

A Hospital-Based and Cross-Sectional Investigation on Clinical Characteristics of Pediatric *Streptococcus pneumoniae* Isolates in Beijing from 2015 to 2021

Zhiyong Lyu¹, Jing Li², Jinghui Zhen¹, Wei Shi³, Qingying Meng¹, Wei Zhou¹, Jingyun An¹, Kaihu Yao^{3,*}, Fang Dong^{1,*}

¹Department of Clinical Laboratory Center, Beijing Children's Hospital, Capital Medical University, National Center for Children's Health, Beijing, People's Republic of China; ²Department of Clinical Laboratory, Capital Institute of Pediatrics, Beijing, People's Republic of China; ³Beijing Key Laboratory of Pediatric Respiratory Infection Diseases, Key Laboratory of Major Diseases in Children, Ministry of Education, National Clinical Research Center for Respiratory Diseases, National Key Discipline of Pediatrics (Capital Medical University), Beijing Pediatric Research Institute, Beijing Children's Hospital, Capital Medical University, National Center for Children's Health, Beijing, People's Republic of China

*These authors contributed equally to this work

Correspondence: Fang Dong; Kaihu Yao, Department of Clinical Laboratory Center, Beijing Children's Hospital Affiliated to Capital Medical University, No. 56 Nan Lishi Road, Beijing, 100045, People's Republic of China, Email fangd32@163.com; yaokaihu@bch.com.cn

Introduction: *Streptococcus pneumoniae* (*S. pneumoniae*) is a major pathogen causing death in children. Few studies have evaluated the importance of *S. pneumoniae* in the identified bacteria in clinical work. This retrospective study aimed to reveal the rank of *S. pneumoniae* in determined bacteria isolated from children in Beijing, China, as well as the antimicrobial resistance of this pathogen.

Methods: The number of specimen for bacterial culture and of bacterial species were cumulated and ranked based on the data of the two largest children's hospitals in Beijing from 2015 to 2021. The temporal change of *S. pneumoniae* culture, as well as the clinical data of *S. pneumoniae* isolates were collected and analyzed. The minimum inhibitory concentrations of antimicrobial agents were determined by BD Phoenix 100 automated system or Vitek 2 automated system for antimicrobial susceptibility testing. The breakpoints recommended by CLSI were adopted.

Results: During the 7-year study period, a total of 45,631 bacterial isolates were cultured from 462,144 submitted specimens, in which *S. pneumoniae* was the third frequent agent following *S. aureus* and *H. influenza*, and accounting for 8.79% of the isolates (4011/45,631). In the 4011 *S. pneumoniae* isolates, 2239 and 997 ones were, respectively, isolated from sputum and bronchial lavage fluid. Most of *S. pneumoniae* strains were identified in winter (34.7%) and spring (26.1%), and were mainly isolated from patients under 5 years old (77.1%). Low susceptible rate (27.6%) of CSF isolates was determined to penicillin according to the parenteral meningitis breakpoints, while high susceptible rate (56.9%) of non-CSF isolates was obtained according to the parenteral non-meningitis breakpoints. The isolates showed low sensitivity to erythromycin and tetracycline (<5%). All isolates were susceptible to vancomycin and linezolid.

Conclusion: The present results demonstrated that *S. pneumoniae* was one of the most commonly detected bacteria in current pediatric clinical tests, especially in young children under 5 years old, which emphasized the importance of prevention. Penicillin could still be the first empiric choice to treat non-meningitis pneumococcal infections, while erythromycin should not be involved in the treatment.

Keywords: *Streptococcus pneumoniae*, antimicrobial resistance, children, China

Introduction

S. pneumoniae is an opportunistic Gram-positive pathogen, normally colonizing in the nasopharynx, which can commonly infect young children, immune-deficient patients, and the elderly, responsible for millions of deaths worldwide. The carriage

rate of *S. pneumoniae* in children is 27% in developed countries and 85% in developing countries.¹ In common circumstances, it does not cause diseases, however, when the immunity is compromised, it can invade other parts or tissues and cause infections, including community acquired pneumonia, otitis media, sinusitis, bacteremia, osteomyelitis, meningitis and other diseases.^{2–4}

Antibiotic administration is the main measure to treat *S. pneumoniae* infections. However, along with the continuous renewal of antibiotics and the unreasonable application of antimicrobial agents, *S. pneumoniae* strains resistant to antibiotics, especially multi-drug resistant strains continue to emerge and spread under the increased selection pressure. Penicillin has been used clinically to treat *S. pneumoniae* infections for more than half a century. However, since discovery of the first penicillin resistant *S. pneumoniae* strain in Australia in 1967, erythromycin, tetracycline, sulfamethoxazole, β -lactam and other antibiotic resistant strains are increasing, and the phenomenon of multiple drug resistance is becoming more and more serious.^{5–7}

There is no national prevalence data of *S. pneumoniae* infection in China based on population investigation. However, *S. pneumoniae* culture has already been a part of regular work in clinical laboratories mainly for inpatient diagnosis. In the present study, the data of bacterial culture and some clinical information of *S. pneumoniae* isolates were collected from two clinical laboratories that belonged to the two biggest tertiary children's hospitals in Beijing, from 2015 to 2021. The aim of this study was to evaluate the importance of *S. pneumoniae* in the current detectable bacteria, and the antibiotic resistance profiles of *S. pneumoniae* isolates in Beijing, China.

Materials and Methods

Study Sites

The present data were collected from two study sites. One is Beijing Children's Hospital affiliated to Capital Medical University, the other is Children's Hospital Capital Institute Pediatrics. Both of the two tertiary hospitals were ranked in top of all the domestic children's hospitals with the most pediatric patients visiting in Beijing. Beijing Children's Hospital was National Center for Children's Health, China, with more than 3 million outpatients and 80,000 inpatients per year. Meanwhile, 2.3 million outpatients and 30,000 hospitalized children were treated at the Capital Institute of Pediatrics. The clinical information and laboratory examination results of the children were collected and analyzed retrospectively from the electronic information system.

Species Culture and Identification

Bacterial isolation and identification were performed in the two clinical laboratories of the hospitals. We collected the clinical information of the tested samples and bacterial identification results through the electronic recording system. In accordance with the National Guide to Clinical Laboratory Procedures, clinical specimens were inoculated into Columbia blood agar plate and incubated at 37°C and 5% CO₂ for 24 hours. Sterile samples such as blood were injected into the blood culture bottle and cultured in BD BACTEC FX blood culture instrument, if the alarm was positive, the cultures were transferred to Columbia blood agar plate and incubated at 37°C and 5% CO₂ for 24 hours. Optochin sensitivity test was used to identify the pneumococcal strains. All the Optochin sensitivity positive strains with an inhibition zone diameter of ≥ 14 mm were confirmed by MALDI-TOF MS (bio Mérieux, France) instrument.

The pneumococcal isolates analyzed in this study were collected from clinical laboratories. Our study was a retrospective study based on the clinical samples, which were part of the routine hospital laboratory procedures, and all the clinical samples in this study were not specifically isolated for this research. The Ethics Committees of Beijing Children's Hospital affiliated to Capital Medical University and Children's Hospital Capital Institute Pediatrics exempted this study from review.

Antimicrobial Susceptibility Testing

Laboratories of the two hospitals utilized different systems to test the antimicrobial susceptibility of *S. pneumoniae* isolates, both based on detection of the minimum inhibitory concentrations (MICs). In Beijing Children's Hospital, BD Phoenix 100 automated system was implemented to determine MICs of 2971 isolates. Meanwhile, Children's Hospital

Capital Institute used Vitek 2 automated system to measure MICs of 1040 strains. E-test stripes were used to reconfirm the results of penicillin, cefotaxime, and meropenem. Antibiotic susceptibility testing results were interpreted according to the Clinical and Laboratory Standards Institute (CLSI) guidelines (M100 29th edition). *S. pneumoniae* ATCC 49619 was included as a quality control strain in the whole testing process.

Statistical Analysis

Data were managed and analyzed with SPSS software v17.0 (SPSS Inc., Chicago, Illinois, USA). Antibiotic susceptibility results were analyzed using WHONET 5.6 software. Results were expressed as number of the patients or bacteria isolates, as well as proportion of the total number. Chi-square test or Fisher's exact test were used to evaluate the differences between categorical variables. Difference among antibiotic susceptibility over time was determined using a chi-square test for trend. P value was calculated and considered statistically significant only when it was less than 0.05.

Results

Rank of *S. pneumoniae* in All the Isolated Bacteria Strains

During the 7-year study period from 2015 to 2021, a total of 462,144 specimens were collected, among which 45,631 bacteria strains were identified. The top two common pathogens were *S. aureus* and *H. influenza*, accounting for 15.34% (7000/45,631) and 10.50% (4791/45,631), respectively. *S. pneumoniae* was the third frequent bacterium, accounting for 8.79% (4011/45,631) of the whole isolated strains (Figure 1).

Yearly and Seasonal Distribution

Among the 462,144 specimens, for which regular bacterial cultures were needed, we isolated 4011 *S. pneumoniae* strains, amounting to a positive rate of 0.87%. As shown in Table 1, the positive rate of *S. pneumoniae* strains was higher in the

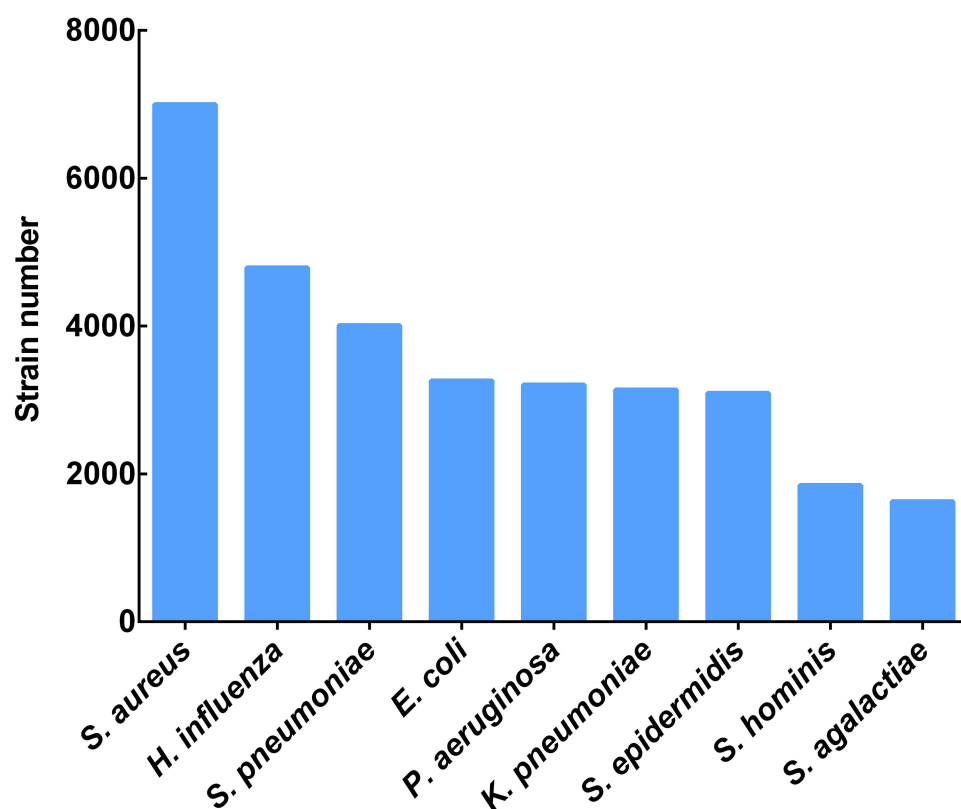


Figure 1 Distribution of top 9 bacterial strains isolated from children patients in Beijing between 2015 and 2021. *S. aureus* and *H. influenza* were the most commonly isolated pathogens, followed by *S. pneumoniae*.

first four years, between 2015 and 2018 ($P<0.05$). The lowest positive rate occurred in 2020 (0.46%, 199/43,240) ($P<0.05$). In our seven-year study, the number of isolated *S. pneumoniae* strains was abundant and relatively stable from 2015 to 2018, around 700 to 750 per year. This annual number slightly decreased to 562 in 2019. However, the number of isolated strains sharply declined to 199 in 2020, followed by a small increase to 353 in 2021. In general, the year of 2017 ($n=741$) and 2020 ($n=199$) accounted for the highest and the lowest number of isolated *S. pneumoniae* strains, respectively. In terms of seasonal distribution, most *S. pneumoniae* strains were identified in winter (during December to February, $n=1394$, 34.7%) and spring (during March to May, $n=1045$, 26.1%), with the lowest number isolated from summer (during June to August, $n=727$, 18.1%).

Specimen Type Distribution and Positive Rate

Among the 462,144 specimens, the most common specimen type was venous blood ($n=309,756$, 67.2%), followed by sputum ($n=54,287$, 11.7%), cerebrospinal fluid ($n=45,560$, 9.9%) and bronchial lavage fluid ($n=30,025$, 6.5%). Among all the 4011 *Streptococcus pneumoniae* isolates, strains from respiratory tract were mainly collected from sputum ($n=2239$, 55.8%) and bronchial lavage fluid ($n=997$, 24.9%) (Table 1). The invasive pneumococcal disease (IPD)-causing strains comprised 7.2% ($n=287$) of the total isolates, which were isolated from venous blood ($n=204$), cerebrospinal fluid ($n=58$) and pleural effusion ($n=20$), joint fluid ($n=3$) and bone marrow ($n=2$). The positive rate of *Streptococcus pneumoniae* strains in ear secretion was the highest (9.01%, 77/854) ($P<0.05$), followed by nasopharynx swab (6.15%, 49/797), fester (5.24%, 191/3647), sputum (4.12%, 2239/54,287), eye secretion (3.45%, 26/754) and bronchial lavage fluid (3.32%, 997/30,025).

Table 1 Distribution of Collecting Year/Season and Specimen Types of the Isolated Strains

| Parameters | Total No. of Sample(n) | <i>S. pneumoniae</i> Isolates | |
|--------------------------|------------------------|-------------------------------|------------------|
| | | No. of Strains(n) | Positive Rate(%) |
| Total | 462,144 | 4011 | 0.87 |
| Collecting year | | | |
| 2015 | 67,930 | 706 | 1.04 |
| 2016 | 74,206 | 737 | 0.99 |
| 2017 | 73,840 | 741 | 1.00 |
| 2018 | 75,761 | 713 | 0.94 |
| 2019 | 78,886 | 562 | 0.71 |
| 2020 | 43,204 | 199 | 0.46 |
| 2021 | 48,317 | 353 | 0.73 |
| Collecting season | | | |
| Spring | 137,257 | 1045 | 0.76 |
| Summer | 78,564 | 727 | 0.93 |
| Autumn | 77,178 | 845 | 1.09 |
| Winter | 169,145 | 1394 | 0.82 |
| Specimen types | | | |
| Venous blood | 309,756 | 204 | 0.07 |
| Sputum | 54,287 | 2239 | 4.12 |
| Cerebrospinal fluid | 45,560 | 58 | 0.13 |
| Bronchial lavage fluid | 30,025 | 997 | 3.32 |
| Vulvar secretion | 10,718 | 145 | 1.35 |
| Fester | 3647 | 191 | 5.24 |
| Pleural effusion | 2506 | 20 | 0.80 |
| Bone marrow | 3107 | 2 | 0.06 |
| Ear secretion | 854 | 77 | 9.01 |
| Nasopharynx swab | 797 | 49 | 6.15 |
| Eye secretion | 754 | 26 | 3.45 |
| Joint fluid | 133 | 3 | 2.26 |

Characteristics of Patients with *S. pneumoniae* Infections

In this retrospective surveillance study, 4011 non-duplicated *S. pneumoniae* isolates were collected from the two tertiary hospitals from Jan 2015 to Dec 2021, with 74.1% (n=2971) of the isolates from Beijing Children's Hospital affiliated to Capital Medical University. The number of male patients (59.3%, n=2378) was higher than the number of female patients (40.7%, n=1633). Among the total isolates, 77.1% were isolated from children under 5 years old (n=3091). With the increase of age, the number of children patients decreased gradually (Table 2). In our study, most of the strains were isolated from hospitalized patients (90.0%, n=3611), especially from pneumology department (43.8%, n=1757), Intensive Care Unit (9.9%, n=397), department of cardiology (9.8%, n=394), and general medicine department (8.3%, n=331).

Antimicrobial Susceptibility Testing of *S. pneumoniae* Isolates

The antimicrobial susceptibility results of the 4011 pneumococcal isolates to the tested antibiotics are shown in Table 3. According to the CLSI susceptibility breakpoints, all of the isolates were susceptible to vancomycin and linezolid. 27.6% (16/58) of the meningitis isolates and 56.9% (2251/3953) of the non-meningitis isolates were susceptible to penicillin. At the same time, the susceptible rates of meningitis strains and non-meningitis strains to cefotaxime, meropenem and trimethoprim-sulfamethoxazole were 36.2% vs 69.3%, 39.7% vs 33.7% and 29.3% vs 20.2%. On the whole, 56.5% and 68.8% of total isolates were susceptible to penicillin and cefotaxime, respectively. However, only 33.8% of the strains were susceptible to meropenem. Most of the isolates were sensitive to moxifloxacin (99.1%), levofloxacin (90.0%) and chloramphenicol

Table 2 Clinical Information of Children with the Isolated *S. pneumoniae* Strains

| | Number | Ratio (%) |
|--------------------------------|--------|-----------|
| Total | 4011 | 100.0 |
| Gender | | |
| Male | 2378 | 59.3 |
| Female | 1633 | 40.7 |
| Age | | |
| < 1 | 1122 | 28.0 |
| ~<2 | 605 | 15.1 |
| ~<3 | 475 | 11.8 |
| ~<4 | 459 | 11.4 |
| ~<5 | 430 | 10.7 |
| ~<6 | 220 | 5.5 |
| ≥ 6~12 | 700 | 17.5 |
| Outpatient | 400 | 10.0 |
| Hospitalized patient | 3611 | 90.0 |
| Pneumology Department | 1757 | 43.8 |
| Intensive Care Unit | 397 | 9.9 |
| Department of Cardiology | 394 | 9.8 |
| General Medicine Department | 331 | 8.2 |
| Emergency | 112 | 2.8 |
| Infectious Disease Department | 111 | 2.8 |
| Hematology Department | 84 | 2.1 |
| Otorhinolaryngology Department | 79 | 1.9 |
| Endocrinology Department | 62 | 1.5 |
| Neonatology Department | 55 | 1.4 |
| Gastroenterology Department | 53 | 1.3 |
| Thoracic Surgery Department | 51 | 1.3 |
| Nephrology Department | 48 | 1.2 |
| Neurology Department | 43 | 1.1 |
| Ophthalmology Department | 27 | 0.7 |
| Orthopedics Department | 7 | 0.2 |

Table 3 Susceptibility of *S. pneumoniae* Isolates to Antimicrobial Agents (%)

| Antibiotics | Total Isolates (N=4011) | CSF Strains (N=58) | Non-CSF Strains (N=3953) |
|-------------------------------|-------------------------|--------------------|--------------------------|
| Penicillin G | 56.5 (n=2267) | 27.6 (n=16) | 56.9 (n=2251) |
| Cefotaxime | 68.8 (n=2760) | 36.2 (n=21) | 69.3 (n=2739) |
| Meropenem | 33.8 (n=1356) | 39.7 (n=23) | 33.7 (n=1333) |
| Erythromycin | 0.4 (n=18) | 0.0 (n=0) | 0.5 (n=18) |
| Clindamycin* | 0.9 (n=36) | 0.0 (n=0) | 0.9 (n=36) |
| Tetracycline | 4.7 (n=190) | 0.0 (n=0) | 4.8 (n=190) |
| Trimethoprim-sulfamethoxazole | 20.3 (n=814) | 29.3 (n=17) | 20.2 (n=797) |
| Moxifloxacin | 99.1 (n=3974) | 100.0 (n=58) | 99.1 (n=3916) |
| Levofloxacin | 99.0 (n=3969) | 100.0 (n=58) | 98.9 (n=3911) |
| Chloramphenicol | 93.6 (n=3753) | 87.9 (n=51) | 93.7 (n=3702) |
| Linezolid | 100.0 (n=4011) | 100.0 (n=58) | 100.0 (n=3953) |
| Vancomycin | 100.0 (n=4011) | 100.0 (n=58) | 100.0 (n=3953) |

Note: *Represent the data of Beijing Children's Hospital affiliated to Capital Medical University.

Abbreviation: CSF, cerebrospinal fluid.

(93.6%). In contrast, only a small part of the strains were sensitive to erythromycin (0.4%) and tetracycline (4.7%). Among non-meningitis strains, the prevalence of penicillin-susceptible, cefotaxime-susceptible, meropenem-susceptible and trimethoprim-sulfamethoxazole-susceptible strains exhibited an increasing trend across the seven years ($P < 0.05$) (Figure 2).

Discussion

The present 7-year retrospective study revealed that *S. pneumoniae* ranked third among all the isolated bacterial strains, following the *S. aureus* and *H. influenza*. In China, surveillance data from the ISPED program demonstrated that *S. pneumoniae* was one of the top three pathogens causing infections in children, from 2016 to 2020.⁸ In all-aged

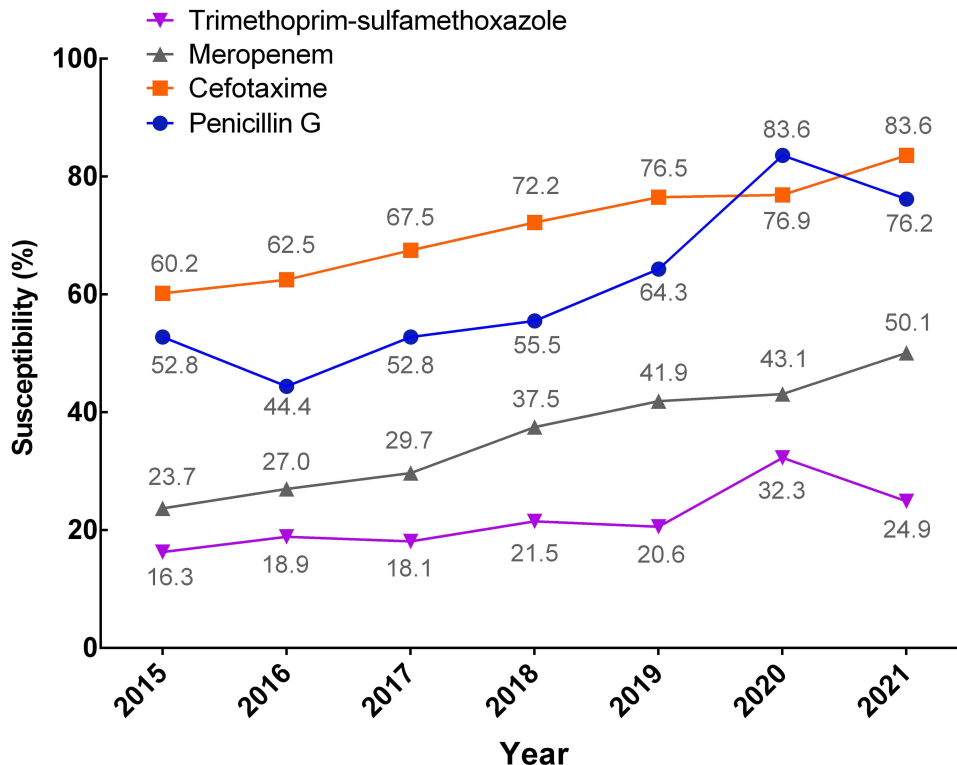


Figure 2 The Changes of susceptible rate of non-meningitis *S. pneumoniae* isolates by year. From 2015 to 2021, the number of non-meningitis strains per year was 689, 725, 735, 712, 544, 195 and 353. The susceptibilities of non-meningitis *S. pneumoniae* to penicillin, cefotaxime, meropenem and trimethoprim-sulfamethoxazole, were summarized by year.

patients with acute respiratory infections, *S. pneumoniae* was the most prevalent bacterial pathogen in China, from 2009 to 2019.⁹ All these studies demonstrated that *S. pneumoniae* played an important role in bacterial isolates from pediatric patients in China.

These results showed that the positive rate of *S. pneumoniae* in the whole specimens was 0.87% in children patients, which was higher than a previous study from Korea, in which the positive rate was 0.15% based on the whole populations including both pediatrics and adults.¹⁰ This phenomenon could indicate that children exhibit higher infection rate of *S. pneumoniae* than adults. In all the specimen types, ear secretion which accounted for 0.18% of the total samples presented the highest positive rate (9.01%). Although the positive rate of ear secretion was higher than other sample types in the present study, it was much lower than previous reports,^{11,12} which demonstrated a positive rate of 26–36% in ear secretion samples. Furthermore, we noticed that the number of ear secretion specimen was relatively less than other specimen types, only 854 in 7 years. Because the acute otitis media (AOM) infection was often treated empirically and directly by antibiotics without performing further bacteria culture in outpatients, this result could indicate the common low vigilance in outpatient diagnosis. Therefore, the pathogen test should be further emphasized for outpatients in children, especially based on the current finding of high positivity of *S. pneumoniae* culture for AOM.

The proportion of pneumococcal isolates in children under 5 years old accounted for 77.1%, which was consistent with the reports concluded from data in developing countries by WHO,¹³ but it was relatively lower than the data (85%) reported in a multicenter retrospective study in mainland China.¹⁴ With development and maturation of the immune system, the positive rate of *S. pneumoniae* infection in children over 5 years old decreased concomitantly.¹⁵ Non-invasive strains accounted for 92.8% of the isolated strains, and the samples were mainly collected from sputum (55.8%) and bronchial lavage fluid (24.9%). Although the proportion of invasive strains was relatively low (7.2%), because of the high mortality of invasive pneumococcal disease (IPD), it should be paid more attention to these invasive strains clinically.¹⁶ Autumn and winter were the major seasons with diagnosis of *S. pneumoniae* infections, which was similar to a relevant report.¹⁷

Current guidelines recommend the use of broad-spectrum antibiotics for acute infections taking into account of normal etiologic pathogens, probably of *S. pneumoniae* infections.¹⁸ Penicillin, as a narrow-spectrum antibiotic, was usually recommended for the treatment of *S. pneumoniae* infections, which can also slow down the emergence of drug-resistant strains.¹⁹ In this seven-year study, we revealed a high Non-susceptibility rate of *Streptococcus pneumoniae* to penicillin (43.5%), which was in high level compared with other literature. Its Non-susceptibility rates differed from 29.3% in Europe to 47.6% in Asia-Pacific region for all years combined from 1997 to 2016.²⁰ Since 2005, epidemiological studies in China showed that the antibiotic resistance of *S. pneumoniae* in pediatrics was becoming more and more serious.²¹ A previous study reported a significant increase, during the year of 2006 to 2007, of the resistance of *S. pneumoniae* strains isolated from children under 5 years old, admitted in four children's hospitals in China, compared with the period from 2000 to 2002.²² The high resistance rate against multiple antimicrobial agents brings stress on the need for the empiric antibiotic treatment of the *S. pneumoniae* infections.^{23,24} In China, to combat drug resistance, the government has taken forceful measures to control the abuse of antibiotics since 2011. Fortunately, the sensitivity of *Streptococcus pneumoniae* to key antibiotics was increasing in children in recent years, which can be concluded from the susceptibility results of our study (Figure 2). In addition, the increasing sensitivity of *S. pneumoniae* to major antimicrobial agents was also confirmed by multicenter surveillance data from pediatric patients in China.^{8,25} However, in contrast to pediatric patients, the resistance of *Streptococcus pneumoniae* to common antibiotics was increasing over time in adult patients from 2009 to 2018, in a tertiary hospital in Beijing, China, with patients aged <18 years old excluded from study.²⁶

Our study showed that the resistance rate to penicillin was 3.4%. In China, the resistance rate was higher than the studies in Antimicrobial Surveillance Network (CHINET, 0.56%, 2021), China Antimicrobial Resistance Surveillance System (CARSS, 0.9–2.7%, 2017–2020) and Asian Network for Surveillance of Resistant Pathogens (ANSORP, 1.4%).¹⁴ Worldwide, the resistance rate to penicillin varied. According to the literature, Japan (1.7–2.2%, 2013–2018) showed lower resistance rate to penicillin than ours.²⁷ Many of the resistance rates from different countries were higher than our studies, such as Korea (9.8%),¹⁰ United States (14.8%),²⁸ Ethiopia (17.5%)²⁹ and Russia (26.1%).³⁰ Although the

resistance rate to penicillin was in low level across all over the country, it was in high level in Beijing. The reason could be interpreted by the fact that the hospitals had various specialist wards to accept children with serious diseases.

The third generation cephalosporins, such as cefotaxime and ceftriaxone, were commonly used for the treatment of *S. pneumoniae* infections to achieve a better therapeutic outcome.³¹ Lee et al reported that inappropriate use of ceftriaxone for the initial treatment of ceftriaxone-resistant isolates had a certain correlation with mortality.³² In our study, more the 60.0% of the non-meningitis strains were non-susceptible to cefotaxime. Our study suggested that susceptibility to penicillin was higher than sensitivity to cephalosporin. Therefore, penicillin seemed to have a better therapeutic effect than cephalosporin in treating pediatric infections caused by *S. pneumoniae*. There were significant differences in the susceptibility to multiple antibiotics between PSSP (penicillin-susceptible *Streptococcus pneumoniae*) and PRSP (penicillin-resistant *Streptococcus pneumoniae*). The resistance rate of PRSP to cefotaxime was significantly higher than that of PSSP in both meningitis and non-meningitis strains. Therefore, when treating the infections caused by *S. pneumoniae*, β -lactam antibiotics should still be considered as the initial empiric antibiotic agent, if the susceptibility test results suggested intermediate, the dosage should be increased appropriately. If the phenotype sensitivity results suggested resistance, it was necessary to pay attention to the multidrug resistance of PRSP and reasonably select antibiotics according to the antibiotic results.^{33,34}

In our study, *S. pneumoniae* strains showed low susceptibility to meropenem. The study by Yu-Te Tsai et al showed that the susceptibility rate to meropenem was 85.2%,³⁵ higher than ours. The reason for the difference in susceptibility rate might be the extensive application in severe infectious diseases.^{36–38}

Our study demonstrated high resistance rates by *S. pneumoniae* strains to erythromycin, clindamycin and tetracycline, all of which were higher than 93.0%. The high resistance rates were consistent with previous reports.³⁹ Due to the high resistance rate to erythromycin, clindamycin and tetracycline, these antibiotics were not suitable for the conventional treatment of *S. pneumoniae* infections.

Irrational use of antibiotics was the leading factor causing high levels of antibiotic resistance, as well as other factors including self-medication, and abuse of antibiotics in agriculture. All these actions could contribute to increasing antibiotic selective pressure, leading to resistant *S. pneumoniae* strain selection. In China, a campaign to curb the abuse of antibiotics and slow down the production of antibiotic-resistant strains was carried out in 2011.⁴⁰ Because of the emergence of COVID-19, the government had taken great efforts to control the use of antibiotics, keep children to study in their households and reduce community contact, the number of *S. pneumoniae* isolates dramatically decreased since 2020. Although the resistance rates to several antibiotics decreased in these years, they were still in high level.

Several limitations exist in our study. First, the serotyping of *S. pneumoniae* is not regular clinical test, which is not available in the present analysis. Therefore, the potential effect of licensed pneumococcal conjugated vaccines could not be evaluated. Second, it was a hospital-based retrospective review, a few of data could not be made a check. Third, there were two different detection methods for antibiotic susceptibility, due to the limitations of testing methods, some strains isolated from Children's Hospital Capital Institute Pediatrics in the early study could not distinguish PISP (penicillin-intermediate *Streptococcus pneumoniae*) and PRSP. The deficiencies need to be consummated in the future monitoring process.

Conclusion

In summary, we reported the distribution and antibiotic resistance profiles of *S. pneumoniae* in Beijing from 2015 to 2021. *S. pneumoniae* infection was common in infants and young children under 5 years old. Winter and autumn were the most common seasons for *Streptococcus pneumoniae* infections. Among patients, the proportion of boys was higher than that of girls. The most common specimen type was venous blood, followed by sputum, cerebrospinal fluid and bronchial lavage fluid. In the midst of the specimens, the average positive rate was 0.87%, with the highest positive rate in ear secretion. Our study thus revealed that penicillin, which was continuously effective in the treatment of pneumococcal diseases, could still be used as a first-line choice for empirical treatment. In terms of high-level β -lactam antibiotics, cefotaxime demonstrated better outcome than meropenem. In consideration of the high resistance rates of erythromycin, tetracycline and clindamycin, they were no longer suitable for empirical treatment in pneumococcal infections.

Therefore, in clinical, we should pay much more attention to monitor antibiotic resistance, and use antibacterial agents reasonably.

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Disclosure

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