Invasive Pneumococcal Disease in Children Aged <5 Years Admitted to 3 Urban Hospitals in Ibadan, Nigeria

A. G. Falade,1 I. A. Lagunju,1 R. A. Bakare,2 A. A. Odekanmi,2 and R. A. Adegbola3

Departments of 1Pediatrics and 2Medical Microbiology, University College Hospital and College of Medicine, University of Ibadan, Ibadan, Nigeria; and 3Medical Research Council Laboratories, Fajara, The Gambia

Background. Streptococcus pneumoniae remains a major cause of childhood morbidity and mortality in the world. The introduction of pneumococcal conjugate vaccine in developing countries will be facilitated by a clearer understanding of the disease burden for bacterial causes of pneumonia and meningitis and the prevalent serotypes of S. pneumoniae.

Methods. We conducted a prospective, hospital-based surveillance for a 2-year period involving children aged 2–59 months at 3 urban hospitals in Ibadan, Nigeria, using standard microbiological methods with confirmation and further testing of isolates at the Medical Research Council Laboratories in The Gambia.

Results. There were 1210 cases overall: 481 (39.8%) were meningitis, 399 (33.0%) were pneumonia, and 330 (27.2%) were bacteremia clinical syndromes. There were 24 cases of definite meningitis, of which 9 were caused by S. pneumoniae, 11 by Haemophilus influenzae type b, and 4 by Klebsiella species. Of the 90 culture-positive pneumonia cases, 9 were caused by S. pneumoniae, 2 by H. influenzae type b, and 79 by other species. Among cases of bacteremia, the pathogen isolation rate was 28.8% (95 of 330); the isolated species included S. pneumoniae (3 isolates), Staphylococcus aureus (20 isolates), Klebsiella species (13 isolates), Salmonella species (15 isolates), and Escherichia coli (6 isolates). Of the 23 S. pneumoniae isolates, 11 were serotyped; the serotypes found were 5 (5 isolates), 19F (3 isolates), and 4 (3 isolates), and 1 isolate was nontypeable. These isolates were all susceptible to penicillin. Eight of 9 patients with definite pneumococcal meningitis died, whereas all patients with pneumococcal pneumonia and septicemia survived.

Conclusions. Of the pneumococcal serotypes identified, 55% were covered by the licensed 7-valent pneumococcal conjugate vaccine, whereas all are covered by the 10- and 13-valent vaccines.
monia, meningitis, and septicemia who presented to 3 hospitals in Ibadan, Nigeria.

PATIENTS AND METHODS

This was a prospective study of children with severe cases of community-acquired pneumococcal syndrome who were admitted to 3 hospitals in Ibadan, a city in the southwestern part of Nigeria: the University College Hospital (UCH), Adeoyo Maternity Hospital, and Oni Memorial Children’s Hospital.

The UCH is a tertiary care center and the first and largest teaching hospital in Nigeria. It serves as the major referral center for the southwestern part of the country and offers specialist inpatient and outpatient care for all age groups, across various specialties. The hospital has 700 beds, of which 160 are dedicated to pediatric admissions. The city of Ibadan has a population of ~4 million, and children aged <5 years constitute ~25% of the population. The Adeoyo Maternity Hospital and Oni Memorial Children’s Hospital are state hospitals. Other hospitals in Ibadan include 2 mission hospitals, 1 public hospital, and several private hospitals, which were not included in this study. We estimated that ~90% of the patients who had pneumococcal syndromes representative of pneumococcal disease—that is, pneumonia, meningitis, and septicemia—during the study period were hospitalized at the 3 hospitals where the study was performed. This assumption was based on the size of the hospitals and the catchment areas. The exact mortality rates among infants and children aged <5 years in the area are unknown, but they are believed to be at least as high as the national averages (infant mortality rate, 110 deaths per 1000 live births; mortality rate among children aged <5 years, 210 deaths per 1000 live births). This is substantially higher than the mortality rates (infant mortality rate, 75 deaths per 1000 live births) in the region of The Gambia where a pneumococcal trial took place [3]. Haemophilus influenzae type b (Hib) vaccine and PCV are not included in the National Programme of Immunisation in Nigeria, although Hib vaccines are given to some infants who receive care at a few of the private hospitals. The main causes of morbidity and mortality are pneumonia, malaria, diarrheal diseases, malnutrition, measles, and tuberculosis. The infant mortality rate is defined as the number of deaths among infants (aged ≤1 year) per 1000 live births, and the mortality rate for children aged <5 years is the number of deaths among children aged <5 years per 1000 live births. A recent hospital-based study at the UCH showed that malaria is the most common single cause of morbidity and mortality among children aged <5 years in the area, being responsible for ~13.1% of mortality, whereas pneumonia is the second most common cause, being responsible for ~9.0% [4]. The prevalence of HIV/AIDS in the adult population (aged, 15–49 years) during 2005–2006 was 3.9% [3]. The government of Nigeria started a national program in 2002 whereby 10,000 adults with HIV were to receive antiretroviral therapy.

Participants. All children between the ages of 2 and 59 months who were admitted consecutively into the pediatric units of the 3 hospitals, from 1 February 2005 through 31 January 2006 and from 1 July 2006 through 30 June 2007, with features compatible with case definitions for community-acquired pneumococcal disease were recruited into the study and had blood specimens taken for culture. In addition, lumbar puncture was performed for all children who met the UCH’s criteria for suspected meningitis. These indications were convulsion, altered consciousness, neck stiffness, irritability, bulging anterior fontanels, lethargy, and poor sucking (in infants). Lumbar puncture was not performed for children with signs of increased intracranial pressure, bleeding dyscrasia, and skin infection in the areas of the back used in lumbar puncture.

Lumbar puncture. All children who presented with clinical features suggestive of meningitis had a lumbar puncture performed, and CSF was collected in a neat, sterile container and was sent to the UCH laboratories for microbiological analysis and for protein and glucose measurement. A blood sample was taken for random plasma glucose measurement just before the lumbar puncture was performed, for comparison with the CSF glucose level. Although physicians normally may want to obtain samples for blood culture from all febrile children, it is not always feasible, because of financial constraints. In this study, blood samples were taken from the children concomitantly because the study received funding support. At least 1.0 mL of blood from each child was placed into each of tryptone soya broth and brain-heart infusion culture media by direct inoculation at the patient’s bedside, with use of standard aseptic procedures for aerobic and anaerobic cultures, respectively.

Laboratory analyses. The UCH was the largest and the main hospital in which the study was conducted. The laboratory was open 24 h per day to receive and process the CSF specimens within ~30 min of receipt. In addition, the CSF samples from the 2 other hospitals—Adeoyo Maternity Hospital and Oni Memorial Children’s Hospital—were collected almost always in the daytime and on weekdays and were sent to the UCH microbiology laboratory. The distance from the Adeoyo Maternity Hospital and Oni Memorial Children’s Hospital to the UCH was ~2 km and 10 km, respectively, and the transit time was ~10 min and 1 h, respectively.

A loopful of turbid CSF or sediment from a centrifuged sample was inoculated onto 5% sheep blood agar, MacConkey agar, and chocolate agar plates. Inoculated plates were incubated under aerobic conditions (for blood and MacConkey agar) or in a candle jar containing 5% carbon dioxide (for chocolate agar). All plates were incubated at 37°C for 24–48 h. Plates were examined after incubation for bacterial pathogens, by use of standard procedures. Isolates of S. pneumoniae and...
**H. influenzae** were transported to the Medical Research Council (MRC) Laboratories in Fajara, The Gambia, for confirmation, further characterization, serotyping, and antibiotic-susceptibility testing for detection of MIC values.

Samples of CSF were batched and tested simultaneously with the latex particle agglutination test (Wellcogen Bacterial Antigen Kit; Remel) and a rapid, sensitive immunochromatographic test for pneumococcal antigen (NOW *S. pneumoniae* Antigen Test; Binax). A proportion of the CSF specimens were tested because sufficient sample was not always available. The Binax NOW immunochromatographic test consists of a hinged device in which rabbit anti-pneumococcal antibody is adsorbed onto a nitrocellulose membrane (the sample line), and goat anti-rabbit IgG is adsorbed onto the same membrane as a second stripe (the control line). A second set of rabbit anti-pneumococcal antibodies are conjugated to gold particles dried onto an inert fibrous support. The technician performing the assay dabs a swab into the CSF sample and inserts it into the test device, adds a citrate buffer to facilitate antigen flow, and closes the device. If pneumococcal antigen is present in the specimen, it binds to the gold-conjugated rabbit antibodies, and the resulting complex is captured by the immobilized rabbit IgG stripe, forming the sample line. In addition, immobilized goat anti-rabbit IgG captures excess conjugated rabbit antibody, forming the control line. Results are read visually after 15 min, with the appearance of 2 pink-to-purple lines signifying a positive test result.

Inoculated blood culture bottles were incubated in the laboratory at 37°C for 24–48 h initially and then until day 7 if there was no bacterial growth. Subcultures of inoculated media were done twice, on days 2 and 3 after incubation, and were inoculated onto blood, MacConkey, and chocolate agar plates, which were incubated as done for CSF cultures. Further identification of bacterial cultures was undertaken at the study site by cultural morphological and biochemical methods. In addition, serotyping of the pneumococcal isolates was performed with capsular and factor-typing sera (Statens Serum Institut), with use of an antibody-coated latex agglutination assay at the MRC Laboratories, as described elsewhere [5]. Antimicrobial-susceptibility testing for MIC values was performed for each available isolate with use of E-strips (AB Biodisk), in accordance with the manufacturer’s instructions.

**Case definition.** Bacterial meningitis was diagnosed on the basis of standard microbiological and biochemical evaluation of CSF, pneumonia was diagnosed on the basis of chest radiograph findings, and septicemia was diagnosed on the basis of positive results of blood culture, with use of the Pneumococcal Vaccines Accelerated Development and Introduction Plan (PneumoADIP) standard case definitions that were made available before the beginning of the study (see the Appendix in this supplement). Purulent CSF was defined by a turbid or cloudy appearance, by a WBC count ≥100 cells/mm³, or by a WBC count of 10–99 cells/mm³ and a glucose level <40 mg/dL or protein level >100 mg/dL.

**Data analysis.** Data were double entered into a computer database (Excel; Microsoft) and were checked for errors by generation of frequencies for all variables. Data summarization was done using proportions, means, medians, and SDs, depending on the units of the variables.

**Ethics approval.** Ethics approval was granted by the Ministry of Health, Oyo State Ethics Committee, Ibadan.

**RESULTS**

During a 24-month period, 1210 children aged 2–59 months with suspected bacterial disease, of whom 61% were male and 39% were female (male-to-female ratio, 1.6:1), were investigated. There were 481 cases of meningitis clinical syndrome, 399 cases of pneumonia clinical syndrome, and 330 cases of septicemia clinical syndrome. Table 1 shows the number of cases and deaths for each diagnosis of disease, and table 2 shows the outcomes for each syndrome. Figure 1 shows the age distribution for the cases of meningitis, pneumonia, and septicemia clinical syndromes.

Eighteen Hib and 13 *S. pneumoniae* isolates identified from blood and CSF specimens at the UCH in Ibadan, Nigeria, were sent to the MRC Laboratories in The Gambia for confirmation and serotyping. The rate of correlation was deemed to be acceptable (75% and 91%, respectively). Of the 18 Hib isolates, 2 were lost during transit and 4 had been contaminated; of the remaining 12 isolates, 9 (75%) were confirmed to be Hib, and 3 were identified as *Brahamella catarrhalis*, *Streptococcus viridians*, and *S. pneumoniae*. Of the 13 isolates of pneumococci, 11 (91%) were confirmed, and 2 were identified as *Salmonella* species and *Streptococcus* species. The serotypes of the pneumococci were 19F (3 isolates), 4 (3 isolates), and 5 (5 isolates), and 1 isolate was nontypeable. The pneumococci of serotype 19F were isolated from 2 patients with meningitis; 2 were isolated from CSF specimens and 1 from a blood specimen. Of the remaining 9 pneumococcal isolates serotyped, 4 were obtained from blood; 2 were from pneumonia cases (serotype 4) and 2 were from sepsis cases (serotype 5). However, correlation between the 2 centers regarding *Staphylococcus aureus* isolates was very poor. Eighteen of the 74 *S. aureus* isolates identified at the UCH were sent for confirmation. Of these 18, only 1 was confirmed to be *S. aureus*; the others were characterized as coagulase-negative staphylococci (16 isolates) and *Salmonella typhimurium* (1 isolate). The identification from the MRC Laboratories was taken as correct. Other pneumococci (8 isolates) and Hib (6 isolates) that were lost during storage were taken to be correctly identified, even though their identification was not confirmed by the MRC Laboratories, because of the high level of correlation of results between the 2 centers for these 2
organisms. According to the current susceptibility criteria [6], 11 S. pneumoniae isolates from CSF and blood specimens were susceptible to penicillin, chloramphenicol, cefotaxime, erythromycin, and ciprofloxacin. They all showed intermediate resistance to tetracycline and were fully resistant to trimethoprim-sulfamethoxazole.

Overall, 21 children had invasive pneumococcal disease. Their ages ranged from 3 months to 48 months (mean ± SD, 17.5 ± 13.4 months; median, 13 months). Of the 21 children, 16 (76%) were aged < 2 years. There were 16 males and 5 females, for a male-to-female ratio of 3.2:1.

Meningitis. According to the case definition for meningitis, there were 535 children with meningitis, but CSF from 54 children was not evaluated, because lumbar puncture was not performed for 44 children and the CSF specimen collected from 10 children contained numerous RBCs. Two of the 44 patients for whom CSF was not available for analysis had isolates identified by blood culture (Pseudomonas aeruginosa and Klebsiella species). Lumbar puncture was performed for the remaining 481 patients, and culture as well as cytological and chemical analyses were performed for all the CSF samples. Blood culture was performed for 443 of these children. Of the 481 CSF samples, 24 (4.9%) were purulent. There were 36 cases of probable meningitis, and 421 cases with negative culture results were categorized as suspected meningitis.

The 24 cases with purulent CSF (definite meningitis) had isolates of S. pneumoniae (9 cases), Hib (11 cases), and Klebsiella species (4 cases). Only 1 of the 9 patients with pneumococcal meningitis survived. Among the cases of probable meningitis, blood culture results were positive for 13; 6 were positive for Hib, 3 were positive for S. aureus, and 1 each was positive for Enterococcus faecalis, Salmonella species, Klebsiella species, and Escherichia coli. In addition, there were 2 cases for which Gram staining revealed gram-positive cocci, but there was no growth on culture, and latex agglutination and immunochromatographic antigen tests could not be performed. Latex particle agglutination test and immunochromatographic antigen test for S. pneumoniae were performed for 16 (26.7%) of the 60 cases of definite or probable meningitis. By culture, 10 (62.5%) of the 16 cases had negative results, whereas 2 (12.5%) and 3 (18.6%) were positive for S. pneumoniae and Hib, respectively. One was positive for Pseudomonas species. The immunochromatographic antigen test did not increase the diagnostic success. The performances of the latex agglutination and immunochromatographic tests in identifying S. pneumoniae were the same, but the numbers were too small to reach any meaningful assertion. Latex particle agglutination testing identified 1 additional case with Hib among the 16 tested, increasing the total from 3 to 4.

Pneumonia. Chest radiographs were obtained for 359 of

Table 1. Cases and deaths due to invasive disease for different clinical syndrome diagnoses.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>No. of cases</th>
<th>No. of specimens collected</th>
<th>No. of specimens with no growth on culture</th>
<th>No. of specimens (no. of deaths) with positive cultures</th>
<th>No. of specimens with missing data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pneumonia</td>
<td></td>
<td></td>
<td></td>
<td>Streptococcus pneumoniae</td>
<td>Haemophilus influenzae type b</td>
</tr>
<tr>
<td>Probable, severe</td>
<td>43</td>
<td>43</td>
<td>34</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Severe, CXR confirmed</td>
<td>359</td>
<td>356</td>
<td>273</td>
<td>9 (0)</td>
<td>2 (0)</td>
</tr>
<tr>
<td>Meningitis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suspected</td>
<td>475</td>
<td>421</td>
<td>421</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Probable</td>
<td>36</td>
<td>36</td>
<td>25</td>
<td>0</td>
<td>6 (0)</td>
</tr>
<tr>
<td>Definite</td>
<td>24</td>
<td>24</td>
<td>0</td>
<td>9 (8)</td>
<td>11 (5)</td>
</tr>
<tr>
<td>Very severe</td>
<td>334</td>
<td>330</td>
<td>237</td>
<td>3 (0)</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>1271</td>
<td>1210</td>
<td>990</td>
<td>21 (8)</td>
<td>19 (5)</td>
</tr>
</tbody>
</table>

NOTE. CXR, chest radiograph.

a Probable severe pneumonia was defined by pneumonia clinical syndrome plus indrawing but no danger signs. CXR was not performed.

b CXR-confirmed severe pneumonia was defined by pneumonia clinical syndrome plus indrawing but no danger signs. CXR confirmed the pneumonia diagnosis.

c Suspected meningitis was defined by the presence of clinical signs and symptoms, but lumbar puncture was not performed or did not confirm a nonbacterial cause.

d Probable bacterial meningitis was defined by the presence of meningitis clinical syndrome, but lumbar puncture was not performed. Also, there were either no results or negative results of CSF culture and either: (1) normal CSF findings and positive results of CSF antigen test or PCR; (b) abnormal CSF findings and positive blood culture results, and either no results or negative results of antigen test or PCR; or (c) purulent CSF and negative blood culture results, or blood culture was not performed and either no results or negative results of antigen test or PCR.

e Definite meningitis was defined by positive CSF culture results or purulent meningitis plus positive blood culture results or positive results of CSF antigen test or by abnormal CSF findings plus positive results of CSF antigen test.

f Very severe disease was defined by the presence of at least 2 danger signs without pneumonia clinical syndrome. For the definition of danger signs, see the Appendix in this supplement.
the 402 children who satisfied the case definition for severe pneumonia—that is, any child with a history of cough or difficulty breathing and lower chest-wall indrawing. Thus, there were 43 cases of probable severe pneumonia. In the 359 cases of severe pneumonia, the chest radiographs showed consolidations, as found by the attending physicians or radiologists. Blood culture was not performed for 3 of the 359 children with severe pneumonia. There were isolates in 90 cases: *S. pneumoniae* (9 cases), Hib (2 cases), and others, such as *Klebsiella* species (14 cases), *Salmonella* species (11 cases), *P. aeruginosa* (6 cases), *E. faecalis* (2 cases), *E. coli* (2 cases), and possible *S. aureus* (44 cases) because only 1 of the 44 isolates was confirmed.

**Septicemia.** Among 334 children who satisfied the case definition for very severe disease, blood culture was not performed for 4. There was growth on culture for 95 (28.8%) of the 330 blood specimens that had blood culture performed. The results were positive for 4. There was growth on culture for 95 (28.8%) of the 330 children with severe pneumonia. There were isolates in 90 cases: *S. pneumoniae* (9 cases), Hib (2 cases), and others, such as *Klebsiella* species (14 cases), *Salmonella* species (11 cases), *P. aeruginosa* (6 cases), *E. faecalis* (2 cases), *E. coli* (2 cases), and possible *S. aureus* (44 cases) because only 1 of the 44 isolates was confirmed.

**DISCUSSION**

In Nigeria, rates of recovery of fastidious bacteria from clinical specimens have been unacceptably low in the past 3 decades [7–10]. There are 2 major reasons for this: human blood was used to prepare laboratory media for specimen culture, and there were high rates of prior treatment with antibiotics among the patients with pneumonia before they were seen in the hospital. Furthermore, not all children with pneumonia and septicemia usually underwent laboratory investigations, because the parents could not pay for the investigations. All these factors affected the practice of laboratory investigation. In this study, sheep blood was used to culture the specimens. In addition, supervisory measures were implemented to ensure prompt transfer of inoculated blood culture bottles to the laboratory, to reduce the levels of contamination.

There were 24 cases of purulent meningitis in which the CSF specimens had positive culture results, with or without the same isolate found in the blood. In addition, there were 36 cases of probable meningitis in which there were abnormal CSF findings; 13 of these cases had positive blood culture results. The low rate of pathogen isolation in CSF of 40% (24 of 60) may underestimate the incidence of bacterial meningitis, because of the widespread use of antibiotics before presentation to the hospital [11]. Indeed, approximately two-thirds of the patients studied had a clear history of antibiotic use at the onset of illness. Use of newer, more-sensitive techniques of pathogen identification, such as latex particle agglutination test and rapid, sensitive immunochromatographic test, only identified 1 additional case among 16 specimens tested. If all CSF specimens underwent these tests, the isolation rates might have been much higher for these organisms. The performances of latex agglutination and immunochromatographic antigen tests in identifying *S. pneumoniae* were similar.

There were 9 cases of *S. pneumoniae* meningitis, which is a close second to the 11 cases of Hib meningitis. This is similar to reports from other parts of the world [12, 13], but the numbers of isolates are too small to make any firm comparisons. However, there were 21 cases of invasive pneumococcal diseases, which is likely to be an underestimate, suggesting that pneumococcus is a common pathogen. It is important to note that serotypes 19F and 4, which constituted ~55% of all the serotypes identified in this study, are contained in the 7-valent vaccine (Prevenar), the only licensed PCV at present [14]. However, 100% of the serotypes identified (4, 5, and 19F) are found in the 10- and 13-valent PCVs. Invasive pneumococcal disease (mainly meningitis and septicemia) has become a public health concern in Europe, and several European countries have introduced programs of routine childhood vaccination against pneumococcal disease after licensure of an effective PCV in the United States in 2000 [15]. In Africa, *S. pneumoniae* has been reported to be a major cause of childhood disease, with high incidence rates documented in The Gambia [16–18], Kenya

![Figure 1](https://academic.oup.com/cid/article-abstract/48/Supplement_2/S190/450226/suppl/1)

**Figure 1.** Age distribution for cases of meningitis, pneumonia, and septicemia clinical syndromes among children aged <5 years.
Incidence rates of pneumococcal disease have been shown to be several-fold higher in communities with a high prevalence of HIV infection [22]. Although national surveillance systems for pneumococcal disease are lacking in many developing countries, there are sufficient data to indicate that the disease is likely to be a greater problem there than has been reported in developed countries. It is pertinent that there were no cases of meningococcal disease, because Ibadan is not in the meningitis belt.

Eight of the 9 patients with pneumococcal meningitis died, yielding a case-fatality rate of 88.9%. This outcome is consistent with reports from other parts of Africa [23, 24]. Pneumococcal meningitis thus remains a major cause of mortality in Ibadan. Introduction of effective programs of vaccination against pneumococcal infections will reduce childhood mortality. There were 17 cases of Hib meningitis—11 were definite and 6 were probable—but only 5 (45.5%) of the 11 patients with definite meningitis died, which suggests that Hib meningitis is a less deadly disease than is pneumococcal meningitis.

Pneumonia remains a major cause of childhood morbidity and mortality in the world. Most cases of severe pneumonia are bacterial, mainly caused by *S. pneumoniae* and *H. influenzae*, usually type b (Hib), among both well-nourished [25] and malnourished [5] children. In the past 3 decades, studies of the etiology of community-acquired pneumonia in Nigeria reported that *S. aureus* and *Klebsiella* species were common causes [7–10]. Various reasons have been adduced for the underreporting of cases of *S. pneumoniae* and Hib infection, including the use of antibiotics before medical consultation, inclusion of malnourished children in studies, and use of human blood for preparation of blood agar. Malnourished children, especially those with edematous malnutrition, are immunocomprised and thus are susceptible to infection with *S. aureus* and gram-negative bacilli [26]. The use of human blood in the preparation of blood agar at the UCH in the past was a contributory factor to the low isolation rate of these fastidious bacteria (UCH, personal communication). The human blood that was used most likely contained antibiotics, given the high rate of antibiotic misuse. In the present study, sheep blood was used.

Although 44 cases of pneumonia were etiologically related to *S. aureus*, it is highly likely that many of the isolates were coagulase-negative *Staphylococcus* and thus were contaminants. This view is supported by the finding of poor correlation (5.6%) between identification of *S. aureus* at the UCH and identification at the MRC Laboratories. During the study, 18 of the 74 *S. aureus* isolates were sent from the UCH to the MRC Laboratories for confirmation. Two of the 18 isolates were confirmed to be *S. aureus* and *S. typhimurium*, and the 16 others were coagulase-negative staphylococci. Future studies of severe pneumonia in Nigeria should endeavor to send all isolates for confirmation to a reference laboratory center such as the MRC Laboratories in The Gambia.

Although the prevalence of HIV/AIDS in the adult population (aged, 15–49 years) in Nigeria during 2005–2006 was 3.9% [3], the impact of HIV/AIDS on invasive bacterial disease in Nigeria was not measured in the present study.

In conclusion, this study has demonstrated the capability of the UCH in Ibadan, Nigeria, to isolate *S. pneumoniae* from specimens obtained from children with pneumonia, meningitis, and septicemia. The study has shown the distribution of serotypes and the antimicrobial-resistance patterns of pneumococcal isolates that cause invasive disease, as well as the percentage of those serotypes that are contained in the currently licensed 7-, 10-, and 13-valent PCVs. This project provides important baseline data for continued surveillance of antibiotic resistance and serotype changes that may occur after introduction of routine vaccination in this community.

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