

Chapter 11: Pneumococcal

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I. Disease Description

Streptococcus pneumoniae (pneumococcus) is a Gram-positive bacterium with more than 90 known serotypes. Pneumococcus is spread by airborne droplets and is a leading cause of serious illness, including bacteremia, meningitis, and pneumonia among children and adults worldwide.^{1,2} Although all serotypes can cause serious disease, a relatively limited number of serotypes cause the majority of invasive pneumococcal disease (IPD).

The Centers for Disease Control and Prevention's (CDC's) Active Bacterial Core Surveillance (ABCs) has tracked IPD in selected regions of the United States since 1994. ABCs data indicate that individuals <2 and ≥65 years of age have the highest rates of invasive disease (Table 1).^{2,3} Approximately 10% of all patients with invasive pneumococcal disease die of their illness, but case-fatality rates are higher for the elderly and patients with certain underlying illnesses.^{3,4}

Table 1: Incidence of pneumococcal infections in the United States

| Age (years) | Disease Incidence Cases/100,000 (number of cases) | Death Rate Deaths/100,000 (number of deaths) |
|--------------|--|---|
| <1 | 17.7 (702) | 0.20 (8) |
| 1 | 12.6 (500) | 0.20 (8) |
| 2–4 | 5.07 (606) | 0.13 (16) |
| 5–17 | 1.23 (659) | 0.00 (0) |
| 18–34 | 2.33 (1,757) | 0.08 (60) |
| 35–49 | 6.48 (3,982) | 0.46 (284) |
| 50–64 | 14.8 (9,326) | 1.47 (932) |
| 65–74 | 18.0 (4,952) | 2.17 (597) |
| 75–84 | 29.0 (4,042) | 4.53 (631) |
| ≥85 | 45.4 (2,856) | 11.4 (718) |
| Total | 9.14 (29,382) | 1.01 (3,254) |

Each year in the United States, pneumococcal disease accounts for a substantial number of cases of invasive and non-invasive disease including meningitis, bacteremia, pneumonia, and acute otitis media (AOM).^{3–8} A recent analysis estimated that pneumococcal disease was responsible for 4 million illness episodes, 445,000 hospitalizations and 22,000 deaths annually.⁹ Pneumococcal disease is preceded by asymptomatic colonization of the nasopharynx which tends to be especially common in children.¹⁰ AOM is the most common clinical manifestation of pneumococcal infection among children and the most common outpatient diagnosis resulting in antibiotic prescriptions in that group.¹¹

II. Background

Pneumococcal vaccines

Two different types of pneumococcal vaccines, polysaccharide and conjugate vaccines, are employed in the prevention of pneumococcal disease. Polysaccharide vaccines contain capsular pneumococcal polysaccharide antigens, while conjugate vaccines contain an immunogenic nonpneumococcal protein conjugated to individual pneumococcal polysaccharides.



A pneumococcal polysaccharide vaccine (PPSV) targeting 23 of the most common serotypes of *S. pneumoniae* has been available since 1983. PPSV23 is approximately 56%–75% efficacious for the prevention of invasive pneumococcal infection caused by vaccine serotypes.^{12,13} The Advisory Committee on Immunization Practices (ACIP) recommends that PPSV23 be administered to persons ≥ 2 years of age who have any of several underlying medical conditions and to all persons >65 years of age.^{5,14}

In February 2000, a 7-valent pneumococcal conjugate vaccine (PCV7) was licensed by the U.S. Food and Drug Administration (FDA) for use among infants and young children. In pre-licensure randomized trials, PCV7 was demonstrated to be safe and highly efficacious against IPD, moderately efficacious against pneumonia, and somewhat effective in reducing otitis media episodes and related office visits.^{15–17} On the basis of the results of these clinical trials, in 2000, the ACIP recommended routine use of PCV7 for all children 2–23 months of age and for children 24–59 months of age who are at increased risk for pneumococcal disease (e.g., children with anatomic or functional asplenia, sickle cell disease (SCD), HIV infection or other immunocompromising conditions, or chronic illnesses including chronic heart or lung disease, cerebrospinal fluid [CSF] leaks, and diabetes mellitus).^[11] In 2007, the ACIP revised its recommendation for routine use to include all children 2–59 months of age.¹⁸

In February 2010, a new 13-valent pneumococcal conjugate vaccine (PCV13) was approved by the FDA and replaced PCV7 for all recommended indications.¹⁹ PCV13 is formulated and manufactured using the same processes as PCV7 and was licensed by FDA on the basis of studies demonstrating safety and ability comparable to that of PCV7 to elicit antibodies protective against IPD. PCV13 contains the 7 serotypes included in PCV7 (4, 6B, 9V, 14, 18C, 19F and 23F), as well as 6 additional serotypes (1, 3, 5, 6A, 7F and 19A). PCV13 is approved in infants and young children for prevention of IPD caused by the 13 serotypes in the vaccine. It is also approved for the prevention of otitis media caused by the seven serotypes covered by PCV7; however, no efficacy data for prevention of otitis media are available for the six additional serotypes.¹

On December 30, 2011, PCV13 was licensed for use in adults ≥ 50 years of age on the basis of studies demonstrating the safety and immunogenicity non-inferior to PPSV23.²⁰ In a double-blind randomized trial among adults in the Netherlands, PCV13 was found to be 75% effective at preventing PCV13-type IPD and 45% effective at preventing non-bacteremic pneumonia caused by vaccine serotypes among adults aged 65 or older.²¹ In late 2014, the ACIP recommended PCV13 for routine vaccination of adults >65 years of age.²² PCV13 is also recommended for individuals 6–64 years of age with select underlying conditions, such as those with anatomic or functional asplenia, sickle cell disease, HIV infection or other immunocompromising condition, as well as persons with a CSF leak or cochlear implant.^{23,24}

Trends in invasive pneumococcal disease

Following the introduction of PCV7 in 2000, dramatic declines in IPD were reported among children <5 years of age. Before introduction of PCV7, rates of PC7-type IPD among children in this age were around 80 cases per 100,000 population. After the introduction of PCV7, rates of disease due to these 7 serotypes dropped dramatically to less than 1 case per 100,000 by 2007 (Figure 1).²⁵

The use of PCV7 in children <5 years of age also reduced the burden of IPD among older children and adults through reduced transmission of vaccine serotype pneumococci (herd protection). In 1998–99, rates of PCV7-type IPD among adults 65 years of age or older were around 40 cases per 100,000 population. After the introduction of PCV7, rates of disease due to these 7 serotypes had declined 45% by 2007 (Figure 2).^{25–29}

At the same time, increases in disease caused by serotypes not included in PCV7 (i.e., replacement disease) were observed among children and adult populations, although these increases were small in magnitude compared with the overall reduction in disease.^{25,30} After the introduction of PCV13 in 2010, cases of invasive disease due to the 6 additional serotypes covered by the vaccine saw a decrease similar to what was observed post-PCV7.^{29,31} In 2007–08 (pre-PCV13), rates of PCV13-type IPD among children <5 years of age were around 14 cases per 100,000. In 2014–15 (post-PCV13), rates of PCV13-type disease had decreased by 87% (Figure 1).³ After introduction of PCV13 in children, older adults also saw reductions in IPD through herd protection. In 2007–08, rates of PCV13-type IPD among adults 65 years of age and older were around 17 cases per 100,000. In 2014–15, rates of PCV13-type disease had

decreased by 70% (Figure 2). As of 2014–15, no significant increases in non-PCV13-type IPD have been observed in any age group since the introduction of PCV13.³ In late 2014, PCV13 was approved for routine use among adults 65 years of age or older. It will be important to continue to monitor trends in IPD as vaccination use increases among this age group.

Figure 1. Rates of invasive pneumococcal disease among children <5 years of age, 1998–2015³

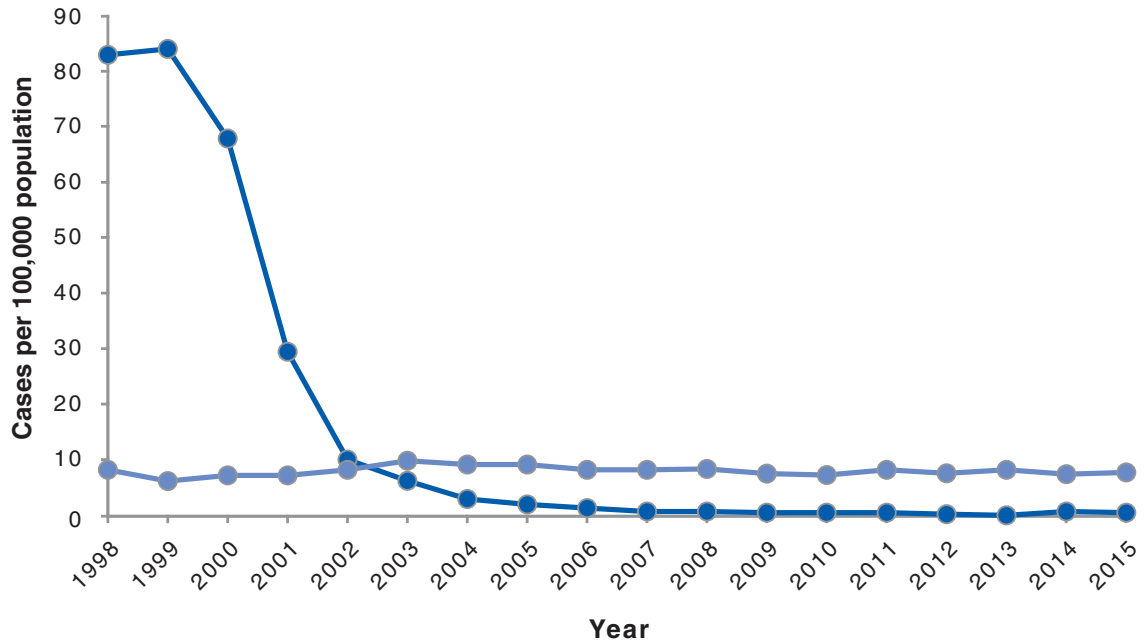
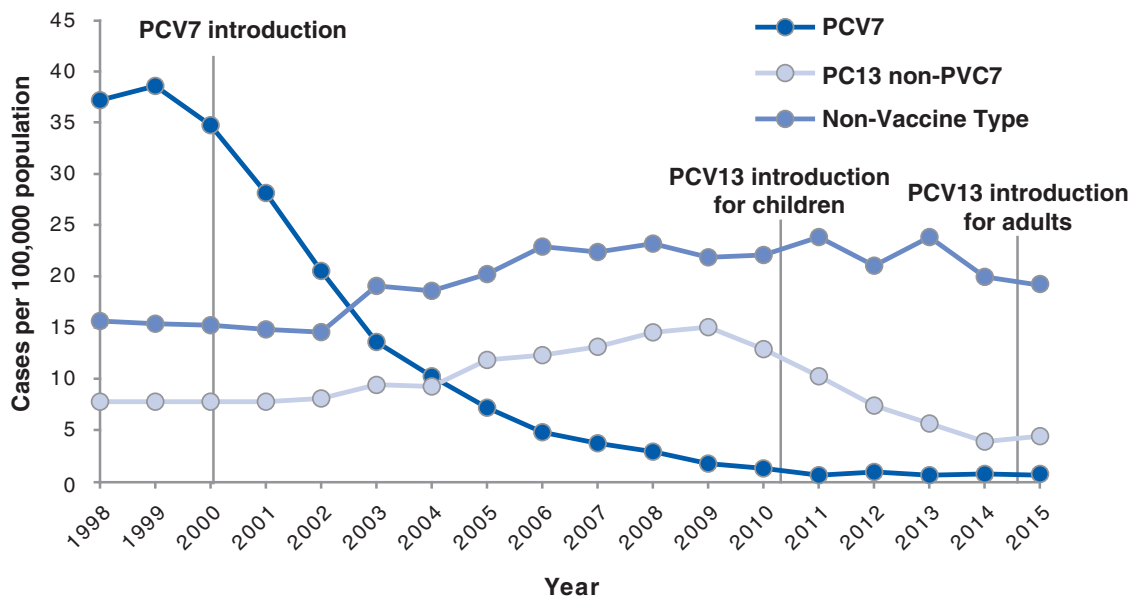


Figure 2. Rates of invasive pneumococcal disease among U.S. adults >65 years of age, 1998–2015³



Antimicrobial resistance trends

Before 1990, *S. pneumoniae* was almost uniformly susceptible to penicillin, allowing most physicians to treat persons with severe infections with penicillin alone. However, during the 1990's, resistance to penicillin and to multiple classes of antimicrobial agents spread rapidly in the United States with an increasing trend of invasive pneumococci resistant to 3 or more drug classes.^{32–35}

Following the introduction of PCV7 into the routine childhood immunization program in 2000, the incidence of antibiotic-resistant invasive disease declined substantially among both young children and older persons due to reductions in resistant infections caused by vaccine serotypes.^{28, 36–40} Between 1998–99 and 2008, penicillin-nonsusceptible IPD rates declined 64% for children <5 years of age and 45% for adults ≥65 years of age.⁴⁰ An increase in penicillin-nonsusceptible disease caused by serotypes not included in PCV7 was also identified during the same time period, although the magnitude of this effect remains small.³⁶ The prevalence of resistance varied by geographic area both before and after PCV7 introduction, with higher prevalence noted in the southeastern United States.^{32, 36} During 2007–08, serotypes unique to PCV13 (i.e., serotypes contained in PCV13 but not PCV7) caused 78–97% of penicillin-nonsusceptible IPD, depending on age.⁴⁰ The introduction of PCV13 in 2010 has led to further reductions in antibiotic-nonsusceptible IPD rates. From 2009–2013 rates of antibiotic-nonsusceptible IPD caused by serotypes included in PCV13, but not in PCV7, decreased by 97% among children <5 years old, and 64% among adults >65 years old.⁴¹

In 2008, the Clinical and Laboratory Standards Institute (CLSI) established new, higher minimum inhibitory concentration (MIC) breakpoints for defining pneumococcal susceptibility to parenterally administered penicillin when treating pneumococcal disease other than meningitis.⁴² Regardless of whether the old or new parenteral penicillin breakpoints are used, penicillin-nonsusceptible IPD caused by PCV13 serotypes has decreased significantly for all age groups.^{40, 41}

The emergence of drug resistant *S. pneumoniae* (DRSP) has made treatment of pneumococcal disease more difficult. Because of a lack of rapid, sensitive, and specific diagnostic tests, therapy for pneumonia and milder illnesses such as otitis media remains empiric. In addition groups of experts have provided national guidance for treating infections commonly caused by pneumococcus, such as otitis media and pneumonia, because of the increasing prevalence of DRSP.^{43–46} Few communities exist in which resistance remains uncommon, and even in these communities, resistant infections can occur. For these reasons, clinicians and public health officials should follow national guidelines rather than attempt to create local treatment recommendations based on local resistance data. Due to the limitations of current diagnostic testing, clinicians often prescribe empiric antibacterial therapy that is not indicated or is unnecessarily broad. Inappropriate antimicrobial use contributes to the development of DRSP. Principles have been developed to encourage appropriate use of antimicrobial agents for adults and children with upper respiratory infections.^{6, 47–50}

III. Importance of Surveillance

Surveillance for invasive pneumococcal disease has four main goals:

- characterization of national and local trends,
- detection of geographic and temporal changes in the prevalence of DRSP,
- monitoring impact of vaccines on disease, and
- informing future vaccine development.

With the recent introduction of PCV13, surveillance for IPD disease among children <5 years of age is particularly important for identifying populations that may not be receiving vaccination and for monitoring the incidence of disease caused by non-vaccine serotypes (i.e., replacement disease). Surveillance for IPD disease in persons ≥5 years of age is useful to monitor the impact of PPSV vaccination, the indirect effects of PCV13, and replacement disease. Following the 2014 recommendations for PCV13 use among adults ≥65 years of age, monitoring disease trends in this age group is important to assess whether PCV13 use among adults led to further reductions in disease burden, in addition to the benefits observed through PCV13 use among children (herd effects).²⁹

Serotyping of pneumococcal isolates can improve understanding of vaccine effects. However, serotyping is expensive and requires specialized reagents and extensive technical training; therefore, serotyping capacity is not widely available. The use of polymerase chain reaction (PCR) to identify pneumococcal capsular genes specific for individual capsular serotypes may be feasible for some state public health and academic research centers.^{51,52} CDC's Antibiotic Resistance Laboratory Network (ARLN) and Vaccine Preventable Disease (VPD) programs can provide serotyping assistance for state health departments. For additional information on serotyping requests, contact ARLN@cdc.gov.

Pneumococcal surveillance enables recognition of new or rare resistance patterns. Surveillance information can be used on the national level for research and policy development and at the state or local level to raise awareness of DRSP among clinicians and the general public. Surveillance data also may be useful for tracking the impact of interventions aimed at reducing unnecessary use of antimicrobial agents.

IV. Disease Reduction Goals

Healthy People 2020¹⁰ includes targets for reducing IPD among children and adults.⁵³ Target reduction goals for children <5 years and adults ≥65 years of age are 12 and 31 IPD cases per 100,000, respectively. In addition, Healthy People 2020 includes a target goal to reduce antibiotic-resistant pneumococcal infection among children <5 years of age and adults ≥65 years of age are 12 and 31 IPD cases per 100,000, respectively.⁵³ The 2 Healthy People 2020 targets for children and the IPD target for older adults were met in 2011, and the target for antibiotic-resistant IPD in older adults was met in 2013.⁴¹

Continuous surveillance is important to evaluate the impact of PCV13 on the incidence of invasive pneumococcal disease, antibiotic-resistant pneumococcal infections, and to monitor disease caused by pneumococcal serotypes not included in PCV13 (i.e., replacement disease).

Disease reduction goals also focus on minimizing complications of DRSP infections through prevention and control measures. Geographic differences in antibiotic prescribing practices have been described.⁵⁴ In sites where antibiotic prescribing is high, the proportion of IPD nonsusceptible to antibiotics is also high, suggesting that local prescribing practices may contribute to local resistance patterns.

In 1995, the CDC launched a national campaign to reduce antimicrobial resistance through promotion of appropriate antibiotic use a program which was later named *Get Smart: Know When Antibiotics Work* (www.cdc.gov/getsmart). The program continues to work with a wide variety of academic and government stakeholders, including state and local health departments, academic institutions, large healthcare systems, and healthcare professional organizations to address appropriate antibiotic use in their communities.

V. Case Definition

Case definitions for DRSP and IPD originally approved by the Council of State and Territorial Epidemiologists (CSTE) in 1994 and 2000, respectively.^{55,56} Invasive DRSP for all ages was nationally notifiable, as was all IPD in children <5 years of age. The 2 different case definitions had separate reporting codes. To avoid the potential for duplicate notification of individual cases, the CSTE case definitions were modified in 2006 to clarify that a case should be reported only once, under a single code.⁵⁷ In 2009, the CSTE case definition was modified so that all IPD was nationally notifiable, regardless of drug resistance or the case patient's age. Prior to 2017, case definitions for "confirmed" and "suspected" cases of IPD were specifically defined, and both were notifiable under CSTE definition.⁵⁸ Beginning in 2017, a new "probable" case classification was added to capture cases diagnosed using culture-independent diagnostic tests (CIDTs), and replaced the "suspected" case definition. The following definitions are in use for national notification of IPD in the United States.

Confirmed: Isolation of *S. pneumoniae* from a normally sterile site (e.g., blood, cerebrospinal fluid, or, less commonly, joint, pleural or pericardial fluid). (Event code 11723)

Probable: Identification of *S. pneumoniae* from a normally sterile body site by a CIDT without isolation of the bacteria.⁵⁹

Confirmed and suspected cases of IPD should be reported to public health authorities within 1 week of diagnosis. CSTE also recommends certain clinical and epidemiological information be collected, including

date of illness onset, clinical syndrome (e.g., pneumonia, meningitis), underlying medical conditions, type of diagnostic test used, and pneumococcal vaccination history. DRSP is no longer collected in national surveillance as a separate event from IPD.⁵⁸

VI. Laboratory Testing

Specimen collection

Specimen collection and shipping are important steps in obtaining laboratory diagnosis or disease confirmation. Guidelines have been published for specimen collection and handling for viral and microbiologic agents. Information is also available on using CDC laboratories as support for reference and disease surveillance; resources include:

- a central website (<https://www.cdc.gov/laboratory/specimen-submission/index.html>) for requesting lab testing;
- the CDC Infectious Diseases Laboratories Test Directory (<https://www.cdc.gov/laboratory/specimen-submission/list.html>);
- the form required for submitting specimens to CDC (Form 50.34, <https://www.cdc.gov/laboratory/specimen-submission/pdf/form-50-34.pdf>); and
- information on general requirements for shipment of etiologic agents (<https://www.cdc.gov/vaccines/pubs/surv-manual/appx/appendix24-etiological-agent.pdf>).

Similarly to CDC, state laboratories provide online test directories containing lists of orderable tests for that institution, along with appropriate specimen types, collection methods, specimen volume, and points of contact.

Specimen testing

Definitive diagnosis of pneumococcal infection is confirmed by the recovery of *S. pneumoniae* from a normally sterile body site (e.g., blood, CSF, pleural fluid, or peritoneal fluid). Because pneumococci frequently colonize the upper respiratory tract in the absence of disease, the clinical significance of recovering the organism from nonsterile body sites (e.g., expectorated sputum, conjunctiva) is less certain. Gram stain may be helpful in interpreting cultures of expectorated sputum; finding a predominance of gram-positive diplococci and >25 leukocytes with <10 epithelial cells per high power field on microscopic examination supports the diagnosis of pneumococcal pneumonia, but does not satisfy the case definition for national surveillance for IPD. Detection of pneumococcal capsular antigen in urine is useful for the diagnosis of pneumococcal pneumonia in adults.

Based on recommendations from the CLSI, clinical laboratories should test all isolates of *S. pneumoniae* from CSF for resistance to penicillin and cefotaxime, ceftriaxone, or meropenem, using a reliable Minimum Inhibitory Concentration (MIC) method. CSF isolates can also be tested for resistance to vancomycin using the MIC or disk method.⁶⁰ Penicillin susceptibility breakpoints were changed in 2009 for nonmeningitis isolates, resulting in somewhat lower proportions of nonmeningeal isolates characterized as nonsusceptible.⁶¹ For organisms isolated from other invasive sources, laboratories should consider testing for resistance to erythromycin, penicillin, trimethoprim-sulfamethoxazole, clindamycin, cefotaxime, ceftriaxone, meropenem, tetracycline, vancomycin, and a fluoroquinolone such as levofloxacin. Pneumococci resistant to vancomycin or linezolid have never been described. For vancomycin, a strain is considered non-susceptible if it has a MIC of >1 µg/ml or zone diameter <17 mm. For linezolid, nonsusceptible strains are those with a MIC of >2 µg/ml or zone diameter <21 mm. Strains found to be nonsusceptible to vancomycin or linezolid should be submitted to a reference laboratory for confirmatory testing, and if resistant, reported to the state health department.⁶⁰ Because pneumococci are fastidious organisms, some susceptibility testing methods used for other organisms are not appropriate for pneumococci (see the CLSI document for testing recommendations).⁶⁰

CDC's ARLN is available to assist state public health laboratories with susceptibility testing of IPD isolates. States can request testing for select IPD isolates. Contact ARLN@cdc.gov for information on this program. Additionally, isolates with unusual resistance features can be sent to the CDC Streptococcus Laboratory for phenotypic verification and genomic analysis employing their specialized bioinformatics

pipeline for detecting resistance determinants (<https://www.ncbi.nlm.nih.gov/pubmed/27542334>). Contact pneumococcus@cdc.gov for additional information. State health department laboratories that obtain penicillin-binding protein gene sequencing information may consider using the CDC Streptococcus Laboratory database for deducing β -lactam antibiotic MICs (<https://www.cdc.gov/streplab/mic-tables.html>; <https://www.ncbi.nlm.nih.gov/pubmed/27302760>).

Serologic testing

Currently licensed vaccines target a limited number of pneumococcal polysaccharide capsule serotypes. Identifying the serotypes of pneumococcal strains can be useful for evaluating outbreaks of pneumococcal disease, such as those that occur in institutional settings. Serotyping is currently performed in only a limited number of state public health laboratories, academic centers, or at CDC Jurisdictions' public health laboratories may consider adopting a PCR-based technique for determining capsular serotypes.^{51,52} The CDC Streptococcal Reference Laboratory (<https://www.cdc.gov/streplab/index.html>) provides numerous protocols and references for jurisdictions' health departments and clinical laboratories to identify pneumococcal serotypes using PCR.

If jurisdictions are unable to perform PCR serotyping, the CDC's ARLN and VPD programs can provide serotyping assistance for select IPD isolates or specimens. Contact ARLN@cdc.gov for serotyping assistance. The CDC *Streptococcus* Laboratory will conduct serotyping of pneumococcal isolates from blood, CSF, or other sterile sites in outbreak settings, and when appropriate will perform whole genome sequence analysis to determine strain features and relatedness between isolates from disease clusters. Contact pneumococcus@cdc.gov for outbreak assistance.

VII. Reporting and Case Notification

Case reporting within a jurisdiction

Each state and territory has regulations and laws governing the reporting of diseases and conditions of public health importance.⁶² These regulations and laws list the diseases that are to be reported, and describe those persons or institutions responsible for reporting, such as health-care providers, hospitals, laboratories, schools, daycare and childcare facilities, and other institutions. Detailed information on reportable conditions in each state is available through CSTE.⁶³

Most states currently require IPD to be reported to local or state health authorities, regardless of the age of the patient or presence of drug resistance. Additional states require reporting in limited populations, such as children <5 years of age. In jurisdictions with reporting requirements, confirmed and probable cases of IPD should be reported to state or local health departments by healthcare providers, which may include clinicians, laboratories, hospitals, and pharmacies.^{63,64} Healthcare providers should identify cases through microbiology laboratories, death certificates, hospital discharge or outpatient records, and electronic medical records. The following data are recommended for case investigation and reporting: patient's date of birth or age, the anatomic site of specimen collection, and type of infection. Other epidemiological information that is useful includes the patient's demographic information (e.g., sex, race and ethnicity), specimen collection date, whether the patient was hospitalized, clinical syndrome, antibiotic susceptibility, details of pneumococcal vaccination history, underlying medical conditions, daycare attendance, and outcome. Additional information may be collected at the direction of the state health department. The *S. pneumoniae* Surveillance Worksheet is included as Appendix 13 to serve as a guide for data collection during investigation of reported cases.

Case notification to CDC

Notifications for confirmed cases of IPD should be sent to CDC using event code 11723 in the National Notifiable Diseases Surveillance System (NNDSS).^{58,64,65} The *S. pneumoniae* Surveillance Worksheet is included as Appendix 13, to serve as a guide for data collection to be included in case investigations and case notification to CDC. Case notification should not be delayed because of incomplete information or lack of confirmation. The state in which the patient resides at the time of diagnosis should submit the case notification to CDC.

VIII. Vaccination

Pneumococcal conjugate vaccine (PCV13)

ACIP recommends that the 13-valent pneumococcal conjugate vaccine (PCV13) be used for all children <5 years of age.¹⁹ For routine immunization of infants, PCV13 is recommended as a 4-dose series at 2, 4, 6, and 12–15 months of age. Children 2–18 years of age with certain underlying medical conditions that put them at higher risk for disease should also receive PPSV23 after completing all recommended doses of PCV13.¹

In addition, a single dose of PCV13 should be administered to PCV13-naïve children 6–18 years of age who are at increased risk for IPD because of sickle cell disease, human immunodeficiency virus (HIV) infection or other immunocompromising condition, cochlear implant, or CSF leaks, regardless of whether they have previously received PCV7 or PPSV23.²³ A dose of PCV13 is also recommended for adults >19 years of age with sickle cell disease, HIV infection or other immunocompromising condition, cochlear implant, or CSF leaks, and for all adults >65 years of age.^{22,24}

Pneumococcal polysaccharide vaccine (PPV23)

Children ≥2 years of age with underlying medical conditions should receive PPSV23 at least 8 weeks after completing all recommended doses of PCV13.¹ Adults >19 years of age with sickle cell disease, HIV infection or other immunocompromising condition, cochlear implant, or CSF leaks, and all persons ≥65 years of age are recommended to receive a dose of PPSV23 following a dose of PCV13.^{22,24,66}

A single revaccination with PPSV23 at least 5 years following the most recent PPSV23 dose should be considered for persons ≥2 to 64 years of age who are at highest risk or likely to have rapid declines in serum antibody levels. This includes those with functional or anatomic asplenia, HIV infection, leukemia, lymphoma, Hodgkin's disease, multiple myeloma, generalized malignancy, chronic renal failure, nephrotic syndrome or immunosuppression (e.g., organ transplants or receiving chemotherapy). Pneumococcal vaccine may be administered concurrently with influenza vaccine by separate injection in the opposite arm.⁶⁷

IX. Enhancing Surveillance

Several surveillance activities may improve the detection and reporting of pneumococcal disease and the quality of the reports.

Enhancing reporting of antibiotic susceptibility results

Concern over rising resistance to antibiotics has prompted many state health departments to increase their focus on reporting susceptibility results. CDC has worked with state health departments to evaluate different surveillance methods to determine which methods would enhance the reliability of surveillance data, given certain goals and resource limitations.⁶⁸ Use of aggregated antibiogram data collected from all hospital laboratories within a specific area has been shown to give a relatively accurate description of the proportion of isolates that are resistant to penicillin and a limited number of other drugs.⁶⁹ Such data, however, typically cannot be analyzed by age group or other factors of interest. Sentinel systems, which may collect individual reports with more details from a limited number of laboratories, can give an accurate view of resistance if designed well.⁷⁰

Encouraging provider reporting

Most jurisdictions' infectious disease surveillance systems depend upon the receipt of case reports from healthcare providers and laboratories. These data are often incomplete and may not be representative of certain populations; completeness of reporting has been estimated to vary from 6% to 90% for many of the common notifiable diseases.⁶² It is important for healthcare providers to understand which events should be reported, and how critical accurate reporting is for control of communicable diseases. Increasing provider awareness of local rates of IPD and local reporting requirements may enhance surveillance.

Improving detection of DRSP in laboratories

Universal adoption of optimal testing methods and testing for resistance to recommended antibiotics would improve our ability to detect and monitor resistant pathogens.⁶⁰

Streamlining reporting using electronic methods

Although some surveillance systems still rely on paper and pencil for data collection, use of data from sources such as electronic medical records, electronic case reporting, and laboratory information management systems can significantly improve reporting speed, enhance data quality, and reduce workload.^{71–77}

X. Case Investigation

As with most respiratory pathogens, rapid, sensitive, and specific diagnostic tests are not available, although an assay to detect pneumococcal antigen in urine can be used to diagnose pneumococcal pneumonia or to rapidly detect pneumococcal meningitis. Early in the course of illness, diagnosis of *S. pneumoniae* infection is most often presumptive and the choice of antimicrobial therapy is nearly always empiric. However, once *S. pneumoniae* is isolated from a normally sterile body site, antimicrobial susceptibility testing may be necessary for patient management. Case investigations are not usually warranted, except in outbreaks or as determined by the state health department. CDC is available during outbreaks to assist with epidemiologic and laboratory investigations.

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