



Etiological Characteristics and Associated Factors in Older Patients with Coronary Heart Disease Complicated by Pulmonary Infection

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Abstract

Background: Pulmonary infection is a common complication in older patients with coronary heart disease (CHD) and severely compromises their quality of life and prognosis. The distribution of pathogens in older patients with CHD complicated by pulmonary infection is complex, and increasing bacterial drug resistance poses a significant challenge to antibiotic therapy.

Objectives: This study investigated pathogen types, antimicrobial susceptibility, and factors associated with pulmonary infection in older patients with CHD.

Methods: Clinical data from 143 older patients with CHD complicated by pulmonary infection and 77 older patients without pulmonary infection were analyzed. Pathogen distribution was assessed in patients with pulmonary infection. Univariate and multivariate logistic regression analyses were performed to identify factors associated with pulmonary infection in older patients with CHD.

Results: A total of 143 sputum specimens were collected from older patients with CHD complicated by pulmonary infection, yielding 152 pathogenic isolates. Univariate logistic regression analysis identified significant associations between pulmonary infection and a CHD history (≥ 5 years), comorbid chronic obstructive pulmonary disease (COPD), and procalcitonin (PCT) levels (all $P < 0.05$). Multivariate logistic regression analysis indicated that a CHD history (≥ 5 years), comorbid COPD, and PCT levels were associated with pulmonary infection in older patients with CHD (odds ratios = 2.377, 9.467, and 1.623, respectively; all $P < 0.05$).

Conclusions: Antibiotics for older patients with CHD complicated by pulmonary infection should be selected on the basis of drug susceptibility test results. A CHD history (≥ 5 years), comorbid COPD, and PCT levels are associated with pulmonary infection in older patients with CHD.

Keywords: Coronary Heart Disease, Pulmonary Infection, Pathogens, Antimicrobial Susceptibility Testing, Associated Factors

1. Background

Coronary heart disease (CHD) is a chronic, complex disease primarily caused by atherosclerotic lesions in the coronary arteries (1). It is a major contributor to global mortality and adversely affects patients' quality of life (2,3). In patients with CHD, aging is associated with a gradual decline in multiple organ functions, weakened immune defenses, and reduced antiviral resistance, thereby increasing vulnerability to concomitant pulmonary

infection (4). Concomitant pulmonary infection in older patients increases hospitalization costs, prolongs treatment, and worsens prognosis (5). Pulmonary infection is generally treated with antibacterial drugs. However, pathogen distribution in older patients with CHD and pulmonary infection is complex, and bacterial resistance increases with continued antibiotic use and treatment escalation (6,7).

2. Objectives

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This study aimed to analyze pathogen distribution and antimicrobial susceptibility among older patients with CHD complicated by pulmonary infection to inform the rational clinical use of antibacterial drugs. It also investigated factors associated with pulmonary infection in this population to inform clinical prevention.

3. Methods

3.1. Patient Selection

We retrospectively analyzed the clinical records of patients with CHD who were hospitalized at The First Affiliated Hospital of Hebei North University from January 2025 to December 2025. The inclusion criteria were: 1) a confirmed diagnosis of CHD (8); 2) age ≥ 60 years; and 3) provision of informed consent. The exclusion criteria were: 1) infection at other sites; 2) underlying immune system dysregulation; and 3) antimicrobial administration before the initial collection of specimens for pathogen testing. Eligible patients were assigned to the case or control group according to the presence or absence of community-acquired pneumonia (CAP) (9). The pulmonary infection group comprised 143 older patients with CHD complicated by pulmonary infection, and the non-pulmonary infection group comprised 77 older patients with CHD without pulmonary infection. The Ethics Committee of The First Affiliated Hospital of Hebei North University approved the study (approval number: K2024205). The definition of CHD, diagnostic criteria for CAP and multidrug resistance (MDR), differentiation of colonizing bacteria from pathogens, and quality-control standards are specified in Appendices 1 - 5 in the Supplementary File, with relevant references (8-12).

3.2. Data Collection

Baseline data included age, sex, comorbid diabetes, comorbid chronic obstructive pulmonary disease (COPD), invasive procedures, and a history of CHD. Laboratory indicators included albumin (ALB) and procalcitonin (PCT). Expecterated sputum was collected from patients with pulmonary infection. Detailed microbial culture methods are described in Appendix 6 in the Supplementary File. Pathogen identification and susceptibility testing were performed using the American BD Phoenix™ M50 device. Minimum inhibitory concentration (MIC) values were determined for each isolate. Results were classified as susceptible (S), intermediate (I), or resistant (R) according to the Clinical

and Laboratory Standards Institute (CLSI) M100-Ed33 (33rd edition, 2023). The intermediate category was defined, according to CLSI recommendations, as susceptibility achievable at elevated drug concentrations. Each isolate was counted individually in the pathogen distribution and susceptibility analyses. Quality-control strains included *Staphylococcus aureus* ATCC 29213, *Escherichia coli* ATCC 25922, and *Pseudomonas aeruginosa* ATCC 27853.

3.3. Statistical Analysis

Data were analyzed using SPSS version 27 (IBM Corp., Armonk, NY, USA). The Kolmogorov-Smirnov test was used to assess the distribution of continuous variables. Normally distributed variables were expressed as the mean $\pm$ standard deviation and compared between groups using independent t tests. Skewed data were expressed as the median and interquartile range and compared using the Mann-Whitney U test. Categorical data were expressed as percentages and compared using the χ^2 test. Potential associated factors were screened using univariate logistic regression. Multicollinearity was assessed using the variance inflation factor (VIF); variables with VIF ≥ 5 were excluded from subsequent analyses. The Box-Tidwell test was used to assess the linearity-in-the-logit assumption for continuous predictors. Multivariate logistic regression was performed to identify independent correlates and calculate odds ratios (ORs) and 95% confidence intervals (CIs). The Hosmer-Lemeshow test was used to assess model goodness of fit, with larger P values indicating better calibration. After rescaling, each OR for PCT represented the change in odds per 0.1 ng/mL increase. Statistical significance was defined as $P < 0.05$.

4. Results

4.1. Distribution of Pathogens in Patients with Pulmonary Infection

In total, 152 pathogenic isolates were recovered from 143 sputum specimens obtained from older patients in the pulmonary infection group (Table 1). These included 14 gram-positive bacterial strains (9.21%) and 138 gram-negative bacterial strains (90.79%). The main gram-positive bacteria were *S. aureus*, *Streptococcus pneumoniae*, and *Enterococcus faecium*, accounting for 6.58%, 1.97%, and 0.66% of all isolates, respectively. The main gram-negative bacteria were *Klebsiella pneumoniae*, *Acinetobacter baumannii*, and *P. aeruginosa*, accounting for 28.95%, 15.79%, and 13.16%, respectively. Thirty-one MDR strains (20.39%) were

Table 1. Distribution of Pathogens in the Pulmonary Infection Group ^a

Pathogens	Strains	Proportion (%)
Gram-negative bacteria	138	90.79
<i>Klebsiella pneumoniae</i>	44	28.95
<i>Acinetobacter baumannii</i>	24	15.79
<i>Pseudomonas aeruginosa</i>	20	13.16
<i>Stenotrophomonas maltophilia</i>	7	4.60
<i>Escherichia coli</i>	5	3.29
Other	38	25.00
Gram-positive bacteria	14	9.21
<i>Staphylococcus aureus</i>	10	6.58
<i>Streptococcus pneumoniae</i>	3	1.97
<i>Enterococcus faecium</i>	1	0.66
Total	152	100.00
MRSA	2	20.00

^a Abbreviation: MRSA, methicillin-resistant *Staphylococcus aureus*.

identified (Table 1 in the Supplementary File). Two isolates were methicillin-resistant *S. aureus* (MRSA), accounting for 20.00% of the *S. aureus* isolates.

4.2. Pathogen Drug Susceptibility Test Results

As shown in Table 2, *K. pneumoniae* was most susceptible to amikacin, meropenem, gentamicin, and imipenem, with a susceptibility rate of 97.73%, followed by amoxicillin/clavulanate (95.45%), cefepime (95.45%), and piperacillin/tazobactam (95.45%). *Acinetobacter baumannii* was most susceptible to amikacin (87.50%), followed by trimethoprim/sulfamethoxazole, ciprofloxacin, meropenem, cefepime, imipenem, levofloxacin, and piperacillin/tazobactam (83.33% each). *Pseudomonas aeruginosa* showed 100.00% susceptibility to amikacin, meropenem, tobramycin, and imipenem and was also susceptible to ciprofloxacin (95.00%), levofloxacin (95.00%), ceftazidime (90.00%), cefepime (90.00%), and piperacillin/tazobactam (90.00%).

As shown in Table 3, *S. aureus* was most susceptible to moxifloxacin, rifampicin, linezolid, vancomycin, and teicoplanin (100%), followed by tetracycline (90.00%) and oxacillin (80.00%).

4.3. Differences in Clinical Characteristics Between the Two Groups

As shown in Table 4, CHD history, comorbid COPD, and PCT levels differed significantly between the two groups (all $P < 0.05$).

4.4. Univariate and Multivariate Logistic Regression Analysis of Pulmonary Infection in Older Patients with Coronary Heart Disease

As summarized in Table 5, univariate logistic regression analysis identified associations between pulmonary infection and CHD history (≥ 5 years) (OR = 1.967; 95% CI, 1.104 - 3.505; $P = 0.022$), comorbid COPD (OR = 7.640; 95% CI, 4.086 - 14.284; $P < 0.001$), and PCT levels (OR = 1.779; 95% CI, 1.313 - 2.409; $P < 0.001$). The Box-Tidwell test confirmed the linearity-in-the-logit assumption for PCT ($P = 0.212$). VIF analysis of the three significant variables indicated no significant collinearity, with all VIF values < 5 (Table 6). Multivariate logistic regression analysis showed that CHD history (≥ 5 years), comorbid COPD, and PCT levels were associated with pulmonary infection in older patients with CHD (ORs = 2.377, 9.467, and 1.623, respectively; all $P < 0.05$) (Table 6). The Hosmer-Lemeshow test suggested good calibration of the clinical prediction model ($\chi^2 = 15.060$; $P = 0.058$).

5. Discussion

Previous studies have shown that pulmonary infection contributes to a poor prognosis and complicates treatment in older patients with CHD (4). Antibiotic use has improved recovery in older patients with pulmonary infections; however, the increasing prevalence of drug-resistant bacteria poses a substantial challenge (7). Pathogen distribution data and rational antibiotic selection are therefore essential to reduce antimicrobial

Table 2. Antimicrobial Susceptibility of Gram-Negative Bacteria from Older Patients with Coronary Heart Disease and Pulmonary Infection (%)^a

Antibiotic	<i>Klebsiella pneumoniae</i> (n = 44)		<i>Acinetobacter baumannii</i> (n = 24)		<i>Pseudomonas aeruginosa</i> (n = 20)		<i>Stenotrophomonas maltophilia</i> (n = 7)		<i>Escherichia coli</i> (n = 5)	
	Susceptibility	Resistance	Susceptibility	Resistance	Susceptibility	Resistance	Susceptibility	Resistance	Susceptibility	Resistance
Amikacin	97.73	2.27	87.50	12.50	100.00	0.00	—	—	100.00	0.00
Amoxicillin/clavulanate	95.45	2.27	—	—	—	—	—	—	80.00	0.00
Aztreonam	93.18	6.82	—	—	85.00	5.00	—	—	20.00	80.00
Ampicillin/sulbactam	90.91	6.82	75.00	12.50	—	—	—	—	40.00	40.00
Trimethoprim/sulfamethoxazole	88.64	11.36	83.33	16.67	—	—	100.00	0.00	60.00	40.00
Ciprofloxacin	86.36	13.64	83.33	16.67	95.00	5.00	—	—	40.00	60.00
Chloramphenicol	84.09	15.91	—	—	—	—	85.71	0.00	60.00	40.00
Meropenem	97.73	2.27	83.33	16.67	100.00	0.00	—	—	100.00	0.00
Minocycline	—	—	—	—	—	—	100.00	0.00	—	—
Gentamicin	97.73	2.27	79.17	12.50	—	—	—	—	60.00	40.00
Tetracycline	86.36	13.64	—	—	—	—	—	—	40.00	60.00
Ceftazidime	93.18	4.55	79.17	16.67	90.00	5.00	42.86	57.14	40.00	60.00
Cefepime	95.45	4.55	83.33	16.67	90.00	0.00	—	—	40.00	60.00
Cefazolin	—	—	—	—	—	—	—	—	20.00	80.00
Tobramycin	—	—	—	—	100.00	0.00	—	—	—	—
Imipenem	97.73	2.27	83.33	16.67	100.00	0.00	—	—	100.00	0.00
Levofloxacin	86.36	13.64	83.33	16.67	95.00	5.00	71.43	14.29	40.00	60.00
Piperacillin/tazobactam	95.45	2.27	83.33	16.67	90.00	5.00	—	—	100.00	0.00

^a Values are expressed as percentage.**Table 3.** Antimicrobial Susceptibility of Gram-Positive Bacteria from Older Patients with Coronary Heart Disease and Pulmonary Infection (%)^a

Antibiotic	<i>Staphylococcus aureus</i> (n = 10)	
	Susceptibility	Resistance
Amoxicillin/clavulanate	—	—
Trimethoprim/sulfamethoxazole	50.00	50.00
Ciprofloxacin	70.00	20.00
Chloramphenicol	—	—
Meropenem	—	—
Gentamicin	70.00	30.00
Tetracycline	90.00	10.00
Ceftriaxone	—	—
Cefuroxime	—	—
Cefepime	—	—
Levofloxacin	—	—
Azithromycin	—	—
Doxycycline	—	—
Moxifloxacin	100.00	0.00
Erythromycin	0.00	100.00
Clindamycin	10.00	90.00
Rifampicin	100.00	0.00
Linezolid	100.00	0.00
Penicillin	10.00	90.00
Vancomycin	100.00	0.00
Oxacillin	80.00	20.00
Teicoplanin	100.00	0.00

^a Values are expressed as percentage.

overuse and resistance in older patients with CHD complicated by pulmonary infection. Our findings regarding associated factors may also inform early

prevention and support the diagnosis of pulmonary infection in this population.

Table 4. Comparison of Clinical Characteristics Between the Two Groups ^a

Clinical data	Non-pulmonary Infection Group (n = 77)	Pulmonary Infection Group (n = 143)	χ^2/t Value	P-Value
Age (y)			0.004	0.947
60 to < 80	59	109		
≥ 80	18	34		
Gender			2.257	0.133
Male	36	82		
Female	41	61		
Comorbid diabetes			0.294	0.588
No	50	98		
Yes	27	45		
Invasive procedure			0.323	0.570
No	46	91		
Yes	31	52		
CHD history (y)			5.341	0.021
< 5	34	41		
≥ 5	43	102		
Comorbid COPD			45.024	< 0.001
No	56	37		
Yes	21	106		
PCT (ng/mL)	1.20 (0.80 - 1.60)	1.80 (0.90 - 4.90)	-4.612	< 0.001
ALB (g/L)	38.13 ± 4.72	37.42 ± 5.70	-0.983	0.327

^a Abbreviations: CHD, coronary heart disease; COPD, chronic obstructive pulmonary disease; PCT, procalcitonin; ALB, albumin.

Table 5. Univariate Logistic Regression Analysis of Pulmonary Infection in Older Patients with Coronary Heart Disease ^a

Variables	β	SE	OR (95% CI)	P Value
CHD history (≥ 5 y)	0.677	0.295	1.967 (1.104 - 3.505)	0.022
Comorbid COPD	2.033	0.319	7.640 (4.086 - 14.284)	< 0.001
PCT	0.576	0.155	1.779 (1.313 - 2.409)	< 0.001

^a Abbreviations: CHD, coronary heart disease; COPD, chronic obstructive pulmonary disease; PCT, procalcitonin; SE, standard error; OR, odds ratio; CI, confidence interval.

5.1. Drug Resistance and Susceptibility of Pathogens

In this study, gram-negative bacteria were the predominant pathogens in older patients with CHD complicated by pulmonary infection, followed by gram-positive bacteria. The main gram-negative bacteria were *K. pneumoniae* (28.95%), *A. baumannii* (15.79%), and *P. aeruginosa* (13.16%), whereas *S. aureus* (6.58%) was the predominant gram-positive bacterium. These findings are consistent with previous reports; differences in proportions may reflect regional environmental conditions (13). Susceptibility testing showed that amikacin, meropenem, and imipenem had substantial antibacterial activity against *K. pneumoniae*, *A. baumannii*, and *P. aeruginosa*.

Klebsiella pneumoniae showed 84.09% susceptibility and 15.91% resistance to chloramphenicol. These findings may provide preliminary guidance for empirical antimicrobial selection in our local setting, although their generalizability is limited by the single-center design.

Staphylococcus aureus was the most common gram-positive bacterium identified in older patients with CHD complicated by pulmonary infection. The isolates were susceptible to moxifloxacin, rifampicin, linezolid, vancomycin, and teicoplanin. Methicillin-resistant *S. aureus* accounted for 14.29% of the 14 gram-positive strains. In patients at low risk of MRSA infection, these agents exhibit in vitro activity against *S. aureus* isolates. Published data indicate that linezolid, teicoplanin, and vancomycin

Table 6. Multivariate Logistic Regression Analysis of Pulmonary Infection in Older Patients with Coronary Heart Disease ^a

Variables	β	SE	OR (95% CI)	P Value	VIF
CHD history (≥ 5 y)	0.866	0.375	2.377 (1.139 - 4.958)	0.021	1.000
Comorbid COPD	2.248	0.360	9.467 (4.671 - 19.189)	< 0.001	1.008
PCT	0.484	0.159	1.623 (1.190 - 2.214)	0.002	1.008

^a Abbreviations: CHD, coronary heart disease; COPD, chronic obstructive pulmonary disease; PCT, procalcitonin; SE, standard error; OR, odds ratio; CI, confidence interval; VIF, variance inflation factor.

are therapeutic options for patients at high risk of MRSA infection (14). *Staphylococcus aureus* isolates from older patients with CHD and pulmonary infection also showed high resistance to erythromycin, clindamycin, penicillin, and trimethoprim/sulfamethoxazole; therefore, initial empirical monotherapy with these agents should be avoided.

To our knowledge, few studies have described MDR in older patients with CHD complicated by pulmonary infection. In this study, 31 MDR isolates (20.39%) were identified among 152 cultured isolates: 20 gram-negative and 11 gram-positive strains, mainly *K. pneumoniae*, *A. baumannii*, *E. coli*, and *S. aureus*. The incidence of pneumonia caused by MDR bacteria is increasing, with adverse effects on prognosis (15-17). Because MDR is associated with excessive and inappropriate antibiotic administration, stronger hospital antimicrobial stewardship and pathogen-directed therapy are needed to improve outcomes in this older population.

5.2. Analysis of Associated Factors

We also assessed factors associated with pulmonary infection in older patients with CHD. CHD history (≥ 5 years), comorbid COPD, and PCT levels were associated with pulmonary infection. Prolonged CHD leads to gradual cardiac impairment and pulmonary congestion, increasing vulnerability to pulmonary infection (18). Comorbid COPD is associated with airway inflammation and bacterial proliferation, increasing the likelihood of pulmonary infection (19-21). As an infection-related biomarker, elevated PCT reflects the presence of pulmonary infection (22). Therefore, older patients with a CHD history ≥ 5 years, comorbid COPD, and elevated PCT warrant heightened vigilance for pulmonary infection.

For older patients with CHD and concurrent pulmonary infection, the following clinical considerations should be noted: 1) an appropriate antibacterial treatment plan should be formulated based on the pathogens identified

and susceptibility test results to reduce the risk of pulmonary infection; 2) laboratory testing for inflammatory indicators should be performed promptly to improve detection of pulmonary infection; and 3) underlying diseases, particularly comorbid COPD, should be treated actively to prevent pulmonary infection.

5.3. Study Limitations

This study had several limitations. First, it was a single-center retrospective analysis with a relatively small sample size. Second, all participants were recruited from the Hebei region of China. Given geographical variation in antimicrobial resistance patterns and clinical characteristics, the findings cannot be generalized to other regions of China. Third, relatively few inflammatory indicators were evaluated, potentially limiting assessment of their role in older patients with CHD complicated by pulmonary infection. Therefore, we plan to conduct multicenter studies with larger samples and additional inflammatory indicators to confirm these findings.

5.4. Conclusions

Pathogen distribution in older patients with CHD complicated by pulmonary infection is complex. These findings may provide preliminary guidance for antimicrobial selection; however, final treatment decisions should be individualized based on susceptibility test results and clinical response. CHD history (≥ 5 years), comorbid COPD, and PCT levels were associated with pulmonary infection in older patients with CHD. Targeted interventions may reduce the incidence of pulmonary infection and improve prognosis.

Supplementary Material

Supplementary material(s) is available [here](#) [To read supplementary materials, please refer to the journal website and open PDF/HTML].

Footnotes

AI Use Disclosure: The authors declare that no generative AI tools were used in the creation of this article.

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