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Characteristics of multidrug-resistant pathogens and treatment outcomes of lobar pneumonia in Northern Vietnam

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ABSTRACT

Purpose: We aimed to investigate the antibiotic resistance characteristics of bacterial pathogens causing lobar pneumonia (LP) in children and the treatment outcomes of these individuals.

Methods: 123 children diagnosed with LP in 2020 were enrolled in this study. Nasopharyngeal swab culture and antibiogram were performed on all patients.

Results: The group aged 24-60 months old was the most common. The most common bacterial pathogens were *S. pneumoniae* (37.5%), *H. influenzae* (34.5%) and *M. catarrhalis* (18.7%). *S. pneumoniae* showed high resistance to trimethoprim-sulfamethoxazole, clindamycin and cefuroxime. *H. influenzae* was resistant to cefuroxime and ampicillin (> 80%). *M. catarrhalis* was resistant to cefuroxime, trimethoprim/sulfamethoxazole and macrolide (> 50%). The third-generation cephalosporin/aminoglycoside combination was the most commonly used as the initial treatment (69.1%), with relatively high treatment success rate (62.4%).

Conclusions: The most common bacterial pathogens causing LP in children were *S. pneumoniae*, *H. influenzae* and *M. catarrhalis*. Almost detected agents were multi-resistant.

Keywords: lobar pneumonia, children, bacteria, antibiotic resistance, multidrug-resistant

INTRODUCTION

Pneumonia is a common acute disease of the respiratory tract in children. It is also one of the leading causes of death in children because of its serious clinical manifestations, rapid progress, and dangerous complications [1, 2]. Lobar pneumonia (LP), which is a common pediatric lower respiratory tract infection, is a severe clinical form of pneumonia in children [3]. In severe cases without timely treatment, the lesions of LP may spread to the pleura, pericardium, leading to dangerous complications, such as pleurisy, lung abscess, or pericarditis [2, 4]. In Taiwan, a previous study reported that the proportion of children with LP experienced a dramatic increase by 12.0% to 19.0% over the period of 2 years from 2002 to 2004 [5]. The previous studies showed that the causes of pneumonia in children could vary widely by child age, regions, time points, antibiotic usage, and vaccination [6, 7]. Therefore, identifying bacteria causing LP in children is essential in both early diagnosis and treatment. However, due to the alarming increase in bacterial resistance to antibiotics, most of the classes of antibiotics are already used widely [8]. That is the reason why there is an urgent need for the rational use of antibiotics.

We found that in Vietnam, there were some previous research about LP in children, but studies about bacterial resistance to antibiotics in LP were still limited [9]. Therefore, we conducted this study in order to provide data about bacterial pathogens causing LP in children, their antibiotic resistance profile, as well as treatment outcomes of these patients.

MATERIALS AND METHODS

Patients

We conducted a descriptive study using retrospective data at the Department of Respiratory in Haiphong Children's Hospital from January 1, 2020, to December 31, 2020, on 123 medical records of patients with LP enrolled who met 3 criteria as follows:

- Patients aged from 2 months to 15 years old.
- Patients diagnosed with LP [9].
- Patients who underwent nasopharyngeal fluid culture, in case of presenting bacteria, antibiogram was then performed.

By contrast, those having other systemic infections or suffering from other serious co-diseases were excluded from the study.

Table 1. General features of patients with lobar pneumonia (n = 123)

General features of patients		Frequency: n (%)
Age: Mean ± standard deviation (range): 39.41 ± 38.59 months (2-180)	2 months-< 6 months	16 (13.0)
	6 months-< 12 months	14 (11.4)
	12 months- 24 months	25 (20.3)
	24 months-< 60 months	41 (33.3)
	≥ 60 months	27 (22.0)
Gender	Male	69 (56.1)
	Female	54 (43.9)
Residence	Rural	88 (71.5)
	Urban	35 (28.5)

Laboratory Methods

The isolation and identification of isolates and antibiotic susceptibility testing were performed according to the standard operating procedure of department of microbiology, which met criteria of biosafety level 2. The whole procedure and result checking interpretation were carried out by microbiologists.

Process of culturing and identification of bacterial isolates and antibiogram: For organisms identified, antibiotic susceptibilities and minimum inhibitory concentrations were determined. Its interpretation of results was based on guidelines provided by the Clinical Laboratory Standards Institute [10].

Chest Computerized Tomography Scan

Chest computed tomography (CT) scan was considered to be obligatory in the diagnosis of LP in all patients, conducted by 64-slice GE revolution™ EVO CT scanner (RE36A1800299YC, Japan, 2018).

Statistical Analysis

Data were analyzed using the SPSS software for Windows version 26.0. Descriptive statistic was used to calculate the counts and proportions of variables and then compared by chi-squared ($\chi 2$) test with a 95% confidence interval. A p-value of less than 0.05 was considered to show statistically significant difference.

Ethical Approval

The research related to human use has been complied with all the relevant national regulations, institutional policies and in accordance with the tenets of the Helsinki Declaration and has been approved by the Board of Direction of Haiphong Children's Hospital. Patients were anonymized before data entry, with no identifiable data entered into the database. Information about patients was guaranteed to be completely confidential and only served for scientific research.

RESULTS

General Characteristics of Patients with Lobar Pneumonia

A total of 123 patients with LP were enrolled in the study. The ratio of male to female was 1.3 (69/54). Nearly one-third of patients were 24-60 months, followed by the group 5 years old and 12-24 months (22.0% and 20.3%, respectively). Mean age was 39.41 ± 38.59 months (range, 2-180 months). The majority of patients (71.5%) lived in rural areas (**Table 1**). The incidence was observed more frequently in the spring-winter months (**Figure 1**).

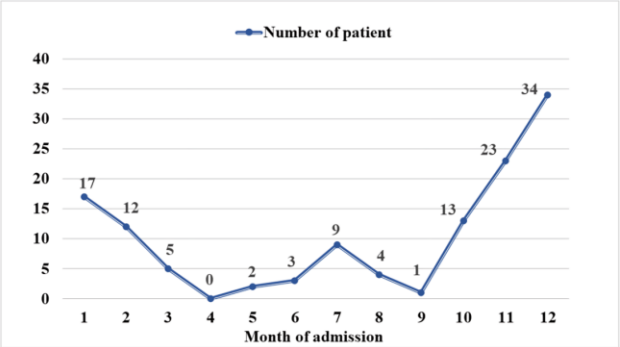

Figure 1. Monthly distribution of cases of admission (n = 123) (Source: Authors' own elaboration)

Table 2. Nasopharyngeal culture results

Nasopharyngeal culture results			Frequency: n (%)
NPC results (n = 123)	Non-detected pathogen		59 (48.0)
	Detected pathogen		64 (52.0)
NPC isolates (n = 64)	Gram-positive	*S. pneumoniae*	24 (37.5)
		S. aureus	5 (7.8)
	Gram-negative	*H. influenzae*	22 (34.4)
		M. catarrhalis	12 (18.7)
		B. cepacia	1 (1.6)

Nasopharyngeal Fluid Culture Results

The NFC test was performed for all patients and pathogenic microorganisms were detected in 64/123 (52.0%) culture samples. Of the 123 patients who had NPCs sent on the first day of hospitalization, more than a half of these cultures were positive for bacterial growth. Noticeably, there was no case of mixed infection detected. Among positive cultures, Gram-positive bacteria and Gram-negative bacteria constituted 29 cases (45.3%) and 35 cases (54.7%), respectively. While the three leading pathogens recorded were *S. pneumoniae* (24/64; 37.5%), *H. influenzae* (22/64; 34.4 %) and *M. catarrhalis* (12/64; 18.7%), *S. aureus* and *B. cepacia* only accounted for small rates (7.8% and 1.6%, respectively) (**Table 2**).

Antimicrobial Resistance

The overall antimicrobial resistance patterns of the isolated pathogens were summarized in **Table 3**. More than 90% of *S. pneumoniae* isolates were susceptible to ampicillin/sulbactam, cefotaxime, ceftriaxone, cefepime, chloramphenicol, imipenem, meropenem, vancomycin and levofloxacin. In contrast, among these 24 *S. pneumoniae* isolates, resistance to oxacillin, erythromycin, trimethoprim/sulfamethoxazole and clindamycin was found in 94.5%, 76.5%, 75.0% and 84.2% of the isolates, respectively (**Table 3**).

In our study, antibiotic susceptibility of *S. pneumoniae* causing LP was tested by Kirby-Bauer test. There were 20/22 *H. influenzae* isolates and 11/12 *M. catarrhalis* isolates had antibiogram results. For *H. influenzae* strains, a large proportion of isolates (75.0-100%) were still sensitive to ciprofloxacin, meropenem, piperacillin/tazobactam, meropenem, third- and fourth-generation cephalosporins (cefepime, cefotaxime, ceftazidime and ceftriaxone). Resistance to cefuroxim accounted for up to 100%, while the rates to ampicillin, trimethoprim/sulfamethoxazol (TMP/SMX) and azithromycin also exceeded more than 90% (**Table 4**).

Table 3. Antibiotic susceptibility of *S. pneumoniae* causing lobar pneumonia (n = 24)

AS	AMS (n = 20)	OXC (n = 18)	CFR (n = 24)	CFT (n = 23)	CTX (n = 23)	CFP (n = 23)	CRP (n = 11)	VCM (n = 24)	ERT (n = 17)	TMP (n = 21)	IPM (n = 20)	MRP (n = 24)	CDM (n = 19)	LVF (n = 22)
S	19 (95.0)	0 (0.0)	13 (54.2)	23 (100)	22 (95.5)	23 (100)	9 (81.8)	23 (95.4)	4 (23.5)	2 (8.3)	19 (95.0)	22 (91.2)	3 (15.8)	21 (95.5)
I	0 (0.0)	1 (5.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (9.1)	0 (0.0)	0 (0.0)	1 (4.2)	0 (0.0)	1 (4.4)	0 (0.0)	0 (0.0)
R	1 (5.0)	17 (94.5)	11 (45.8)	0 (0.0)	1 (4.5)	0 (0.0)	1 (9.1)	1 (4.2)	13 (76.5)	18 (75.0)	1 (5.0)	1 (4.4)	16 (84.2)	1 (4.5)

Note. AS: Antibiotic susceptibility; S: Sensible; I: Intermediate; R: Resistant; AMS: Ampicillin/sulbactam; OXC: Oxacillin; CFR: Cefuroxime; CFT: Cefotaxime; CTX: Ceftriaxone; CFP: Cefepime; CRP: Chloramphenicol; VCM: Vancomycin; ERT: Erythromycin; TMP: TMP/SMX; IPM: Imipenem; MRP: Meropenem; CDM: Clindamycin; & LVF: Levofloxacin

Table 4. Antibiotic susceptibility of *H. influenzae* causing lobar pneumonia (n = 20)

AS	AMP (n = 20)	AMS (n = 20)	AMO (n = 20)	CFR (n = 9)	CFT (n = 20)	CTX (n = 20)	CTD (n = 20)	CFP (n = 19)	AZT (n = 11)	TMP (n = 13)	IPM (n = 18)	MRP (n = 20)	CPF (n = 18)	PTB (n = 19)
S	0 (0.0)	15 (75.0)	9 (45.0)	0 (0.0)	20 (100)	20 (100)	20 (100)	19 (100)	1 (9.1)	1 (7.7)	15 (91.7)	20 (100)	18 (100)	18 (94.7)
I	1 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
R	19 (95.0)	5 (25.0)	11 (55.0)	9 (100)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	10 (90.9)	12 (92.3)	3 (8.3)	0 (0.0)	0 (0.0)	1 (5.3)

Note. AS: Antibiotic susceptibility; S: Sensible; I: Intermediate; R: Resistant; AMP: Ampicillin; AMS: Ampicillin/sulbactam; AMO: Amoxicillin/clavulanic; CFR: Cefuroxime; CFT: Cefotaxime; CTX: Ceftriaxone; CTD: Ceftazidime; CFP: Cefepime; AZT: Azithromycin; ERT: Erythromycin; TMP: TMP/SMX; IPM: Imipenem; MRP: Meropenem; CPF: Ciprofloxacin; &PTB: Piperacillin-tazobactam

Table 5. Antibiotic susceptibility of *M. catarrhalis* causing lobar pneumonia (n = 11)

AS	AMO (n=11)	CFR (n=10)	AZT (n=10)	ERT (n=10)	TMP (n=10)	CPF (n=10)
S	11 (100)	0 (0.0)	0 (0.0)	0 (0.0)	3 (30.0)	10 (100)
I	0 (0.0)	4 (40.0)	1 (10.0)	1 (10.0)	0 (0.0)	0 (0.0)
R	0 (0.0)	6 (60.0)	9 (90.0)	9 (90.0)	7 (70.0)	0 (0.0)

Note. AS: Antibiotic susceptibility; S: Sensible; I: Intermediate; R: Resistant; AMO: Amoxicillin/clavulanic; CFR: Cefuroxime; AZT: Azithromycin; ERT: Erythromycin; TMP: TMP/SMX; & CPF: Ciprofloxacin

Table 6. Multi-drug resistance of bacterial pathogens causing lobar pneumonia in children

Bacterial isolates	Resistance level							
	R0	R1	R2	R3	R4	R5	R6	Total ≥ R3
S. pneumoniae (n = 24)	1	-	2	7	6	7	1	21/24 (87.5%)
H. influenzae (n = 20)	-	-	6	5	7	2	-	14/20 (70.0%)
M. catarrhalis (n = 11)	1	4	-	6	-	-	-	6/11 (54.5%)
S. aureus (n = 5)	-	1	2	1	1	-	-	2/5 (40.0%)
B. cepacia (n = 1)	1	-	-	-	-	-	-	0/1
Total (n = 60)	3	5	10	19	14	9	1	43/60 (71.7%)

Note. R0: Susceptible to all antibiotic classes & R1-R6: Resistance to 1-6 different antibiotics classes, consistently

For *M. catarrhalis* strains, all isolates were sensitive to amoxicillin/clavulanic and ciprofloxacin, whereas all *M. catarrhalis* strains showed high resistance to macrolides (erythromycin and azithromycin; 90.0%). Besides, 70.0% and 60% of isolates were found resistant to TMP/SMX and cefuroxime (**Table 5**).

Multi-Drug Resistance

In order to characterize organisms as MDR is based on *in vitro* antimicrobial susceptibility test results as shown before, the definition used is resistant to at least one agent in three or more different antimicrobial categories [11]. In our study, 43/60 (71.7%) of isolates were found MDR. That meant approximately two-thirds of isolates showed resistance to three and more antimicrobial classes, in which the MDR proportion of *S. pneumoniae* was by far the highest, at 87.5%. The figures for *H. influenzae* and *M. catarrhalis* were also remarkably noticeable, at 70.0% and 54.5%, respectively (**Table 6**).

In terms of treatment, for patients without antibiogram result, antibacterial choice was generally empirical. The rate of individuals received combined-antibiotic therapy comprising C3G and aminoglycosides initially was highest (85/123 cases, 69.1%) (**Table 7**).

Table 7. Antibiotic therapy for lobar pneumonia (n = 123)

Antibiotic therapy of lobar pneumonia			Frequency: n (%)
Initial antibiotic therapy		Single therapy	2 (1.6)
		Combination therapy	121 (98.4)
Initial antibiotic combination	C3G + fluoroquinolones	Ceftriaxone + levofloxacin	13 (10.6)
		Cefoperazone + levofloxacin	3 (2.4)
	C3G + aminoside	Cefoperazone + amikacin	40 (32.5)
		Ceftriaxone + amikacin	26 (21.1)
		Cefotaxime + amikacin	9 (7.3)
		Ceftazidime + amikacin	5 (4.1)
		Ceftizoxime + amikacin	5 (4.1)
	Penicillin-β-lactamase inhibitors + aminoside	Ampicillin-sulbactam + amikacin	20 (16.3)
	Fluoroquinolone	Levofloxacin	2 (1.6)

Additionally, 64.2% of patients had no change in antibiotic therapy. When it came to antibiotic change, the rates of patients treated with the combination of cefotaxime and amikacin and ampicillin-sulbactam and amikacin who needed to change antibiotics were up to 88.9% and 55.0%, respectively. Patients with fluoroquinolones monotherapy and

Table 8. Efficiency of initial antibiotic therapy

Initial antibiotic therapy		Patients change antibiotics: n1/n2 (%)	
C3G + fluoroquinolones	Ceftriaxone + levofloxacin	0/16 (0.0)	
	Cefoperazone + levofloxacin		
C3G + aminoside	Cefoperazone + amikacin	14/40 (35.0)	32/85 (37.6)
	Ceftriaxone + amikacin	6/26 (23.1)	
	Cefotaxime + amikacin	8/9 (88.9)	
	Ceftazidime + amikacin	2/5 (40.0)	
	Ceftizoxime + amikacin	2/5 (40.0)	
Penicillin-β-lactamase inhibitors + aminoside	Ampicillin-sulbactam + amikacin	12/20 (55.0)	
Fluoroquinolone	Levofloxacin	0/2 (0.0)	

Note: n1: Number of cases with antibiotic change& n2: Number of initial antibiotic therapy uses

Table 9. Summary of treatment of lobar pneumonia in children

NPC results treatment result		Detected pathogen (n = 64)	Non-detected pathogen (n = 59)	p-value
Treatment duration	≤ 2 weeks	57 (89.1)	47 (79.7)	0.149484 (*)
	> 2 week	7 (10.9)	12 (20.3)	
Treatment result	Recovery	64 (100)	56 (94.9)	N/A
	Hospital referral	0 (0)	3 (5.1)	
Average treatment duration (days): Mean ± standard deviation (range): 13.3 ± 3.55 (7-28) days		11.41 ± 2.77 (8-18)	12.69 ± 3.38 (7-28)	0.0229 (**)

Note. *Chi-square test; **Unpaired t-test; N/A: Not applicable; & NPC: Nasopharyngeal swab culture

C3G and fluoroquinolones combination therapy showed good treatment response, thus changing antibiotics was unnecessary. Vancomycin and pimenem/imipenem were not chosen empirically, they were prescribed with antibiogram proven (**Table 8**).

During hospitalization, antibiotic therapy would be regularly efficient within 2 weeks (84.6%). There were only 4 patients (3.3%) of which treatment required more than 3 weeks. Parenteral antibiotics were usually prescribed for 7-28 days. The average treatment duration of patients was 13.31 ± 3.55 days, and significant differences were observed in this case ($p < 0.05$). In terms of treatment outcome, 90.2% of patients completely recovered from LP and there was no significant difference between detected-pathogen group and non-detected pathogen group ($p > 0.05$). Especially, no death cases were recorded and there were 3/123 (2.4%) patients needed to be transferred to the Children's National Hospital (Hanoi, Vietnam) for further treatment (**Table 9**).

DISCUSSION

In this study, we noticed that the children aged 24-60 months old were the most common age group with LP, accounting for 33.3%. This result was consistent with a recent study which revealed that the age in the LP group was 4.00 ± 2.44 years, markedly older than that observed in the non-LP group (2.62 ± 2.18 years) [12]. Other previous studies conducted in our country showed consistent results. A study at the Department of Respiratory in National Hospital of Pediatrics showed that the age of LP was mostly from 3 to 7 years old (61.8%) and rarely seen in children under 12 months (5.9%) [9]. The average age of patients diagnosed with LP in our study was 39.41 ± 38.59 months. Older children have stronger natural immune systems and more developed self-protective mechanisms. Antibodies in their system can limit lung inflammation to particular lobes or segments, while younger children with immature immune systems frequently suffer from more extensive lung inflammation involving several lobes or segments [12]. On admission, our youngest patient was 2 months of age, the oldest one was 15 years old. We also recorded those female patients suffered from LP more than male patients in all age groups, and the male to female ratio was 1/1.3. However, the gender difference was not statistically significant. The average age of children with LP was 55.76 ± 39.44 months, the oldest was 14 years old, the youngest was 7 months, and there was no significant difference in terms of gender. LP occurred mainly in children from 3 to 7 years old (46.3%), less common in children under one year old ($p < 0.001$), the incidence of boys and girls was almost equal. This could be explained by the fact that the financial and economic conditions in several rural areas are limited, the health system in rural regions is not as well-developed as in urban areas [13]. Having greater awareness as well as better quality of life, city dwellers often take their children to private clinics for medical examinations and early treatment [14]. This can reduce the number of cases of hospitalization in urban areas, thus leading to such situation recorded above.

Our result was consistent with some other research. In Taiwan, the incidence of LP in children was remarkably higher in spring and winter months [15]. It was also reported that LP in children was more frequent in the winter month [5]. In fact, cold weather favors the occurrence of acute respiratory infections in children. In this research, among all the isolated bacterial pathogens, the two leading bacterial pathogens were *S. pneumoniae* and *H. influenzae*. It was remarkable that co-infections with multiple pathogens were not observed in our study. This result was similar to several other research. According to [16], *S. pneumoniae* was recognized as the most important cause of bacterial pneumonia in children aged less than 5 years old. *S. pneumoniae* remains the single biggest cause of bacterial pneumonia in children. However, another recent finding in 2020 in China reported that atypical bacteria (*M. pneumoniae*) was by far the most commonly detected pathogen (72.3%) and *S. pneumoniae* only made up for 8.8% of patients [7]. Our finding reported that *S. pneumoniae* was susceptible to common antibiotics, such as C3G and C4G (except ceftazidime), glycopeptides (vancomycin), carbapenems (pimenem, imipenem), fluoroquinolones (levofloxacin) and penicillin (ampicillin). In contrast, these isolates showed high rates of resistance to some antibiotics, such as oxacillin, clindamycin, erythromycin and TMP/SMX. A

similar finding in Ba Vi District (Hanoi, Vietnam) showed a high level of resistance to tetracycline, erythromycin, TMP/SMX, and Phenoxymethylpenicillin (70-78%) [17].

These proportions were much more than those in a study in Lithuania in 2013, which recorded that the rates of pneumococcal non-susceptibility to penicillin, clindamycin, erythromycin, and TMP/SMX ranged from 15.8% to 27.3%, but none of the tested isolates was resistant to vancomycin [18]. Our study noted that the majority of *H. influenzae* was susceptible to C3G and C4G (cefotaxime, ceftriaxone; ceftazidime and cefepime), meropenem, imipenem, ciprofloxacin, piperacillin-tazobactam and ampicillin/sulbactam. However, *H. influenzae* showed remarkable resistance to cefuroxime, ampicillin, azithromycin and TMP/SMX. Our result was similar to the study in [19], which showed that more than half of *H. influenzae* strains isolated from children were resistant to ampicillin, primarily due to the production of β-lactamase. The majority of *M. catarrhalis* isolates were susceptible to amoxicillin/clavulanic acid and ciprofloxacin. The rates of non-susceptibility to cefuroxime, TMP/SMX and macrolide were high (ranging from 60.0% to 90.0%). Our result was similar to the study in [20], which found that the non-susceptibility rates of erythromycin and azithromycin were 40.3% and 22.5%, respectively.

Most patients responded well to the initial antibiotics, so they only received one antibiotic therapy during the course of treatment. About one-third of patients needed antibiotic change once and 4.1% of patients were assigned to change antibiotics twice. The majority of patients in our study were initially treated with a combined-antibiotic therapy (98.4%), while only 2 cases received quinolone monotherapy (levofloxacin). Penicillin is no longer the first-line antibiotic for children with pneumonia in many countries, in fact, clinicians tend to use C3G and C4G [21, 22]. The combination of β-lactam combined and macrolide was proven to help shorten the hospital stay by 20.0% [23]. In our study, C3G/aminoglycoside combination was the most commonly used (69.1%), followed by β-lactam/aminoglycoside (16.3%) and C3G/fluoroquinolones combination (13.0%). The antibiotics use for patients diagnosed with LP on admission was based on empirical antibiotics use or regimens. If NFCs returned positive results and antibiogram provided evidence about bacterial susceptibility to antibiotics, we would proceed to adjust the antibiotics. However, in cases where the bacteria were susceptible to the antibiotic used, patients did not need to adjust. In our research, after the initial treatment time (2-3 days), patients were re-assessed clinically and paraclinically, we recorded that 35.8% of them needed to change antibiotics. The failure rate of initial antibiotic treatment for LP was by far the highest in the group of patients who used the combination of cefotaxime/amikacin and ampicillin-sulbactam/amikacin. This fact was in line with our results mentioned as above.

The second antibiotic therapy was mainly C3G/levofloxacin combination (24/44 cases) and a few other patients were prescribed carbapenem or carbapenem combined with quinolone because in our hospital, common bacterial pathogens of LP remained highly susceptible to C3G, C4G and carbapenems. The reason why fluoroquinolones were used as the second therapy was because these antibiotics are not recommended in many countries to treat children under 18 years old [24, 25]. Our study showed good treatment results: 90.2% of patients recovered from LP and none of the patients died due to LP during the treatment.

About the average length of treatment duration of patients, our results were in line with other studies, Lin CJ, et al. (Taiwan, 131 patients) showed that the average durations of treatment for the group of uncomplicated LP and complicated LP in children were 13.81 ± 16.25 days and 14.75 ± 11.7 days, respectively [5]. We chose the time points as above because of some reasons: the duration of treatment for LP in children recommended is 7-10 days and it takes at least 3 to 5 days to assess clinical efficacy in case of changing other antibiotic therapy [26]. The successful rate of treatment of LP in this study was 120/123 (97.6%), which was similar to the results of a study performed in the Southern Vietnam previously with the successful rate of treatment of LP in children was 63/65 (96.9%) [9].

There were still some limitations associated with this study, for example the sample size used in the study was relatively small leading to a limited number of bacterial isolates. Also, diagnostic tools to identify atypical bacteria in the patient's specimen (such as multiplex PCR) were not available at the time of this study. It should be noted that *M. pneumoniae* and other atypical bacteria were also considered to play a remarkable role in LP in children [9, 27, 28].

CONCLUSIONS

We found that *S. pneumoniae* was still the most common pathogen causing LP in children. Almost detected agents were multidrug-resistant as the rates of antibiotic resistance were increasing, the combined-antibiotics therapy was effective in the treatment of LP in children.

Author contributions: TADD & THTH: formal analysis, investigation, methodology, software, validation, and writing–original draft & **TADD:** conceptualization, data curation, project administration, resources, supervision, visualization, and writing–review & editing. Both authors have agreed with the results and conclusions.

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Ethical statement: The authors stated that the study was approved by the Ethics Committee at Hai Phong Children's Hospital on the 5th February 2021 (Approval code: 15.264/QĐ-YDHP). Written informed consents were obtained from the participants.

AI statement: The authors stated that they have not used any type of generative artificial intelligence for the writing of this manuscript, nor for the creation of images, graphics, tables, or their corresponding captions.

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Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

1. Wen H, Qu F, Sun L, Lei Y, Wang R. Clinical study and analysis of 700 cases of pneumonia in children. Ann Pediatr. 2018;2:1006. https://doi.org/10.4172/0032-745X.1000300
2. Ma Y, Fan S, Xi JS. Recent updates regarding the management and treatment of pneumonia in pediatric patients: A comprehensive review. Infection. 2025. https://doi.org/10.1007/s15010-025-02605-w

3. Mannu GS, Loke YK, Curtain JP, Pelpola KN, Myint PK. Prognosis of multi-lobar pneumonia in community-acquired pneumonia: A systematic review and meta-analysis. Eur J Intern Med. 2013;24(8):857-63. https://doi.org/10.1016/j.ejim.2013.05.001 PMid:23747042
4. de Freitas Freire T, de Souza EC, de Ribarmar Barroso Juca Neto J, et al. Treatment of complicated bacterial pneumonia in children. Res Soc Dev. 2024;13(2): e8913245091. https://doi.org/10.33448/rsd-v13i2.45091
5. Lin C-J, Chen P-Y, Huang F-L, Lee T, Ch, C-S, Lin C-Y. Radiographic, clinical, and prognostic features of complicated and uncomplicated community-acquired lobar pneumonia in children. J Microbiol Immunol Infect. 2006;39(6):489-95. PMid:17164952
6. Yun KW. Community-acquired pneumonia in children: Updated perspectives on its etiology, diagnosis, and treatment. Clin Exp Pediatr. 2024;67(2):80-9. https://doi.org/10.3345/cep.2022.01452 PMid:37321577 PMCid:PMC10839192
7. Wang Y, Ma L, Li Y, Zheng Y, Zhang X. Epidemiology and clinical characteristics of pathogens positive in hospitalized children with segmental/lobar pattern pneumonia. BMC Infect Dis. 2020;20(1):205. https://doi.org/10.1186/s12879-020-4938-7 PMid:32143599 PMCid: PMC7060602
8. Uddin TM, Chakraborty AJ, Khusro A, et al. Antibiotic resistance in microbes: History, mechanisms, therapeutic strategies and future prospects. J Infect Public Health. 2021;14(12):1750-66. https://doi.org/10.1016/j.jiph.2021.10.020 PMid:34756812
9. Tran Quang K, Pham VH, Nguyen PM, et al. Lobar pneumonia and bacterial pathogens in Vietnamese children. Curr Pediatr Res. 2020;24:247-53.
10. Wanger A, Chavez V, Huang RSP, Wahed A, Actor J, Dasgupta A. Antibiotics, antimicrobial resistance, antibiotic susceptibility testing, and therapeutic drug monitoring for selected drugs. In: Microbiology and molecular diagnosis in pathology. Elsevier; 2017. p. 119-53. https://doi.org/10.1016/B978-0-12-805351-5.00007-7
11. Thummeepak R, Leerach N, Kunthalert D, Tangchaisuriya U, Thanwisai A, Sitthisak S. High prevalence of multi-drug resistant streptococcus pneumoniae among healthy children in Thailand. J Infect Public Health. 2015;8(3):274-81. https://doi.org/10.1016/j.jiph.2014.11.002 PMid: 25541228
12. Shen L, Wu J, Lu M, et al. Advancing risk factor identification for pediatric lobar pneumonia: The promise of machine learning technologies. Front Pediatr. 2025;13:1490500. https://doi.org/10.3389/fped.2025.1490500 PMid:40123673 PMCid:PMC11925904
13. Karim SA, Tilford JM, Bogulski CA, Rabbani M, Hayes CJ, Eswaran H. Financial performance of rural hospitals persistently lacking or having telehealth technology. J Hosp Manag Health Policy. 2023;7. https://doi.org/10.21037/jhmhp-22-85
14. Khoo EJ, Miin LY, Yin NX, et al. Family and parental decision making when choosing a paediatric general practice service: What factors mattered most? Child Care Pract. 2024;30(4):446-63. https://doi.org/10.1080/13575279.2021.1920368
15. Wu P-S, Huang L-M, Chang, I-S, et al. The epidemiology of hospitalized children with pneumococcal/lobar pneumonia and empyema from 1997 to 2004 in Taiwan. Eur J Pediatr. 2010;169(7):861-6. https://doi.org/10.1007/s00431-009-1132-8 PMid:20052488 PMCid:PMC7086680
16. O'Brien KL, Wolfson LJ, Watt JP, et al. Burden of disease caused by Streptococcus pneumoniae in children younger than 5 years: Global estimates. Lancet. 2009;374(9693):893-902. https://doi.org/10.1016/S0140-6736(09)61204-6 PMid: 19748398
17. Hoa NQ, Trung NV, Larsson M, et al. Decreased Streptococcus pneumoniae susceptibility to oral antibiotics among children in rural Vietnam: A community study. BMC Infect Dis. 2010;10:85. https://doi.org/10.1186/1471-2334-10-85 PMid:20356399 PMCid:PMC2853544
18. Stacevičienė I, Petraitienė S, Vaičiūnienė D, Alasevičius T, Kirslienė J, Usonis V. Antibiotic resistance of Streptococcus pneumoniae, isolated from nasopharynx of preschool children with acute respiratory tract infection in Lithuania. BMC Infect Dis. 2016;16:216. https://doi.org/10.1186/s12879-016-1544-9 PMid:27206423 PMCid:PMC4875676
19. Wang H-J, Wang C-Q, Hua C-Z, et al. Antibiotic resistance profiles of *haemophilus influenzae* isolates from children in 2016: A multicenter study in China. Can J Infect Dis Med Microbiol. 2019;2016:6456321. https://doi.org/10.1155/2019/6456321 PMid:31485283 PMCid:PMC6710757
20. Liu Y, Zhao C, Zhang F, Chen H, Chen M, Wang H. High prevalence and molecular analysis of macrolide-nonsusceptible moraxella catarrhalis isolated from nasopharynx of healthy children in China. Microb Drug Resist. 2012;18(4):417-26. https://doi.org/10.1089/mdr.2011.0175 PMid:22394083
21. Breuer O, Blich O, Cohen-Vymberknoh M, et al. Antibiotic treatment for children hospitalized with community-acquired pneumonia after oral therapy. Pediatr Pulmonol. 2015;50(5):495-502. https://doi.org/10.1002/ppul.23159 PMid:25652187
22. Kumar A, Rais H, Prakash A, Ali A, Jung S, Siddiqui FG. Ampicillin & gentamicin V/S 3rd generation cephalosporin for the management of community-acquired pneumonia in children: A comparative analysis. J Pharm Res Int. 2021;33(59B):29-35. https://doi.org/10.9734/jpri/2021/v33i59B34348
23. Ambroggio L, Taylor JA, Tabb LP, Newschaffer CJ, Evans AA, Shah SS. Comparative effectiveness of empiric β-lactam monotherapy and β-lactam-macrolide combination therapy in children hospitalized with community-acquired pneumonia. J Pediatr. 2012;161(6):1097-103. https://doi.org/10.1016/j.jpeds.2012.06.067 PMid: 22901738
24. Adefurin A, Sammons H, Jacqz-Aigrain E, Choonara I. Ciprofloxacin safety in paediatrics: A systematic review. Arch Dis Child. 2011;96(9):874-80. https://doi.org/10.1136/adc.2010.208843 PMid:21785119 PMCid:PMC3155117
25. Li Y, Wang J, Wang CL, Chen L. Safety analysis of quinolones use in minors–Based on the FAERS database. Front Med (Lausanne). 2024;11:1437376. https://doi.org/10.3389/fmed.2024.1437376 PMid:39267976 PMCid:PMC11390674
26. Li Y, Han F, Yang Y, Chu J. Principles of antibiotic application in children with lobar pneumonia: Step-up or step-down. Exp Ther Med. 2017;13(6):2681-4. https://doi.org/10.3892/etm.2017.4319 PMid:28587330 PMCid:PMC5450740

27. Gao J, Yue B, Li H, Chen R, Wu C, Xiao M. Epidemiology and clinical features of segmental/lobar pattern mycoplasma pneumoniae pneumonia: A ten-year retrospective clinical study. Exp Ther Med. 2015;10(6):2337-44. https://doi.org/10.3892/etm.2015.2818 PMid:26668638 PMCid: PMC4665157

28. Shah SS. Mycoplasma pneumoniae as a cause of community-acquired pneumonia in children. Clin Infect Dis. 2019;68(1):13-4. https://doi.org/10.1093/cid/ciy421 PMid:29788200