



# Impact of the corona virus disease 2019 pandemic on the prevalence of common respiratory pathogens in hospitalized young patients with non-severe community-acquired pneumonia

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**Background:** Community-acquired pneumonia (CAP) remains a significant global health concern, yet the characteristics of non-severe CAP in young adults, particularly following the corona virus disease 2019 (COVID-19) pandemic, are not well elucidated. This study aimed to investigate the impact of COVID-19 infection on the epidemiological trends of common respiratory pathogens in young patients with non-severe CAP and to provide a theoretical basis for treatment protocols.

**Methods:** A retrospective analysis was conducted on data from all young CAP patients hospitalized at The Third Affiliated Hospital of Guangzhou Medical University from January 2018 to December 2023. The respiratory pathogen profiles of young CAP inpatients were compared across three periods: pre-pandemic (January 2018 to December 2019), during the pandemic (January 2020 to December 2022), and post-pandemic (January 2023 to December 2023). Descriptive statistical analysis was used to evaluate the epidemiological characteristics, infection seasonality, and patterns of CAP patients. The Chi-squared or Fisher's exact test was used to compare the differences in pathogen positivity rates and co-infection rates among different stages.

**Results:** There were no significant differences in age, white blood cell count, neutrophil count, lymphocyte count, and C-reactive protein (CRP) among the three groups of young non-severe CAP inpatients. The proportion of males showed statistical significance among the three groups: pre-pandemic (12.5%), during the pandemic (28%), and post-pandemic (23.23%). The proportion of young CAP inpatients to total CAP inpatients also differed significantly: pre-pandemic (17.75%), during the pandemic (11.93%), and post-pandemic (23.77%). Changes in pathogen profiles were as follows: bacterial infection rates—pre-pandemic (6.25%), during the pandemic (10%), post-pandemic (21.38%); viral infection rates—pre-pandemic (10.94%), during the pandemic (19%), post-pandemic (23.90%); Mycoplasma infection rates—pre-pandemic (56.25%), during the pandemic (46%), post-pandemic (35.22%); co-infection rates—pre-pandemic (7.81%), during the pandemic (13%), post-pandemic (20.75%). These differences were statistically significant among the three groups. The rate of bacterial-bacterial co-infections significantly increased: pre-pandemic (20%), during the pandemic (53.85%), and post-pandemic (72.72%), with significant differences among the three groups. The top five pathogens in each stage were pre-pandemic—*Mycoplasma pneumoniae*, influenza virus, *Legionella*, *Streptococcus pneumoniae*, *Haemophilus influenzae*; during the pandemic—*Mycoplasma pneumoniae*, influenza virus, *Legionella*, rhinovirus, adenovirus; post-pandemic—*Mycoplasma pneumoniae*, *Haemophilus influenzae*, influenza virus, COVID-19 virus, *Staphylococcus epidermidis*.

**Conclusions:** Following COVID-19 infection, the incidence of CAP in young people increased, with changes in pathogen profiles. There was an increase in bacterial and viral infections, a significant rise in co-infections, predominantly bacterial-bacterial infections, and more atypical pathogen infections were observed.

**Keywords:** Corona virus disease 2019 infection (COVID-19 infection); community-acquired pneumonia (CAP); pathogen profile; young inpatients; trend

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## Introduction

Community-acquired pneumonia (CAP) refers to inflammation of the lung parenchyma that occurs in the community setting and is typically diagnosed outside the hospital. It involves inflammation of the alveoli and lung interstitium, primarily caused by pathogen infections (1). Prior to the corona virus disease 2019 (COVID-19) pandemic, the main pathogens of CAP included *Mycoplasma pneumoniae*, *Streptococcus pneumoniae*, and respiratory syncytial virus. However, with the outbreak of COVID-19, the pathogen spectrum of CAP has changed significantly, with viral

pneumonia becoming the predominant type. According to data from the Chinese Center for Disease Control and Prevention (CDC) in 2020, the number of cases of influenza A and B decreased significantly during the COVID-19 pandemic, which may be attributed to the implementation of epidemic prevention and control measures. To gain a deeper understanding of the pathogenetic characteristics of CAP, the CDC conducted an epidemiological survey in 2021 (2). By analyzing pharyngeal swabs, nasal swabs, sputum, and bronchoalveolar lavage fluid samples, it was found that viruses were the main pathogens of CAP, with single viral infections being the most common, followed by multiple viral infections. Additionally, bacterial pathogens such as *Streptococcus pneumoniae* and *Mycoplasma pneumoniae* were also detected. These findings highlight the significant changes in the pathogen spectrum of CAP in the context of the COVID-19 pandemic and emphasize the importance of viral pneumonia. Before the COVID-19 pandemic, the proportion of young people hospitalized for CAP was relatively low, and there were few studies (3). After COVID-19 infection, the number of young patients hospitalized for CAP increased significantly. There are currently no studies exploring the changes in the microbial spectrum of CAP in young patients after COVID-19 infection. Therefore, to understand the impact of COVID-19 infection on CAP in young people, we investigated the microbial infection pathogens spectrum of CAP in young patients at different stages before and after COVID-19 infection, providing a scientific basis for the prevention and treatment of CAP in young people.

Most existing studies on CAP have focused on elderly populations, who account for the majority of severe cases and hospitalizations. However, hospitalized young patients with CAP remain understudied despite their unique pathogen spectrum, particularly the high prevalence of *Mycoplasma pneumoniae*. Therefore, we specifically focused

### Highlight box

#### Key findings

- The study found that the pathogen spectrum of community-acquired pneumonia (CAP) in young patients has changed significantly due to the corona virus disease 2019 (COVID-19) pandemic. There was an increase in bacterial and viral infections, a higher rate of co-infections, and a shift in the most common pathogens detected.

#### What is known and what is new?

- CAP in young patients was previously dominated by pathogens such as *Mycoplasma pneumoniae* and *Streptococcus pneumoniae*, with relatively low incidence rates.
- This study reveals that the COVID-19 pandemic has altered the pathogen profile of CAP in young patients, with increased bacterial and viral infections, higher co-infection rates, and the emergence of new pathogens like *Pseudomonas aeruginosa* and *Acinetobacter baumannii*.

#### What is the implication, and what should change now?

- Clinical guidelines for treating CAP in young patients should be updated to account for the broader range of pathogens. Advanced diagnostic methods should be considered to guide targeted therapy. Public health efforts should focus on continued monitoring and vaccination against respiratory pathogens to reduce CAP incidence.

on young patients (15–44 years) in this study to explore how the COVID-19 pandemic influenced this age group and to provide insights for age-specific prevention and treatment strategies. We present this article in accordance with the STROBE reporting checklist (available at <https://jtd.amegroups.com/article/view/10.21037/jtd-2025-1162/rc>).

## Methods

### Study population

A retrospective analysis was conducted on the information and related hospitalization records of all adult CAP inpatients at The Third Affiliated Hospital of Guangzhou Medical University from January 2018 to December 2023. The inclusion criteria for young CAP were as follows: (I) discharge diagnosis of CAP (International Classification of Diseases, 10th revision codes: J13–J15); (II) admission date between January 1, 2018, and December 31, 2023; (III) aged 15–44 years, according to the classification used by the World Health Organization (WHO) and the Chinese Guidelines for the diagnosis and treatment of CAP in adults. Exclusion criteria included: (I) incomplete data without pathogen testing; (II) hospital stay <1 day; (III) severe CAP patients—severe CAP was identified based on the 2018 Chinese guidelines and the European Respiratory Society (ERS)/European Society of Intensive Care Medicine (ESICM)/European Society of Clinical Microbiology and Infectious Diseases (ESCMID)/Latin American Thoracic Association (ALAT) international guidelines, which define severity using Confusion, Urea, Respiratory rate, Blood pressure, age  $\geq 65$  years (CURB-65) scores, septic shock, requirement for mechanical ventilation, or multi-organ dysfunction. Patients who did not meet these criteria were categorized as non-severe CAP; (IV) combined with tuberculosis infection. Since the time span was large, the same case might have been admitted multiple times. In this study, “case” represents discharge times. If the same patient was admitted multiple times, it was recorded as different discharge times. For analyses of pathogen spectrum, only patients with complete microbiological testing were included. However, when calculating the overall hospitalization incidence and seasonal distribution of CAP, we included all adult CAP inpatients, regardless of whether pathogen testing was performed, to avoid underestimation of epidemiological trends.

All hospitalized CAP patients included in this study underwent routine microbiological testing according to the hospital's standard diagnostic protocol. Blood and sputum cultures were performed to detect common bacterial

pathogens such as *Streptococcus pneumoniae*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Haemophilus influenzae*. Nasopharyngeal and pharyngeal swabs and pulmonary lavage were analyzed using reverse transcription polymerase chain reaction (RT-PCR) for detection of respiratory viruses, including influenza virus, respiratory syncytial virus, parainfluenza virus, human metapneumovirus, coronavirus, and rhinovirus. In addition, PCR assays were conducted for *Mycoplasma pneumoniae* and adenovirus. Not all patients received every test simultaneously, but all were tested according to clinical presentation and national guideline recommendations.

### Study indicators

Based on the COVID-19 prevention and control levels in Guangdong Province, three time variables were set: January 1, 2018–December 31, 2019, as the pre-pandemic period; January 1, 2020–December 31, 2022, as the pandemic period; and January 1, 2023–December 31, 2023, as the post-pandemic period. Data on demographics, clinical symptoms and signs, laboratory indicators, and clinical outcomes were recorded. Respiratory specimens were collected from all CAP patients included in the study to detect common pathogens: *Pseudomonas aeruginosa*, *Klebsiella pneumoniae*, *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Moraxella catarrhalis*, *Legionella*, influenza virus, respiratory syncytial virus, parainfluenza virus, human metapneumovirus, coronavirus, *Mycoplasma pneumoniae*, and *Chlamydia*. Blood and sputum cultures were performed using bacterial culture methods to identify *Streptococcus pneumoniae*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Haemophilus influenzae*. RT-PCR was used to detect influenza virus, respiratory syncytial virus, parainfluenza virus, human metapneumovirus, coronavirus, and rhinovirus in nasopharyngeal/pharyngeal specimens. PCR was used to detect adenovirus and *Mycoplasma pneumoniae* in nasopharyngeal/pharyngeal specimens.

### Statistical analysis

All data were analyzed using SPSS version 21. Quantitative data were summarized as mean  $\pm$  standard deviation for normally distributed variables and median [interquartile range (IQR)] for skewed distributions, and comparisons among multiple groups were performed using one-way analysis of variance (ANOVA), with Bonferroni correction for pairwise comparisons. Comparisons between two groups for categorical data were performed using Chi-square test, continuity correction Chi-

**Table 1** General characteristics of young CAP inpatients at different stages of COVID-19 prevention and control

Characteristics	2018–2019	2020–2022	2023	P
Number of cases	128	100	159	
Male	48 (37.5)	53 (53.0)	37 (23.3)	<0.001
Age (years)	31.75±6.92	32.02±6.24	31.58±7.48	0.88
White blood cells (×10 <sup>9</sup> /L)	7.8±3.4	8.2±3.7	7.9±4.8	0.83
Neutrophils (×10 <sup>9</sup> /L)	5.5±3.0	5.7±3.5	5.3±3.2	0.51
Lymphocytes (×10 <sup>9</sup> /L)	1.5 (1.1, 2.1)	1.7 (1.3, 2.2)	1.6 (1.1, 2.0)	0.33
CRP (mg/L)	29.2 (8.9, 61.9)	27.0 (8.1, 55.7)	20.5 (6.3, 42.2)	0.13
Diabetes				0.79
Yes	5 (3.9)	3 (3.0)	6 (3.8)	
No	123 (96.1)	97(97.0)	153 (96.2)	
Asthma				0.79
Yes	7 (5.5)	7 (7.0)	8 (5.0)	
No	121 (94.5)	93 (93.0)	151 (95.0)	
COVID-19 vaccination status				>0.99
Yes	128 (100.0)	100 (100.0)	159 (100.0)	
Length of hospital stay (days)				0.56
<5	18 (14.1)	11 (11.0)	21 (13.2)	
5–7	98 (76.6)	77 (77.0)	128 (80.5)	
>7	12 (9.4)	12 (12.0)	10 (6.3)	

Data are presented as number (%) or median (interquartile range) or mean ± standard deviation. CAP, community-acquired pneumonia; COVID-19, corona virus disease 2019; CPR, C-reactive protein.

square test, or Fisher's exact test, with  $P < 0.05$  considered statistically significant.

### Ethical statement

The study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. The study was approved by the Ethics Committee of The Third Affiliated Hospital of Guangzhou Medical University (approval No. 2024-31) and individual consent for this retrospective analysis was waived.

## Results

### General characteristics of young CAP inpatients at different stages of COVID-19 prevention and control

A total of 387 patients were included in the study,

comprising 138 males and 249 females, with a mean age of 31 years (range, 14–45 years). The proportion of males differed significantly among the three groups: pre-pandemic (37.5%), during the pandemic (53%), and post-pandemic (23.3%). There were no significant differences in age, white blood cell count, neutrophil count, lymphocyte count, and C-reactive protein (CRP) among the three groups. Detailed clinical data are shown in *Table 1*.

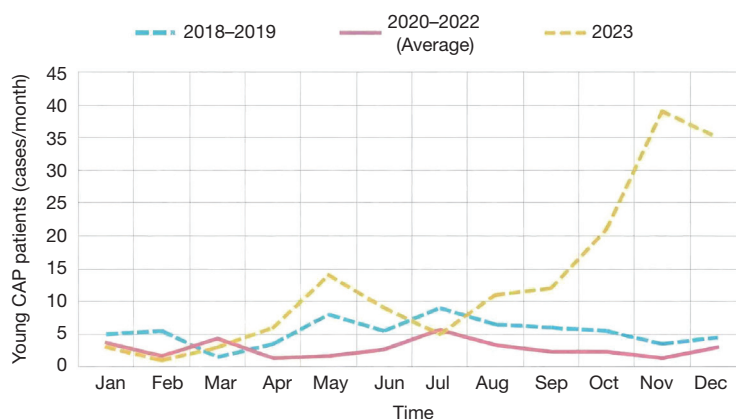
### Proportion of young non-severe CAP inpatients at different stages of COVID-19 prevention and control

The proportion of young non-severe CAP inpatients among all adult CAP inpatients varied across the three periods, with the lowest proportion during the pandemic period and the highest proportion in the post-pandemic period. The differences were statistically significant (*Table 2*). In contrast, the proportion of young severe CAP inpatients among all

**Table 2** Proportion of young non-severe CAP inpatients among all adult CAP inpatients at different stages of COVID-19 prevention and control

Items	2018–2019	2020–2022	2023	P
Total non-severe CAP cases	721	838	669	
Young non-severe CAP cases	128	100	159	
Young non-severe CAP (%)	17.75 <sup>ab</sup>	11.93 <sup>ac</sup>	23.77 <sup>bc</sup>	<0.001
Total severe CAP cases	12	56	32	
Young severe CAP cases	1	0	2	
Young severe CAP (%)	8.33	0	6.25	0.14

<sup>a</sup>, P=0.003; <sup>b</sup>, P=0.048; <sup>c</sup>, P<0.001. CAP, community-acquired pneumonia; COVID-19, corona virus disease 2019.

**Figure 1** Seasonal distribution of young CAP inpatients at different stages. CAP, community-acquired pneumonia.

adult CAP inpatients did not differ significantly across the three periods (Table 1).

#### Seasonal distribution of young CAP inpatients at different stages

During the pre-pandemic period, the number of infections peaked in May to July, with little difference in other months. During the pandemic period, the number of infections increased slightly in March and July, with little difference in other months. In the post-pandemic period, a small peak occurred in May, and the number of infections increased significantly from August, reaching the highest point in November (Figure 1).

#### Changes in pathogen profiles at different stages

The proportion of bacterial and viral infections increased significantly in the post-pandemic period, while the proportion of *Mycoplasma* infections decreased. These

differences were statistically significant. Additionally, the rate of co-infections was higher in the post-pandemic period than in the pre-pandemic and pandemic periods, indicating a significant increase in co-infections in the post-pandemic period (Table 3).

We further analyzed the co-infections, categorizing *Mycoplasma* and *Chlamydia* infections as bacterial infections. Based on the presence of bacterial and viral infections, they were classified into bacterial-bacterial co-infections, viral-viral co-infections, and bacterial-viral co-infections. The proportion of bacterial-bacterial co-infections increased significantly during the pandemic and post-pandemic periods, while the proportions of bacterial-viral and viral-viral co-infections showed no statistically significant differences across the periods (Table 4).

#### Analysis of respiratory pathogens

To further analyze the changes in respiratory pathogens in young CAP patients, we compared the types of bacteria,

**Table 3** Changes in pathogen profiles at different stages

Items	2018–2019	2020–2022	2023	P
Number of cases	128	100	159	
Bacteria	8 (6.25)	10 (10.00)	34 (21.38)	<0.001
Virus	14 (10.94)	19 (19.00)	38 (23.90)	0.02
Mycoplasma	72 (56.25)	46 (46.00)	56 (35.22)	0.002
Co-infection	10 (7.81)	13 (13.00)	33 (20.75)	0.007

Data are presented as number (%).

**Table 4** Changes in co-infections at different stages

Items	2018–2019	2020–2022	2023	P
Number of cases	10	13	33	
Virus-bacteria	7 (70.00)	8 (61.54)	19 (57.58)	0.77
Virus-virus	2 (20.00)	0 (0.00)	3 (9.10)	0.53
Bacteria-bacteria	2 (20.00)	7 (53.85)	24 (72.72)	0.01

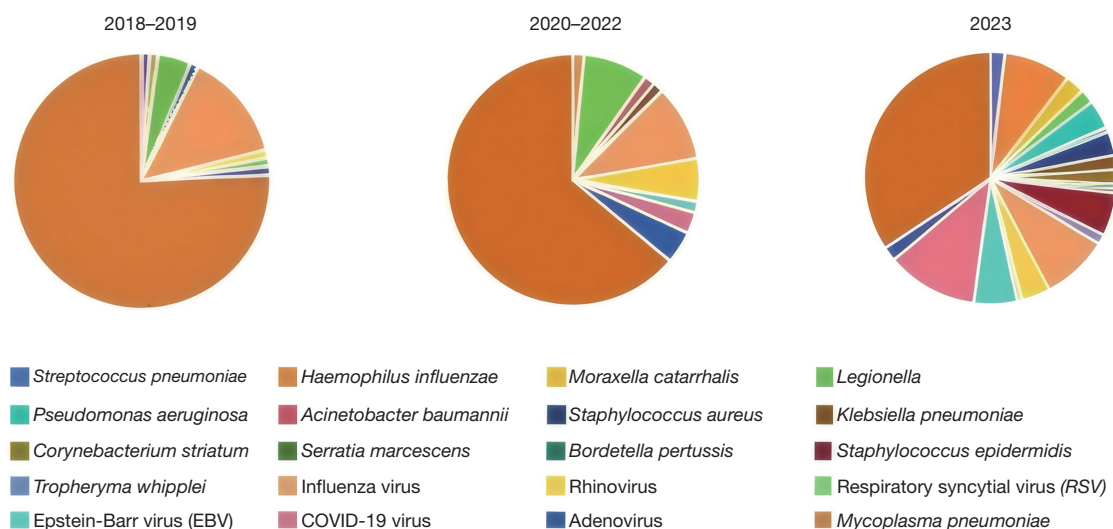
Data are presented as number (%).

viruses, and atypical pathogens at different stages and analyzed the top five common microorganisms in each stage. The top five pathogens in the pre-pandemic period were: *Mycoplasma pneumoniae* (36 cases/year), influenza virus (6.5 cases/year), *Legionella* (2 cases/year), *Streptococcus pneumoniae* (0.5 cases/year), and *Haemophilus influenzae* (0.5 cases/year). During the pandemic period, the top five pathogens were: *Mycoplasma pneumoniae* (15.3 cases/year), influenza virus (2.3 cases/year), *Legionella* (2 cases/year), rhinovirus (1.3 cases/year), and adenovirus (1.0 cases/year). In the post-pandemic period, the top five pathogens were: *Mycoplasma pneumoniae* (51 cases/year), *Haemophilus influenzae* (14 cases/year), influenza virus (11 cases/year), COVID-19 virus (11 cases/year), and *Staphylococcus epidermidis* (9 cases/year). Notably, as visually summarized in Figure 2, a progressive decrease in the detection rate of *Haemophilus influenzae* was observed, while the proportional representation of other pathogens increased over the study periods. Furthermore, the post-pandemic period was characterized by a marked rise in bacterial infections and the identification of several uncommon pathogens, including *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and *Tropheryma whipplei*. This shift in the pathogen distribution highlights an evolving microbial etiology of CAP in the young population during the post-pandemic phase.

## Discussion

CAP is one of the most common infections in respiratory medicine and has a high mortality rate worldwide (4,5). The annual incidence of adult CAP is estimated to be 1.5–14.0 per 1,000 individuals, with a short-term mortality rate of 4–18% among hospitalized patients (6). Therefore, preventing and controlling CAP pathogens is crucial to reducing the incidence of this disease. CAP commonly affects the elderly, children, and individuals with chronic diseases such as chronic obstructive pulmonary disease (COPD), asthma, diabetes, heart failure, renal insufficiency, and immunodeficiency (7). Young people rarely suffer from CAP due to their stronger resistance, and there are few studies on the pathogen spectrum of CAP in young people. However, we observed an increase in hospitalizations for CAP in young people after the COVID-19 pandemic. Therefore, we collected data on the pathogens of CAP in young patients at different stages to analyze the impact of COVID-19 on the pathogen spectrum of CAP.

Our study showed that the proportion of young non-severe CAP inpatients was lowest during the pandemic period and highest in the post-pandemic period. This is closely related to the epidemic prevention and control measures and various self-protection measures taken during



**Figure 2** Types of bacteria, viruses, and atypical pathogens at different stages. COVID-19, corona virus disease 2019.

the pandemic, which effectively blocked the spread of COVID-19 and other respiratory diseases, consistent with previous studies (8). The increase in CAP infections in young people in the post-pandemic period may be related to the damage caused by COVID-19 to the respiratory tract. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) enters respiratory epithelial cells by binding to the angiotensin-converting enzyme 2 receptor on the host cell surface, causing cell damage and death (9). After infection, the virus replicates extensively in the respiratory tract, triggering a severe inflammatory response that damages bronchial and alveolar epithelial cells, weakening the respiratory tract barrier function (9). This makes the respiratory tract more susceptible to other pathogens (such as bacteria and viruses), thereby increasing the risk of CAP. COVID-19 infection also induces immune responses in the body, including dysfunction of innate and adaptive immunity. Even in mild or asymptomatic cases, COVID-19 infection can lead to long-term changes in the immune system (10), increasing the risk of secondary infections with other viruses and bacteria.

Previous studies have shown that elderly patients are more susceptible to CAP in winter and early spring due to cold weather and the flu season (11). Our study found that the seasonal fluctuation of CAP in young people was relatively small during the pre-pandemic and pandemic periods. This may be because young people generally have a stronger immune system. In the post-pandemic period, CAP infections peaked in April and May, followed by

another increase in September, reaching the highest point in November. This change may be related to several factors: the direct impact of COVID-19. In December 2022, China relaxed its epidemic prevention policies, and almost everyone was exposed to the virus, with approximately 80% of the population infected (12). COVID-19 infection damages the respiratory tract, increasing susceptibility to other pathogens. The immune system may be suppressed or disrupted, making individuals more prone to other respiratory infections such as CAP. This may explain the small peak in CAP infections in May. The second small peak of COVID-19 infections in September may have caused a second blow to the immune system, leading to an increase in CAP infections in October and reaching a peak in November. This suggests that with the spread and recurrence of COVID-19 in the post-pandemic period, CAP infections in young people increased significantly. Therefore, we should further investigate and pay attention to the long-term effects of COVID-19 on the respiratory tract.

Our study also found that the proportion of male CAP patients was higher during the pandemic and post-pandemic periods. This is because males have weaker innate and adaptive immune responses to respiratory pathogens, higher viral loads in their bodies, and longer clearance times for pathogens. This result is consistent with previous studies (13). Another study also indicated that males have a higher proportion of severe pneumonia after infection, which, to some extent, explains the higher incidence of disease in

males (11).

Our study found that *Mycoplasma pneumoniae* infections were most prevalent in the pre-pandemic period but decreased in the post-pandemic period. However, *Mycoplasma pneumoniae* remained the most common pathogen in both pre- and post-pandemic periods. This is consistent with previous studies. A study showed that individuals aged 18–44 years are at high risk for *Mycoplasma pneumoniae* pneumonia, with a risk 5.674 times higher than that of individuals aged  $\geq 60$  years (14). In a domestic study on adult *Mycoplasma pneumoniae* pneumonia (15), 75% of patients were aged 18–35 years. Another study also suggested that *Mycoplasma pneumoniae* is more common in young people. This may be related to the higher social activity levels of young people and their work environments, which are often indoors with poor air circulation and close contact among individuals.

Among respiratory viruses, the influenza virus remains the most common cause of viral CAP, consistent with previous studies. During the COVID-19 pandemic, multiple studies on the long-term impact of non-pharmaceutical interventions on the prevalence of influenza and other respiratory infections were conducted worldwide, including in North America (16,17), tropical Asia (18), Europe (19), Japan (20,21), and South Korea (22). These studies found a decrease in influenza infections, which is consistent with the findings of our study on young non-severe CAP patients. This was closely related to various non-pharmaceutical interventions implemented globally, including social distancing, mask-wearing, home quarantine, travel restrictions, and school closures.

Our study found that *Mycoplasma pneumoniae* was the main pathogen in young CAP patients in the pre-pandemic period. In the post-pandemic period, the proportions of bacterial and viral infections increased significantly, and the rate of co-infections was higher than in the pre-pandemic and pandemic periods. Bacterial-bacterial co-infections were rare in the pre-pandemic period but increased during the pandemic and reached the highest level in the post-pandemic period. This indicates that the pathogen spectrum of CAP in young patients has changed in the post-pandemic period, with increased proportions of bacterial and viral infections and a higher likelihood of bacterial-bacterial co-infections.

Virus-bacteria and bacteria-bacteria co-infections were also more common in the post-pandemic period, consistent with previous studies (11). Previous studies have shown that severe CAP patients are mainly infected with bacterial pathogens and have a higher rate of bacterial-bacterial co-

infections. In contrast, non-severe CAP in young people was primarily caused by *Mycoplasma pneumoniae*. However, the pathogen spectrum of non-severe CAP in young people in our study was similar to that of severe CAP patients in previous studies, suggesting that the pathogen spectrum of CAP in young people has changed significantly due to the impact of COVID-19. The mechanisms may include two aspects: first, viral infections may cause airway damage, promoting bacterial adhesion; second, viral infections can affect the host immune system, both of which promote bacterial growth (23,24). Conversely, bacterial infections can also alter the spread and susceptibility of viruses in the respiratory system (25). These bidirectional effects lead to complex mechanisms of virus-bacteria co-infections, which may result in adverse clinical outcomes such as prolonged hospital stays and higher mortality rates.

In our study, *Klebsiella pneumoniae* had a high detection rate and is the fourth most common pathogen in Chinese patients with acute respiratory infections (26). We also found infections with uncommon pathogens such as *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, and *Tropheryma whippelii* in the post-pandemic period. This may be related to the use of high-throughput sequencing methods, which have increased detection rates. However, the main reason is likely the changes in immune function caused by COVID-19 infection, increasing susceptibility to these uncommon pathogens. These findings suggest that we need to improve pathogen detection as early as possible, use appropriate detection methods to increase the detection rate of pathogens, and select and adjust antibiotics appropriately to improve cure rates and shorten hospital stays.

Although most young patients with non-severe CAP are typically managed in the outpatient setting, hospitalization in our cohort reflected local clinical practice and pandemic-related admission policies. Specifically, young non-severe CAP patients were admitted when they had persistent fever or unresolved symptoms despite outpatient therapy, coexisting comorbidities such as asthma or diabetes, preference for closer inpatient monitoring, or epidemiological screening needs during and after the COVID-19 pandemic. These factors should be considered when interpreting the generalizability of our findings.

### Limitations

This study has several limitations that should be acknowledged. First, not all hospitalized CAP patients underwent pathogen testing, which may have introduced

selection bias when describing pathogen distribution. Although we included all CAP admissions when calculating hospitalization rates and seasonal distribution, incomplete microbiological data highlight the need to improve routine testing to strengthen the reliability of CAP surveillance.

Second, the relatively small sample size may have reduced the statistical power of subgroup analyses and limited the generalizability of our findings. Therefore, our results should be interpreted with caution, and future multi-center studies with larger cohorts are warranted to validate and expand upon these observations.

Third, *Mycoplasma pneumoniae* was analyzed separately from typical bacteria, and sensitive PCR-based assays were used for its detection. While this approach reflects clinical practice and improves diagnostic accuracy, it may have contributed to a higher detection rate compared with conventional studies. Caution is therefore needed when comparing our results with other CAP cohorts that used different classification systems or diagnostic methods.

## Conclusions

In conclusion, the pathogen spectrum of CAP in young non-severe patients has changed before and after the pandemic, with an increase in bacterial infections and co-infections, and even the emergence of uncommon pathogens. For young patients with CAP, it is still necessary to cover atypical pathogens primarily. If the treatment effect is not satisfactory, advanced methods, including high-throughput sequencing, should be used as early as possible to clarify the pathogens and adjust antibiotics accordingly.

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## Footnote

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**Ethical Statement:** The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki and its subsequent amendments. The study was approved by the Ethics Committee of The Third Affiliated Hospital of Guangzhou Medical University (approval No. 2024-31) and individual consent for this retrospective analysis was waived.

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