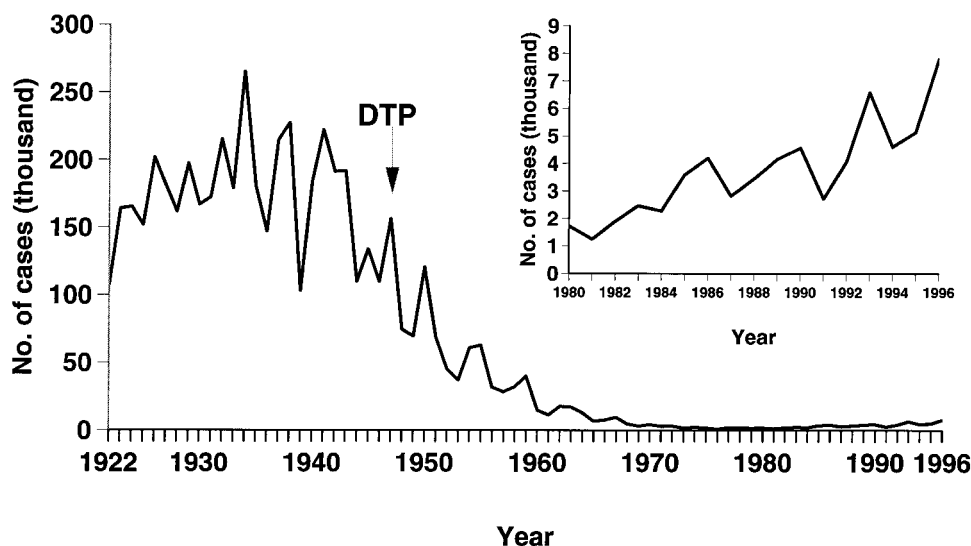
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Clinical Infectious Diseases 1999;28:1230–7

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Figure 1. Reported cases of pertussis in the United States during 1922–1996. Inset, pertussis cases reported in the United States during 1980–1996.



to local and state health departments. State and local health department personnel carry out investigations and determine if reported cases meet the case definition. Data are then submitted to the Centers for Disease Control and Prevention (CDC) by using one of the systems described below.

Case Definition

The clinical and laboratory criteria for defining a case of pertussis as recommended by the Council for State and Territorial Epidemiologists were used during 1990–1996 [12]. The clinical case definition is cough illness lasting ≥ 14 days with one of the following: paroxysms of coughing, inspiratory “whoops,” or posttussive vomiting with no other apparent cause (as reported by a health professional). In outbreak settings, the clinical case definition can be limited to cough illness lasting ≥ 14 days (as reported by a health professional). A probable case is one that meets the clinical case definition and is not laboratory-confirmed or epidemiologically linked to a laboratory-confirmed case. A confirmed case is one that meets the clinical case definition and is laboratory-confirmed or epidemiologically linked to a laboratory-confirmed case.

The laboratory criterion for diagnosis of pertussis is isolation of *B. pertussis* from a clinical specimen. In June 1996, the Council for State and Territorial Epidemiologists revised the case definition to include a PCR assay positive for *B. pertussis* as laboratory confirmation of pertussis [13]. The PCR technique for *B. pertussis* is not widely available in the United States; therefore, in 1996, addition of confirmation by PCR assay to the case definition did not have a major impact on the number of cases reported. Although not applicable to this report, in June 1997, an additional clarification was made to the case definition: a case with any duration of acute cough illness in which a culture is positive is classified as confirmed [14].

National Reporting Systems

The pertussis reporting system has three major components: the National Notifiable Disease Surveillance System (NNDSS), in which core information about pertussis cases is reported electronically through the National Electronic Telecommunications System for Surveillance (NETSS); the Supplementary Pertussis Surveillance System (SPSS), a paper-based system; and a new electronic work sheet linked to NETSS, which collects information similar to that collected by SPSS.

NNDSS. The information collected by this system is limited to basic demographic data and date of disease onset. Data are received on a weekly basis via NETSS. This database is maintained by the Epidemiology Program Office, CDC, and reported cases are tabulated weekly in the Morbidity and Mortality Weekly Report.

SPSS. SPSS was introduced in 1979. Local or state health officials complete detailed case report forms including data such as symptoms, vaccination history (number of doses received), and laboratory test results. Apnea is defined as prolonged failure to take a breath that may occur either after a coughing spasm or without prior coughing in an infant. Pneumonia is assessed as present only if supported by a positive chest roentgenogram. In SPSS, the report forms are mailed or faxed to CDC.

NETSS extended electronic screen for pertussis. Beginning at the end of 1994, an additional electronic screen linked to NETSS was introduced. The extended electronic screen is designed to replace SPSS. By the end of 1996, 44 of 50 states were using the extended electronic screen. This screen allows entry of detailed information on vaccination history (i.e., vaccination date, vaccine type, and vaccine manufacturer). Data on clinical findings, laboratory test results, treatment, and epidemiological classification of the suspected case are also reported. This screen is designed to increase the timeliness of reporting

and to provide more detailed information on vaccination history and laboratory test results of reported pertussis cases than was previously available from SPSS.

Pertussis Vaccination Status

We used the routine schedule for pertussis vaccination recommended by the Advisory Committee on Immunization Practices to determine whether children with pertussis were age appropriately vaccinated at the time of onset of pertussis [15]. The primary series for pertussis vaccination consists of three doses administered at ages 2, 4, and 6 months. Booster doses are recommended at ages 15–18 months and 4–6 years. If at least 6 months have elapsed since the third dose, a child who is not likely to return for a visit at the recommended age can be vaccinated as early as 12 months of age. During 1990–1996, DTP was used widely for the primary series and booster doses. Since 1991, two formulations of acellular pertussis vaccine combined with diphtheria and tetanus toxoids (DTaP) have been licensed for use as booster doses. Since July 1996, four formulations of DTaP have been licensed for use in the primary series, and DTaP is now recommended for both the primary series and booster doses [15].

Analytical and Statistical Methods

Until 1996, data from different surveillance systems were compiled separately, and no attempts were made to match cases from separate systems. Demographic information was obtained from NETSS data. For information on symptoms, vaccination history, and laboratory findings, SPSS data were used. However, because in 1996 it became possible to report the extended information from the same case to both the new NETSS extended electronic screen and SPSS, 1996 data from both SPSS and the extended electronic screen were concatenated, and duplicates (identified by comparing date of birth, date of cough onset, sex, and county and state of report) were deleted.

Except for calculation of the age-specific incidence of pertussis, results were not extrapolated to include missing data. To maintain consistency with previously published reports [1, 16], two groups of cases were excluded from analysis: all cases reported to either surveillance system from Puerto Rico and other U.S. territories ($n = 9$) and cases without cough ($n = 52$).

To assess the age distribution of cases reported by different states in 1996, states were divided into two groups: states that reported high incidences of pertussis (i.e., ≥ 2 cases per 100,000 population in ≥ 4 years between 1990 and 1996) and all the remaining states. The proportion of cases in different age groups was compared between the two groups.

Results

Overall Incidence and Laboratory Diagnosis

During 1990–1996, a total of 35,508 cases of pertussis were reported by state health departments to CDC through NNDSS

(4,570 in 1990; 2,719 in 1991; 4,083 in 1992; 6,586 in 1993; 4,617 in 1994; 5,137 in 1995; and 7,796 in 1996) (figure 1). The incidence generally increased over time, from 1.8 cases per 100,000 population in 1990 to 2.9 cases per 100,000 population in 1996.

Of the 31,867 cases for which extended information was available, 39% were confirmed by a positive laboratory test (culture or PCR assay) or were epidemiologically linked to a laboratory-confirmed case, 44% were probable, and 17% were neither probable nor confirmed but had cough illness.

Results of nasopharyngeal cultures for *B. pertussis* were reported to CDC for 16,895 persons, of whom 11,426 (68%) had a positive result. The proportion of positive cultures declined by age group; *B. pertussis* was isolated from 75% of 8,378 children aged younger than 1 year, 67% of 3,280 children aged 1–4 years, 61% of 1,692 persons aged 5–9 years, 59% of 2,253 persons aged 10–19 years, and 47% of 1,278 persons aged 20 years or older.

Overall in the states other than Massachusetts, the proportion of nasopharyngeal specimens collected in the first 10 days of cough illness from persons aged 10 years or older has not changed; however, in Massachusetts, since 1994 the proportion has increased (40% in 1994; 54% in 1995; and 77% in 1996). During this period, the proportion of culture-positive cases among persons tested who were aged 10 years or older increased from 49% in 1994 to 81% in 1995 and 96% in 1996.

PCR assay was performed on specimens from 360 patients (94% of cases were from 1996). Of these specimens, 280 (78%) were positive. The proportion of patients for whom PCR assays were positive decreased with increasing age: 93% of patients aged younger than 1 year, 74% of patients aged 1–4 years, 83% of patients aged 5–9 years, 67% of patients aged 10–19 years, and 47% of patients aged 20 years or older.

Of the 52 cases that were excluded from the analysis because of absence of cough, 18 were culture-positive. Of the 18 persons for whom cultures were positive, 3 (16%) were aged younger than 1 year, 1 (6%) was aged 1–4 years, 5 (28%) were aged 5–9 years, and 9 (50%) were aged 10 years or older. These people were identified during investigation of contacts. The duration of culture positivity was not investigated.

Age of Patients

Children aged younger than 1 year accounted for the highest proportion of cases reported during 1990–1996. However, the proportion of cases in this age group decreased over time. Forty-four percent of the persons whose cases were reported during 1990–1993 were aged younger than 1 year, and 22% were aged 1–4 years (table 1); during 1994–1996, the proportion of cases in children aged younger than 1 year and 1–4 years was 34% and 16%, respectively. The incidence among preschool-aged children (i.e., age younger than 5 years) remained relatively stable during the 7-year period (figure 2), with a 4% increase among patients aged younger than 1 year

Table 1. Age distribution and age-specific incidence of pertussis cases reported during 1990–1993 and 1994–1996 in the United States and the change in incidence between the two periods.

Age group (y)	1990–1993		1994–1996		Change in incidence (%)
	No. (%) of cases	Incidence*	No. (%) of cases	Incidence*	
Younger than 1	7,640 (44)	48.1	5,857 (34)	50.1	4
1–4	3,861 (22)	6.3	2,817 (16)	6.0	–4
5–9	1,808 (10)	2.5	1,978 (12)	3.5	40
10–19	2,337 (13)	1.7	3,808 (22)	3.4	106
20 or older	1,844 (11)	0.3	2,772 (16)	0.5	93
Total	17,490 (100)	1.8	17,232 (100)	2.2	25

* No. of cases per 100,000 population.

and a 4% decrease among patients aged 1–4 years. Although the proportion of cases in children aged 5–9 years was similar during 1990–1993 and 1994–1996, the incidence increased 40%. The highest increase (106%) was observed among persons aged 10 years or older, and the incidence among persons aged 20 years or older almost doubled (93%).

Most (82%) of the infants (i.e., younger than 1 year of age) whose cases were reported during 1990–1996 were aged younger than 6 months, an age group for whom primary pertussis vaccination with three doses is incomplete. Thirty-five percent of the cases in infants occurred in children aged younger than 2 months who were too young to have received any pertussis vaccine.

Sex

Overall, reported incidences among females and males were similar (1.8 and 1.7 cases per 100,000 population, respectively), although the ratio of incidences among females and males was

greater in older age groups. For example, among children aged younger than 10 years, the incidence was 8.2 cases per 100,000 population among females and 7.9 cases per 100,000 population among males. Incidences among older females and males, respectively, were as follows: persons aged 10–19 years, 2.6 cases per 100,000 population vs. 2.1 cases per 100,000 population; persons aged 20–39 years, 0.6 case per 100,000 population vs. 0.3 case per 100,000 population; and persons aged 40 years or older, 0.3 case per 100,000 population vs. 0.2 case per 100,000 population.

Vaccination Status

Of 10,617 children aged 3 months to 4 years who had reported cases of pertussis and known vaccination status, 5,008 (47%) had not been vaccinated age appropriately against pertussis: 2,680 children (25%) had received no doses of pertussis vaccine. Of 6,828 children aged 7 months to 4 years, 3,353 (49%) had not received at least three doses of pertussis vaccine, the minimal number of doses considered necessary for optimal protection against pertussis. Of 1,317 children between 5 and 6 years of age, 707 (54%) had not received the recommended four or more doses of pertussis vaccine, 643 (49%) had not received three doses (i.e., the primary series), and 422 (32%) had received no doses (table 2).

Clinical Characteristics

Sixty-one percent of infants and 76% of patients aged 10 years or older had cough durations of ≥ 21 days. The proportion of cases with paroxysmal cough was high in all age groups (e.g., 90% of patients aged younger than 5 years and 86% of patients aged 20 years or older). Vomiting, whoop, and apnea, each reported in $>55\%$ of cases in patients aged younger than 1 year, decreased in frequency with increasing age. Of the adults aged 20 years or older who had reported cases, 43% had vomiting, and 38% had whoop.

A total of 9,958 persons were reported to have been hospitalized with pertussis, and 2,735 developed pneumonia (table 3).

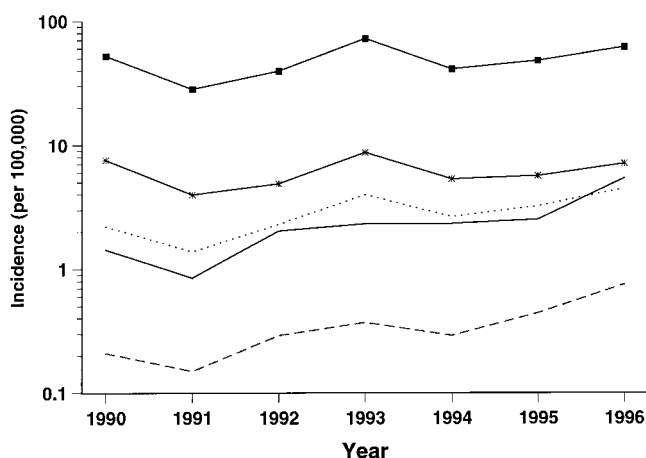


Figure 2. Incidence of reported pertussis cases per 100,000 population by age (y) in the United States during 1990–1996. —■— = younger than 1 y; —*— = 1–4 y; ---- = 5–9 y; — = 10–19 y; - - - = older than 19 y.

Table 2. DTaP or DTP vaccination history of infants and children aged 3 months to 19 years who had reported cases of pertussis in the United States during 1990–1996: comparison with number of DTaP or DTP doses appropriate for age.

Age	No. of persons*	No. of doses of DTaP or DTP appropriate for age†	Percentage of persons who received indicated no. of doses					Percentage of persons who received no. of doses appropriate for age (1980–1989)‡
			0	1	2	3	≥4	
3–4 mo	2,522	1	23	55§	21	<1	0	50
5–6 mo	1,267	2	22	26	41§	11	<1	25
7–11 mo	1,541	3	28	18	18	37§	<1	18
12–18 mo	1,429	3	22	12	11	48§	7	32
19 mo to 4 y	3,858	4	28	11	7	12	43§	28
5–9 y	3,115	4–5	28	13	5	4	50§	50
10–19 y	4,738	4–5	8	4	3	4	80§	NR

NOTE. DTaP = diphtheria and tetanus toxoids with acellular pertussis vaccine; DTP = diphtheria and tetanus toxoids with whole-cell pertussis vaccine; NR = not reported.

* Based on persons for whom age and vaccination status were reported.

† Allowing for a 3-month period (e.g., 2–4 months) to receive each scheduled dose.

‡ Data are from [1].

§ The proportion of children who received the recommended number of doses for their age.

|| Among persons aged 5–6 years.

Seizures were described in 418 patients, encephalopathy was described in 70 patients, and 57 deaths were attributed to pertussis. Patients aged younger than 6 months had the highest rate of complications: 72.2% were hospitalized, 17.3% were reported to have had pneumonia, and 2.1% were reported to have had seizures (compared with 46%, 14.8%, and 2% of patients aged 6–11 months, respectively, during the same period). The proportion of complications declined markedly with increasing age.

The proportion of patients hospitalized, in particular those older than 6 months of age, decreased over time. In 1990, 47% of patients aged 6–11 months, 22% of patients aged 1–4 years, 12% of patients aged 5–9 years, 7% of patients aged 10–19 years, and 5% of patients aged 20 years or older were hospitalized. In 1996, these proportions were 37%, 14%, 4%, 2%, and 3%, respectively.

Geographic Distribution

Pertussis cases were reported from all 50 states and the District of Columbia during 1990–1996. However, the reported annual incidence of pertussis varied greatly between states. Certain states repeatedly reported higher incidences of pertussis than did others. For example, 14 states (Arizona, Colorado, Hawaii, Idaho, Massachusetts, Minnesota, New Hampshire, New Mexico, New York, Oregon, Utah, Vermont, Washington, and Wisconsin) reported incidences of ≥2 cases per 100,000 population for ≥4 years during 1990–1996. Florida, Georgia, Louisiana, Mississippi, New Jersey, and West Virginia reported the lowest incidences throughout the period.

The proportion of patients with reported cases who were adolescents (i.e., 10–19 years of age) and adults varied between states as well. In nine states (Arizona, Colorado, Idaho, Mary-

Table 3. Hospitalizations, complications, and deaths in reported cases of pertussis in the United States during 1990–1996 by age group.

Age	No. of persons*	No. (%) of persons				
		Hospitalization	Pneumonia†	Seizures	Encephalopathy	Death
Younger than 6 mo	10,093	7,199 (72.2)	1,516 (17.3)	205 (2.1)	44 (0.5)	49 (0.5)
6–11 mo	2,282	1,034 (46.0)	297 (14.8)	43 (2.0)	6 (0.3)	3 (0.1)
1–4 y	5,828	1,136 (19.8)	512 (9.7)	101 (1.8)	8 (0.1)	2 (<0.1)
5–9 y	3,439	248 (7.3)	145 (4.5)	26 (0.8)	3 (0.1)	3 (0.1)
10–19 y	5,945	177 (3.0)	130 (2.3)	23 (0.4)	6 (0.1)	0
20 y or older	4,250	164 (3.9)	135 (3.4)	20 (0.5)	3 (0.1)	0
Total	31,837‡	9,958§ (31.7)	2,735 (9.5)	418# (1.4)	70# (0.2)	57# (0.2)

* Based on persons for whom age and clinical data were reported.

† Radiographically confirmed.

‡ Excludes 28 patients (0.001%) whose ages were unknown.

§ Excludes seven hospitalized patients (0.001%) whose ages were unknown. Data on hospitalization were not reported for 431 patients (0.01%).

|| Excludes one patient with pneumonia (0.00003%) whose age was unknown. Data on pneumonia were not reported for 3,005 patients (9.5%).

Data on seizures, encephalopathy, and outcome were not reported for 1,419 patients (4.4%), 814 patients (2.6%), and 142 patients (0.005%), respectively.

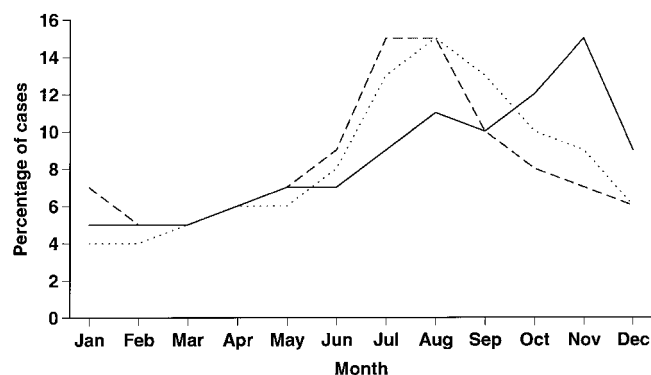


Figure 3. Proportion of pertussis cases reported each month by age (y) in the United States during 1990–1996. --- = younger than 5 y; — = 5–19 y; ---- = older than 19 y.

land, Massachusetts, New Hampshire, North Carolina, Vermont, and Wisconsin), the proportion of cases in adolescents and adults was $\geq 25\%$ during ≥ 4 years in 1990–1996. Except for North Carolina and Maryland, all of these states were also among those 14 states that reported high incidences of pertussis during this period.

The proportion of cases in different age groups was compared between two groups of states: those 14 states that reported incidences of ≥ 2 cases per 100,000 population for ≥ 4 years during 1990–1996 and the remaining 36 states that reported incidences of < 2 cases per 100,000 population for ≥ 4 years during the same period. Although 58% of the cases reported in the 14 states occurred in persons aged 5 years or older, in the rest of the states only 29% of all cases reported were in this age group. More than one-half of the cases reported in states with low incidences occurred in infants.

Seasonality

During 1990–1996, cases occurred in all seasons, but variation in the occurrence of cases was seen when cases in different age groups were analyzed. In general, reported pertussis cases in children aged younger than 5 years and adults aged 20 years or older peaked between June and September (figure 3), and cases in persons aged 5–19 years peaked between October and December (i.e., the first few months of the school year).

Discussion

Similar to what occurred during the 1980s, the incidence of pertussis increased progressively during 1990 through 1996, with peaks occurring every 3 years. The increase in incidence, in particular since 1993, has been mainly due to the substantial increase in the number of reported cases in persons aged 10 years or older. During 1994–1996, the incidence among persons in this age group doubled compared with the incidence during 1990–1993. During the period 1985–1988, it was esti-

mated that only 11.6% of pertussis cases were reported to CDC [17]. Underreporting of pertussis cases, because of a lack of typical pertussis symptoms such as whoop, may be higher for adolescents and adults than for young children. In addition, low yields of cultures of specimens from patients in this age group (due to previous vaccination, late specimen collection, and antibiotic use) may result in fewer diagnoses of pertussis and underestimation of the true incidence; however, intensified surveillance efforts and health care providers' increased awareness of pertussis in adolescent and adult patients may be contributing factors to the increased reporting of cases in this age group in recent years. The decreased proportion of hospitalized cases in older persons that was seen during 1990–1996 also suggests improved diagnosis and reporting of mild disease in this age group.

National surveillance data indicate that the incidence of pertussis and the proportion of cases in adolescents and adults vary greatly among states. Those states that report higher proportions of cases in the older age group also report high incidences of pertussis, and certain states consistently report higher incidences of pertussis than do others. The reasons for this pattern are unclear; however, these data suggest that completeness of reporting may not be similar in all states. In states in which surveillance efforts have been intensified, milder cases in adolescents and adults may be detected and reported. Such efforts appear to have a role in the high incidence of culture-confirmed pertussis that was described among adolescents in Vermont in 1996 [4]. Serological diagnosis (as practiced in Massachusetts [18]), which is not widely available in most states, had an impact on the reported number of cases, especially in adolescents and adults. However, in recent years there has been an increase in the reported number of culture-confirmed cases in adolescents and adults as well. Since 1994, an increase in the proportion of nasopharyngeal specimens collected in the first 10 days of cough illness from persons aged 10 years or older has been noted. This increase may have been due in part to a letter sent out in mid-1995 by the Massachusetts State Laboratory Institute that requested physicians to submit only specimens collected within 2 weeks of cough onset. This practice and extensive contact investigation during school outbreaks may have increased the proportion of specimens collected in the early phase of disease. To better understand whether incidences of pertussis in different states are a result of detection and reporting differences, surveillance activities need to be enhanced in states that report low incidences of pertussis as well.

The limited data available on the duration of pertussis vaccine-induced immunity suggest that vaccinated persons become susceptible to pertussis disease ~ 5 –10 years following vaccination [9–11]. It is also possible that the rate at which vaccine-induced immunity wanes may vary depending on the type or brand of vaccine. Waning immunity likely plays a role in the increasing incidence of pertussis among persons aged 10 years or older; however, it remains unclear as to whether

the role of waning is any greater in the 1990s than it was in the 1970s or 1980s.

Currently, no pertussis vaccines are licensed for use for persons aged 7 years or older. Several studies have suggested that acellular pertussis vaccines are safe and immunogenic when they are administered to adults [19–23]. A randomized, controlled study supported by the National Institutes of Health is under way to evaluate the safety and efficacy of an acellular pertussis vaccine for adolescents and adults.

In recent years, the incidence of pertussis among infants and young children has remained relatively stable in the United States. Most of the cases in infants occurred in those too young to complete the primary series with three doses of pertussis vaccine. The relatively stable incidence among infants and young children may be due to high rates of vaccination coverage in the United States since the early 1990s. Pertussis outbreaks in populations of children for whom the rate of vaccination coverage is high have been reported [2]. It is expected that the proportion of cases in vaccinated persons will increase as the rate of vaccination coverage increases [24]. In comparison with 1980–1989, the proportion of patients who had received the number of pertussis vaccinations appropriate for their age increased during 1990–1996, a period when high rates of vaccination coverage were achieved (table 2) [1].

Assessments based on the screening method suggest that the overall pertussis vaccination program in the United States is effective against clinical pertussis disease [8]. However, estimates of vaccine-specific effectiveness cannot be calculated on the basis of the available surveillance data. Recent data from western Europe and Canada suggest that prevalent *B. pertussis* strains may change over time [25–27]. Although whether available pertussis vaccines are less effective against these new strains is not yet known, it is critical to closely monitor the efficacy of pertussis vaccines and circulating strains in the United States. CDC, in collaboration with state health departments, has initiated enhanced surveillance activities in six states where epidemiological data are collected along with *B. pertussis* isolates to monitor the effect of acellular pertussis vaccines on the strains.

Currently available diagnostic laboratory tests for pertussis have limitations [28, 29]. Culture, which is considered the gold standard, is specific but not sensitive. Direct fluorescent antibody assay is not considered a confirmatory test for purposes of national surveillance, because of variations in sensitivity and specificity [29]. Because serological methods have not been standardized and the correlation between antibody levels and immunity to pertussis has not been established, serology is not yet accepted as a criterion for laboratory confirmation purposes of national reporting. PCR analysis is a new diagnostic technique that is also not standardized, but it is sensitive and specific and is quick to perform [30]. Some laboratories are beginning to use this technique. Contamination of samples with *B. pertussis* in the field during specimen collection or with DNA or bacteria from laboratory strains of *B. pertussis*

or another *Bordetella* species results in false-positive results [30]. Obtaining isolates of *B. pertussis* is critical to confirm the diagnosis, to direct efforts to control spread of infection, to test for antibiotic resistance, and to monitor circulating strains [31–33].

In conclusion, the increase in the reported incidence of pertussis in recent years is mainly due to an increase in the number of reported cases in persons aged 10–19 years. Several factors may contribute to this increase, such as improved reporting of pertussis cases (especially in some states) and use of diagnostic methods that are more sensitive than culture. To understand the true burden of disease in adolescents and adults, active surveillance is needed in different areas of states with low and high incidences as well as enhanced surveillance activities, in particular, in those states that report low incidences. In the near future, acellular pertussis vaccines may be licensed for use for persons 7 years of age or older in the United States. These new vaccines may have a role in the prevention of disease and control of outbreaks in adolescents and adults.

Acknowledgments

The authors acknowledge the personnel of local and state health departments who contributed to the data from the national pertussis surveillance.

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