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Original Article

Evolving Patterns of Antibiotic Resistance in Empyema Thoracis: A Descriptive Analysis from Services Hospital, Lahore

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Abstract

Objective: To characterize the microbiological spectrum and antibiotic susceptibility patterns of pathogens causing empyema thoracis in adults at a tertiary care hospital in Lahore, and to describe the prevalence and temporal trends of multidrug-resistant (MDR) isolates.

Methodology: This observational study comprises 581 cases of bacterial empyema thoracis in patients admitted to the Thoracic Surgery Department, Services Hospital, Lahore, Pakistan, from March 2023 to February 2025. We collected the patient's demographic data, culture results, and patterns of antibiotic sensitivity and resistance. Adults aged ≥18 years were included in the study. Descriptive variables were analyzed as means and frequencies. An independent t-test was applied to compare resistance to antibiotics in gram-negative and gram-positive organisms.

Results: This study includes 581 cases of empyema thoracis, out of which 527 cases show positive bacterial culture growth and 54 cases show no growth on culture. From a total of 527 bacterial cultures, 274 (52%) were Multidrug-resistant (MDR). Multidrug-resistant prevalence fluctuated across half-year periods, ranging from 53.7% to 62.7%. Among positive cultures; most common Bacteria isolated was Pseudomonas aeruginosa in 167 (32%) patients, this was followed by Klebsiella pneumonaie in 51 (10%), Acinetobacter species in 47 (9%), E. coli in 48 (9%) and other gram negative organisms. Meropenem shows the highest sensitivity followed by gentamycin.

Conclusion: Empyema thoracis remains prevalent in our country and is now more commonly associated with gram-negative organisms. Antibiotic resistance is increasing alarmingly, producing Multidrug-resistant pathogens upto (62%) in our study.

Keywords: Antibiotic sensitivity, Empyema thoracis, Multidrug resistance, Pleural space

Introduction

Empyema thoracis, defined as infected fluid accumulation in the pleural space, represents a major clinical burden in Pakistan, frequently following pneumonia and rarely after chest trauma. Delay in diagnosis and treatment due to limited rural healthcare access and high cost of therapy amplifies morbidity in resource-constrained settings.[1]

Antimicrobial resistance (AMR) poses a threat globally, especially in developing countries. National surveillance through the Pakistan Antimicrobial Resistance Surveillance System (PASS), aligned with WHO's GLASS, has demonstrated resistance levels more than 50% among E. coli and Klebsiella pneumoniae to third-generation cephalosporins, fluoroquinolones, and trimethoprim–sulfamethoxazole, while carbapenem resistance was detected below 30% in these isolates.[2,3] These trends leads to failure of empirical treatment and prolong hospital stays, increasing both direct and indirect economic burden.

Data on empyema thoracis, specifically AMR patterns in Pakistan remain limited. A descriptive cross-sectional study from Bahawalpur of N = 110 reported a 52.7% culture positive yield, with Pseudomonas aeruginosa (18.8%), Klebsiella spp. (10%), and E. coli (10%) as the most frequently isolated bacteria. Most showed high-level resistance to empirical regimens such as piperacillin/tazobactam, while sensitivity was preserved to agents like colistin, tigecycline, fosfomycin, and vancomycin.[4] A separate cohort in Abbottabad ($n \approx 219$) found culture positivity in 32.9%, with low susceptibility (~28%) to cefotaxime, ciprofloxacin, gentamicin, and co-amoxiclav [5]. Together, these results highlight that one-third to half of cultures yield positive results, and the resistance to most commonly used antibiotics is increasing.

Despite the existence of the National AMR Action Plan and PASS, national surveillance experiences major gaps, especially in under-reported regions like Balochistan, and lacks a standardized, empyema-specific antibiogram to guide empirical therapy.[6] In Pakistan's socio-economic conditions, characterized by a mix of public and private healthcare, delayed or inappropriate antibiotic therapy can have the worst financial and clinical consequences.[2]

This study characterizes the microbiological spectrum and antibiotic susceptibility profiles of empyema thoracis patients in our institute. By formulating local antibiograms and analyzing resistance trends, this work will form empirical guidelines for antibiotic therapy tailored to Pakistani socioeconomic conditions.

Methodology

This ambispective (retrospective–prospective) descriptive case series was conducted in the Department of Thoracic Surgery, Services Hospital, Lahore, Pakistan, from March 1, 2023, to February 28, 2025. The study identified microbial pathogens isolated from empyema thoracis patients and assessed the prevalence of multidrug-resistant (MDR) strains. Multidrug resistance was defined according to international consensus criteria as non-susceptibility to at least one antimicrobial agent in three or more relevant drug classes,[7] applied separately for Gram-negative organisms (β-lactams, cephalosporins, carbapenems, fluoroquinolones, aminoglycosides, folate pathway inhibitors) and Gram-positive organisms (β-lactams, macrolides, lincosamides, fluoroquinolones, aminoglycosides, glycopeptides, tetracyclines)

The study design included both retrospective and prospective components. A structured study questionnaire was formulated in March 2024. From that date onward, pleural fluid culture results of all empyema patients were prospectively collected and entered into a dedicated study database to ensure data completeness. For the retrospective component, records of eligible empyema cases presenting in the initial months of the study period were retrieved from the inpatient department culture register. Data compilation was done between March 1 and April 15, 2024. By prospectively maintaining complete culture records, we minimized common retrospective biases such as missing information and variability in documentation. The study population included consecutive adults aged ≥18 years diagnosed with empyema thoracis, defined by the presence of purulent/infected pleural fluid or a positive culture supported by imaging and clinical features. Patients requiring pleural drainage or surgical management were included. Patients were excluded if records didn't have essential information (demographics, culture results, or susceptibility profiles) or if pleural fluid specimens were inadequate or contaminated.

Pleural fluid specimens were collected under aseptic measures and processed with Gram staining, culture, and identification by MR numbers. Antimicrobial susceptibility testing was performed and interpreted according to the Clinical and Laboratory Standards Institute (CLSI) guidelines. [8, 9]

Data were entered into SPSS version 26.0 for statistical analysis. The ambispective design allowed us to strengthen the study by including a full consecutive series of cases over two years, combining the retrospective data with the prospective data collection. This approach minimized bias by ensuring completeness of data, prospective standardization of data variables, and consistency in MDR classification, while sensitivity checks confirmed that retrospective and prospective datasets were comparable in baseline characteristics.

The study was approved by the Institutional Review Board of the Services Institute of Medical Sciences (reference no. IRB/2025/1535/SIMS, issued February 11, 2025). Written informed consent for diagnostic and surgical procedures, including the use of pleural fluid samples, was obtained at the time of chest intubation from the prospective cohort in accordance with institutional ethics policies.

Results

A total of 581 patients with empyema thoracis were included in this study, of whom 527 (90.7%) had positive bacterial cultures. All patients were ≥ 18 years of age. Males constituted 398 cases (68.5%), while females accounted for 183 cases (31.5%).

Table 1. Baseline demographic characteristics of patients with pleural effusion

Variable	N	%
Total patients	581	100.0
Positive bacterial cultures	527	90.7
Age groups		
≥18 years	581	100.0
Sex		
Male	398	68.5
Female	183	31.5

Among the culture-positive organisms, aerobic Gram-negative bacteria were predominant, representing 386 cases (73.2%), whereas aerobic Gram-positive bacteria accounted for 141 cases (26.8%). Approximately 54 (10%) of cultures yielded no bacterial growth.

Among the culture-positive patients, 280 (53%) had a single pathogen, 184 (35%) had two pathogens, and 63 (12%) had three or more pathogens.

In gram negative organisms the most common isolate was Pseudomonas aeruginosa (167; 32%), followed by Klebsiella spp. (51; 10%), Escherichia coli (48; 9%), and Acinetobacter spp. (47; 9%). Other gram-negative bacterial infections were observed in 19% of cases.

In Gram-positive organisms Staphylococcus aureus was the most frequent isolate identified in 47 patients (33%), followed by streptococcus species in 45 (32%) while all other Gram-positive bacteria accounted for an additional (49) 35% of cases.

The bacterial antibiotic sensitivity results showed that they were more sensitive to the aminoglycosides gentamycin 177 (30.5%) and amikacin 171 (29.4%), the carbapenems meropenem 187 (32.2%) and imipenem 166 (28.6%), and combinations such as piperacillin-Tazobactam 179 (30.8%) as shown in the Figure 3 below.

Antimicrobial resistance predominated among the isolates, as shown in Table 2. The highest resistance was observed for ciprofloxacin (246; 42.3%) and trimethoprim/sulfamethoxazole (175; 30.1%). Penicillin resistance was 28.7% for ampicillin and 22% for amoxicillin/clavulanic acid.

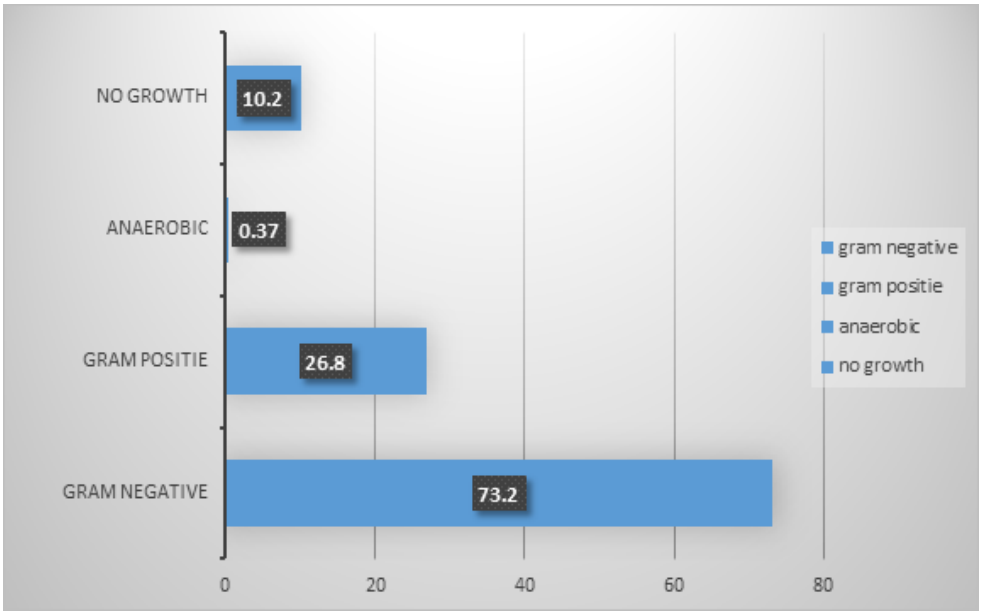

Figure 1: Percentages of Growth on Cultures

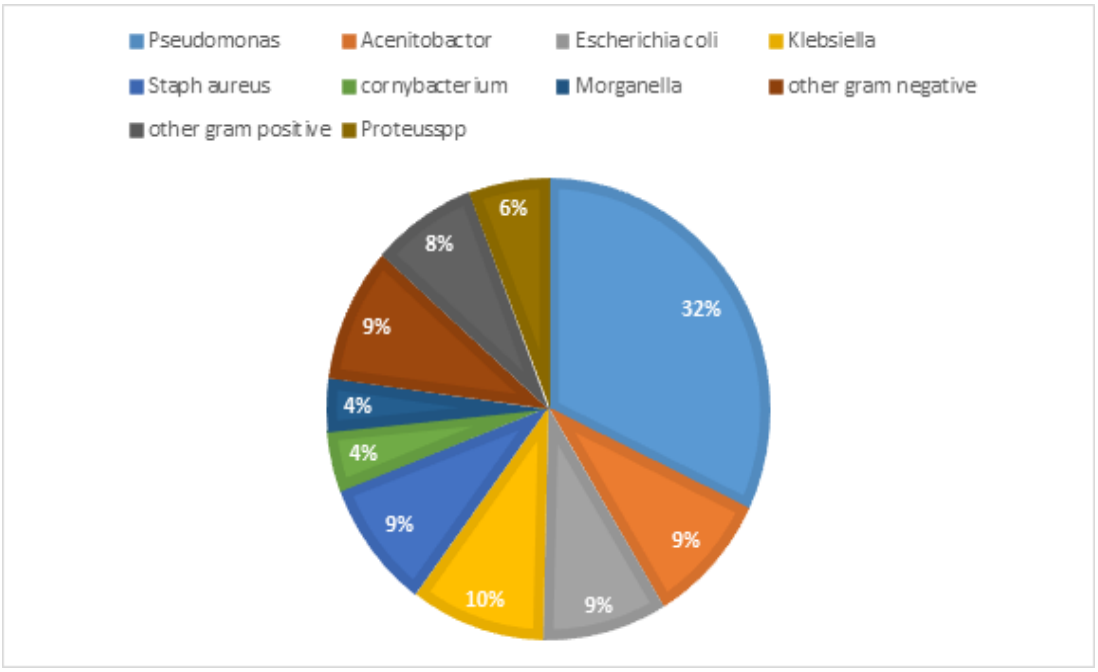

Figure 2: Collective Positive bacterial Cultures

The mean resistance rate for Gram-negative antibiotics was significantly higher compared to Gram-positive antibiotics (22.4% vs. 2.7%, respectively; $p < 0.001$, independent t-test). Gram-negative pathogens, the predominant causative organisms in empyema thoracis, exhibited significantly higher resistance than Gram-positive bacteria, as shown in Table 3.

Across the five half-year periods, from 527 positive bacterial cultures, 274 (52.1%) were MDR, and its prevalence fluctuated between 53.7% and 62.7% across intervals at an average of 55.3%. A chi-square test for association demonstrated significant variation in MDR rates between periods ($p = 0.008$). The observed values demonstrate non-linear temporal fluctuations, showing the MDR pattern in Figure 4.

Discussion

In this large ambispective case series of 581 patients with empyema thoracis (527 culture-positive, 90.7%), three interrelated and clinically important findings stand out. First, aerobic Gram-negative organisms predominated (386/527, 73.2% of culture-positive isolates), with Pseudomonas aeruginosa the single most frequent pathogen (167 isolates, ~32%). Second, polymicrobial infections were common. Third, antimicrobial resistance among Gram-negative pathogens was high and clinically concerning, including substantial levels of carbapenem resistance. These observations have direct implications for the selection of empirical therapy, infection control, and regional antimicrobial stewardship. Our very high culture positivity is likely explained by the selection of patients requiring drainage

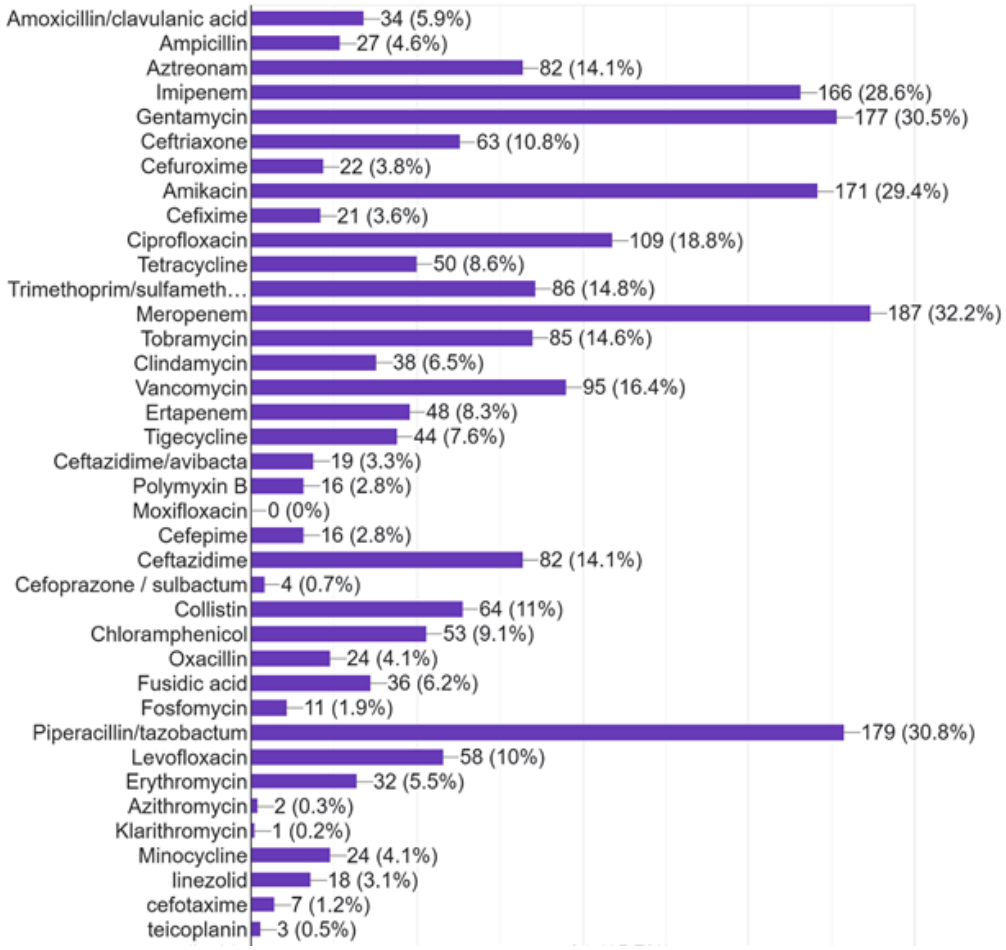

Figure 3: Antibiotic Sensitivity Pattern of Bacterial Organisms

Table 2: Culture-based antibiotic resistance pattern

Antibiotic Class	Antibiotic	Resistance in organisms' n (%)
β-lactams (Penicillins)	Amoxicillin/clavulanic acid	128 (22.0)
	Ampicillin	167 (28.7)
	Piperacillin/tazobactam	173 (29.8)
Cephalosporins	Ceftriaxone	135 (23.2)
	Cefuroxime	117 (20.1)
	Ceftazidime	102 (17.6)
	Cefepime	28 (4.8)
Carbapenems	Imipenem	168 (28.9)
	Meropenem	159 (27.4)
Monobactams	Aztreonam	129 (22.2)
Aminoglycosides	Gentamicin	152 (26.2)
	Amikacin	123 (21.2)
	Tobramycin	82 (14.1)
Fluoroquinolones	Ciprofloxacin	246 (42.3)
	Levofloxacin	138 (23.8)
Folate Pathway Inhibitors	Trimethoprim/sulfamethoxazole	175 (30.1)
Tetracyclines	Tetracycline	75 (12.9)
Glycopeptides	Vancomycin	3 (0.5)
Macrolides	Erythromycin	50 (8.6)

or surgical intervention (enriching for higher bacterial load), prospective and standardized specimen collection with prompt laboratory processing, and the referral bias inherent in a tertiary thoracic surgery service. These factors contrast with retrospective or mixed cohorts, where yields are often lower (50–60%) in Pakistan.[4, 10] Improved culture techniques, such as bedside inoculation into blood culture bottles and use of molecular diagnostics, have also been shown to increase yields internationally.[11, 12]

The predominance of Gram-negative aerobes, particularly P. aeruginosa and Enterobacteriaceae, contrasts with older reports where Gram-positive cocci predominated. Recent national and regional studies have similarly reported a predominance of Gram-negative bacteria in empyema.[13,14.] Comparable trends have been described internationally: in Nigeria, Klebsiella pneumoniae was the leading cause of empyema,[15] while in Qatar, a recent study highlighted Pseudomonas and other Gram-negative organisms in a substantial proportion of cases.[17] Global reviews also confirm this epidemiological shift.[11,18] From an antimicrobial stewardship perspective, our antibiogram is concerning. Fluoroquinolone and TMP-SMX resistance were high, and although carbapenem resistance was not universal, its prevalence (~28%) mirrors regional reports from Pakistan and exceeds 30% in recent global analyses of P. aeruginosa.[14, 18] Preservation of susceptibility to aminoglycosides and glycopeptides was also noted, consistent with other reports from South Asia and beyond.[13, 15]

Our analysis revealed a high overall multi-drug resistance prevalence (55.3%) with significant variability across half-year intervals ($p = 0.008$), indicating that resistance patterns in empyema thoracis are dynamic rather than stable. Such temporal fluctuations are likely caused by medication practices and infection-control measures. Shorter reporting cycles, rather than annual reviews, may better inform empiric therapy and guide effective antimicrobial stewardship.[2, 18]

Our study fills a critical gap for thoracic surgery-treated pleural infections in Pakistan, providing up-to-date, center-level data to guide empiric therapy for empyema thoracis. Future work should focus on multicenter studies, incorporation of anaerobic and molecular diagnostics, and linking microbiological findings to patient outcomes. These steps will help build the evidence base needed for national guidelines and contribute to global antimicrobial resistance (AMR) reporting systems.

Table 3: Mean Antimicrobial Resistance in Gram-negative versus Gram-positive Bacteria

Bacterial Group	Mean Resistance Rate (%)	Statistical Test	p-value
Gram-Negative	22.4	Independent t-test	<0.001
Gram-Positive	2.7		

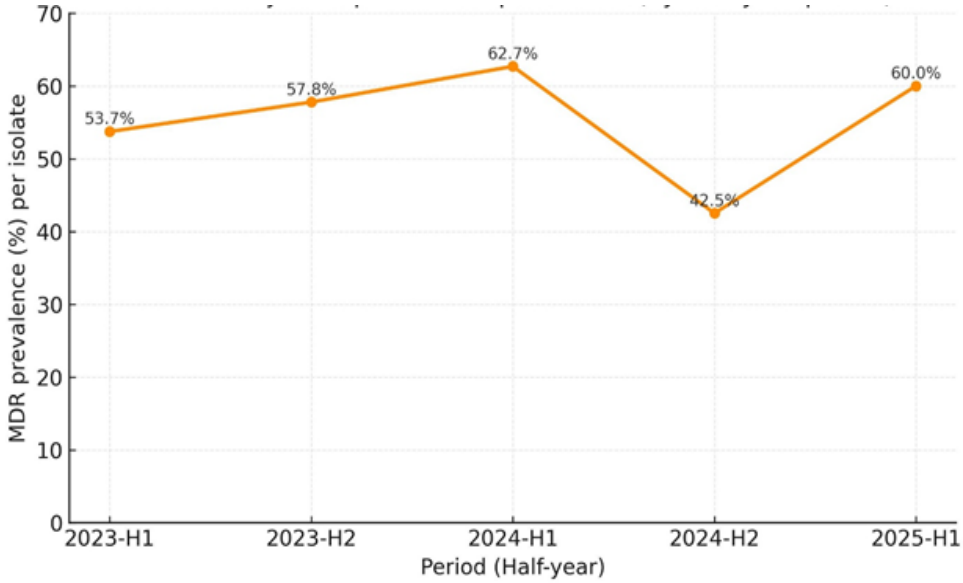

Figure 4: Six-monthly MDR prevalence rates

Limitations

This study has several limitations. Tuberculous and fungal empyema were not properly excluded despite their high regional prevalence. This may have led to the missing of some cases as culture-negative bacterial empyema. The absence of anaerobic cultures and molecular diagnostics likely underreports organisms and resistance mechanisms. Undocumented previous antibiotic exposure among referred patients may have reduced culture yield. The single-center, convenience sampling design from a tertiary-care referral hospital limits generalizability and introduces selection bias. Finally, incomplete outcome data limits meaningful analysis of clinical endpoints, and therefore, the findings should be interpreted as center-level microbiological results informing local empiric therapy and antimicrobial stewardship.

Conclusion

Empyema thoracis in our cohort was predominantly caused by multidrug-resistant Gram-negative organisms, particularly Pseudomonas aeruginosa, with the highest susceptibility mainly to amikacin, carbapenems, and vancomycin. By providing region-specific data from thoracic surgery patients in Pakistan, this study offers clinicians practical guidance for empirical antibiotic therapy and establishes a foundation for multicenter, prospective research. For clinicians, the key message is that dependence on conventional empiric regimens is unsafe in this setting; empiric therapy should be guided by local antibiograms and culture results.

Authors' Contributions: ZS contributed to the conception and design of the study, acquisition and analysis of data, interpretation of findings, and drafting of the original manuscript. MSN contributed to the conception of the study, data curation, statistical analysis, interpretation of findings, and critical revision and editing of the manuscript for important intellectual content. AA contributed to the literature review, verification of data, manuscript preparation, and visualization of data, and assisted in interpretation of findings. All authors reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Conflict of Interest: The authors declare that they have no known competing financial interests that could have appeared to influence the work reported in this paper.

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Data availability statement: All data are included in this article; further details are available from the corresponding author upon reasonable request.

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