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Trends in Antimicrobial Resistance of Serratia Marcescens: Insights from a Seven-Year Retrospective Study at a Tertiary Care Hospital in Rawalpindi, Pakistan

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Abstract

Background: *Serratia marcescens is a Gram-negative opportunistic pathogen linked to hospital-acquired infections and increasing multidrug resistance. Data on its resistance patterns in Pakistan, particularly carbapenem resistance, remain limited. This study assesses antimicrobial resistance trends of S. marcescens over seven years at a tertiary hospital in Rawalpindi.*

Methods: *A retrospective registry-based study was conducted at the Microbiology Department, Fauji Foundation Hospital, Rawalpindi, from January 2017 to December 2023. Clinical isolates from patients aged 10–80 years were obtained using consecutive non-probability sampling. Standard microbiological techniques, including API 10S® (bioMérieux), were employed for identification of Serratia marcescens. Antimicrobial susceptibility testing was performed using the modified Kirby-Bauer disc diffusion method on Mueller-Hinton agar, by CLSI guidelines. Data were analyzed using Microsoft Excel 19.0. We identified the number of strains resistant to different antibiotics.*

Results: *A total of 108 S. marcescens isolates were identified, with a marked increase in incidence in 2022 (45.4%) and 2023 (28.7%). Most isolates were from the Medicine (39.8%), Surgical (31.5%), and ICU (21.3%) wards. Pus (47.2%), blood (20.4%), and bronchial washings (12.0%) were the most common clinical samples. High resistance was observed against amoxicillin-clavulanate (97.3%), ampicillin (94.2%), and ceftazidime (58.2%). ciprofloxacin showed moderate resistance (43.5%). Lower resistance rates were found for tigecycline (5.3%), minocycline (12.8%), meropenem (24.6%), and imipenem (25.9%).*

Conclusion: *The study shows rising multidrug resistance in S. marcescens, including emerging carbapenem resistance, threatening empirical treatment. Strengthened surveillance and antimicrobial stewardship are essential to limit spread in healthcare settings.*

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Introduction

Serratia is a genus that comprises Gram-negative, rod-shaped bacteria belonging to the order Enterobacterales [1,2]. So far, 23 species have been recognized within the genus, of which 6 have been associated with human infections. These include S. marcescens, S. plymuthica, S. liquefaciens, S. rubidaea, S. odorifera, and S. fonticola. S. marcescens is an opportunistic pathogen mainly affecting patients with a history of antibiotic treatment or weakened immune systems. It provokes a wide range of infections, including pneumonia, meningitis, sepsis, endocarditis, keratitis, osteomyelitis, urinary tract infections, and skin infections [3,4]. Management is difficult due to intrinsic resistance to several antibiotics such as first- and second-generation cephalosporins, macrolides, ampicillin, and cationic antimicrobial peptides (CAPs). The bacterium exhibits two main characteristics: production of prodigiosin, a red pigment, and presence of non-pigmented strains. It acquires resistance intrinsically and can attain new features, making treatment difficult.

S. marcescens outbreaks have been reported from 1968 to 2019 [5]. In the past, an outbreak in San Francisco caused UTIs in 11 patients [6]. Most outbreaks target neonatal and intensive care units. A notable outbreak in Gaza in 2005 caused septicemia in 159 patients and resulted in 70 fatalities [7]. A study at Children's Hospital, Lahore, Pakistan, analyzing 7,680 blood cultures, showed the presence of this pathogen in neonatal infections [8]. Effective epidemiological surveillance is key to containing outbreaks.

S. marcescens resists various beta-lactam antibiotics and aminoglycosides. It enhances its defense by producing beta-lactamases, using efflux pumps, and reducing porin permeability [9]. It is intrinsically resistant to antibiotics such as ampicillin, amoxicillin, amoxicillin-clavulanate, ampicillin-sulbactam, narrow-spectrum cephalosporins, cefuroxime, nitrofurantoin, macrolides, and polymyxin [10]. It increases AmpC β-lactamase production, rendering most β-lactams ineffective except carbapenems [11]. Efflux pump overexpression (ABC, RND, SMR, MFS) contributes to multidrug resistance [12]. Recently, carbapenem-resistant S. marcescens has emerged due to widespread antibiotic use and carbapenemase production [13].

KPC (Klebsiella pneumoniae carbapenemase) plays a key role in carbapenem resistance in S. marcescens. KPC-2 has been reported in China and Brazil, while KPC-3 is dominant in the USA [14,15]. This rapidly developing resistance is alarming.

The emergence of antibiotic resistance is a serious public health issue in Pakistan. There is a lack of research on carbapenem-resistant S. marcescens (CRSM) despite rising concern. Knowledge on prevalence, resistance mechanisms, and epidemiology is limited. Strengthening surveillance and antibiotic stewardship programs is essential. Further research is crucial for understanding local resistance trends and guiding effective treatment strategies.

Materials and Methods

Ethical approval was granted by the institutional review board of Fauji Foundation Hospital, Rawalpindi,

to conduct this retrospective study in the department of microbiology, Fauji Foundation Hospital, Rawalpindi, for the period of January 2017 to December 2023. A consecutive non-probability sampling technique was used, consisting of male and female patients from different wards and outpatient departments between the age group of 11-85 years. Patients taking antibiotics and those whose ages were <11 and >85 years were excluded from the study. The number of samples according to different age groups is shown in Table (1). Resistance pattern against different antibiotics is checked and is shown in Table (2). During study period, all clinical samples (including pus culture, urine culture, tissue culture, HVS fluid culture, blood culture, sputum culture, tracheal tube for culture & bronchial wash) shown by Table (3), were collected aseptically as per standard microbiological methods from different departments of the hospital as shown in Table (4).

Age Group (years)	Number of Isolates
11-15	7
16-20	8
21-25	4
26-30	7
31-35	2
36-40	1
41-45	13
46-50	11
51-55	18
56-60	6
61-65	9
66-70	13
71-75	5
76-80	2
81-85	2
Total	**108**

Table 1: Number of Isolates in Various Age Groups.

Antibiotic Name	Sensitive		Intermediate Resistant		Resistant		Total
Beta-Lactam Antibiotics;							
Penicillins;							
Augmenten	1	2.70		0.0	36	97.30	37
Ampicillin	2	3.85	1	1.9	49	94.23	52
Penicillin		0.00	1	25.0	3	75.00	4
Cephalosporins;							
Cefepime	9	64.29		0.0	5	35.71	14
Cefoparazone	1	100.00		0.0		0.00	1
Cefotaxime	15	44.12	1	2.9	18	52.94	34
Ceftazadime	31	39.24	2	2.5	46	58.23	79
Ceftriaxone	37	41.11	1	1.1	52	57.78	90
Cephalexin		0.00		0.0	1	100.00	1
Cephradine	18	48.65		0.0	19	51.35	37
Carbapenems;							
Imipenem	80	74.07	2	1.9	26	24.07	108
Meropenem	52	75.36	2	2.9	15	21.74	69
Monobactams;							
Aztreonam	1	20.00		0.0	4	80.00	5
Tetracycline;							
Doxycycline	42	41.58	2	2.0	57	56.44	101
Minocycline	68	87.18		0.0	10	12.82	78
Tetracycline	1	100.00		0.0		0.00	1
Tigecycline	72	94.74	1	1.3	3	3.95	76
Aminoglycosides;							
Gentamycin	55	50.93		0.0	53	49.07	108
Vancomycin	1	100.00		0		0.00	1
Amikacin	83	76.85		0	25	23.15	108
Fluoroquinolones;							
Levofloxacin		0.00		0.0	1	100.00	1
Ciprofloxacin	61	56.48	1	0.9	46	42.59	108
Miscellaneous;							
Chloramphenicol	12	75.00		0.0	4	25.00	16
Colistin	2	40.00		0.0	3	60.00	5
Polymycin B	4	22.22		0.0	14	77.78	18
Polymyxin B	2	22.22		0.0	7	77.78	9
Sulzone	58	79.45	1	1.4	14	19.18	73
Tazocin	41	73.21	1	1.8	14	25.00	56
Fosfomycin		0.00	1	50.0	1	50.00	2
Co- Trimoxazole	53	49.07		0.0	55	50.93	108

Table 2: Antibiotic Resistance profile of Serratia marcescens.

Culture Specimen	Number of Isolates
Blood Culture	22
Bronchial Washing Fluid	13
HVS Fluid Culture	1
Pus Culture	51
Sputum Culture	5
Tissue Culture	7
Tracheal Tube Culture	8
Urine Culture	1
Total	108

Table 3: Distribution of Serratia marcescens isolates by culture specimen type.

Year of Isolates	Number of Isolates
2017	6
2018	4
2019	7
2020	6
2021	5
2022	49
2023	31
Total	108
Total	108

Table 4: Year-wise distribution of Serratia marcescens isolates from 2017 to 2023.

A well-isolated colony of a Gram-negative rod (GNR) showing late lactose fermentation was selected from a blood agar plate after overnight incubation (18–24 hours). A standardized bacterial suspension equivalent to 0.5 McFarland turbidity was prepared in sterile distilled water. For biochemical identification, the suspension was inoculated into the API 10S® strip (bioMérieux, France), which is designed for the identification of Enterobacterales. The strip was incubated at 35–37°C as per the manufacturer's recommendations. The next day, specific reagents such as Indole and TDA were added to the corresponding cupules. The color changes were interpreted using the API color chart, and a numerical code was obtained. This code was used to enter into the APIweb™ database to get the most probable or confirmed identification of the organism.

The antimicrobial susceptibility testing of the samples was done on Mueller-Hinton agar plates by the modified Kirby-Bauer disc diffusion method. The inoculum was evenly spread on Mueller-Hinton agar plates, and antibiotic discs which includes amikacin(30µg), ampicillin(10µg), amoxicillin-clavulanate(30µg), cefotaxime (30µg), ceftazidime(30µg),ceftriaxone(30µg), cepharadine(30pg), chloramphenicol(30µg), ciprofloxacillin(5µg), co-trimoxazole (25µg), doxycycline (30µg), gentamycin (10µg), imipenem(10µg), meropenem(10µg), sulzone(75/30 µg), tazocin (100/10 µg), tigecycline(15µg), minocycline(30µg) were applied according to CLSI(Clinical and Laboratory Standards Institute) guidelines. Plates were incubated at 35–37°C for 16–18 hours, and zones of inhibition were measured to interpret susceptibility profiles. After susceptibility profiles, the collected data were analyzed using Microsoft Excel 19.0 to generate tables and charts.

Results

Age Group Distribution

Isolates were observed across a wide age range. The highest number of isolates was found in the 51–55 age group (n = 18), followed by 46–50 years (n = 11) and 66–70 years (n = 13). These findings suggest a greater burden of S. marcescens infections among middle-aged to older adults (Table 1).

Distribution of Isolates Over Time

A total of 108 Serratia marcescens isolates were recovered over the study period (2017–2023). A relatively low and stable number of isolates was reported between 2017 and 2021, ranging from 4 to 7 isolates annually. However, a marked surge in isolates occurred in 2022, with 49 cases—the highest in the study period. This was followed by a slight decline in 2023, with 31 isolates recorded (Table 4, Figure 2). This spike in 2022 indicates a potential outbreak or increased transmission in clinical settings during that year.

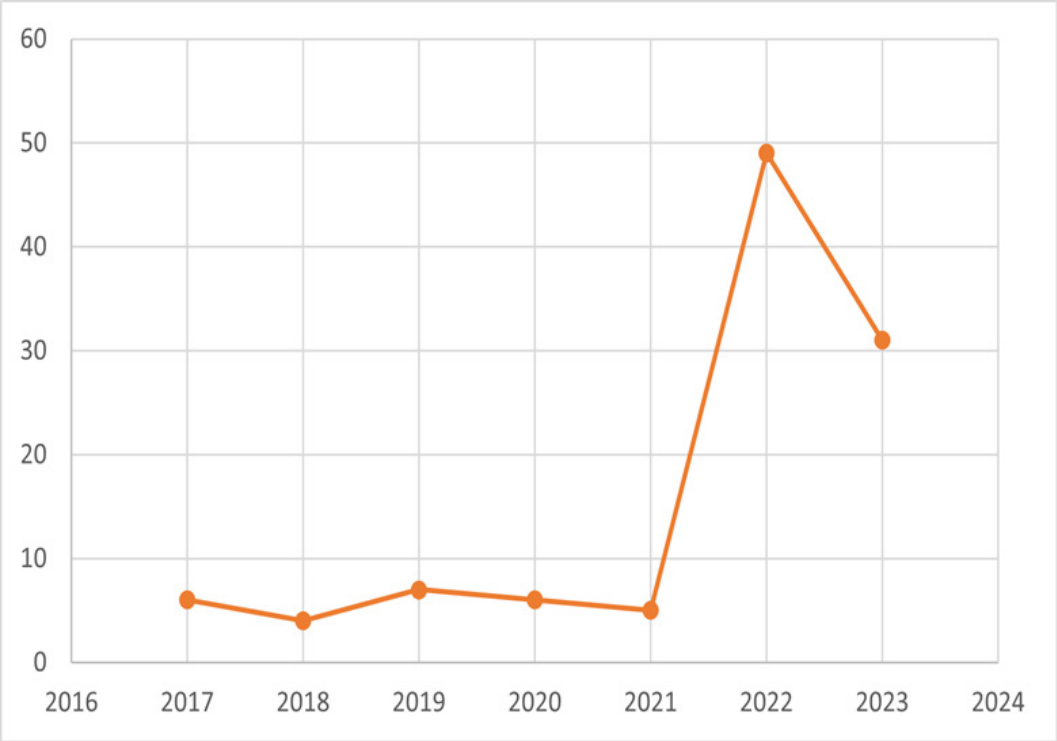

Figure 2: Year-wise trend in the number of Serratia marcescens isolates showing antimicrobial resistance from 2017 to 2023. A sharp rise was observed in 2022, followed by a decline in 2023.

Specimen and Departmental Distribution

Among the various clinical samples, pus culture was the most common source of Serratia marcescens isolates, accounting for 47.2% (n = 51) of cases, followed by blood cultures (n = 22, 20.4%) and bronchial washings (n = 13, 12%) (Table 3). Departmentally, the majority of isolates originated from the Medicine ward (n = 43), followed by Surgery (n = 34) and the ICU (n = 23) (Table 5), indicating that S. marcescens was frequently encountered in both general wards and high-dependency areas.

Department from where sample is obtained	Number of Isolates
Medicine	43
Surgery	34
Gynaecology	8
ICU	23
Total	108

Table 5: Distribution of Serratia marcescens isolates according to the hospital department from which the samples were obtained.

Antibiotic Resistance Profile

The resistance profile of Serratia marcescens revealed high levels of antimicrobial resistance to several commonly used antibiotics. Notably, resistance to amoxicillin-clavulanate and ampicillin was 97.30% and 94.23%, respectively. Among the β-lactam antibiotics, third-generation cephalosporins such as ceftriaxone and ceftazidime showed resistance rates of 57.78% and 58.23%, respectively. Aztreonam, a monobactam, showed 80% resistance, further indicating reduced efficacy of β-lactam agents (Table 2, Figure 1).

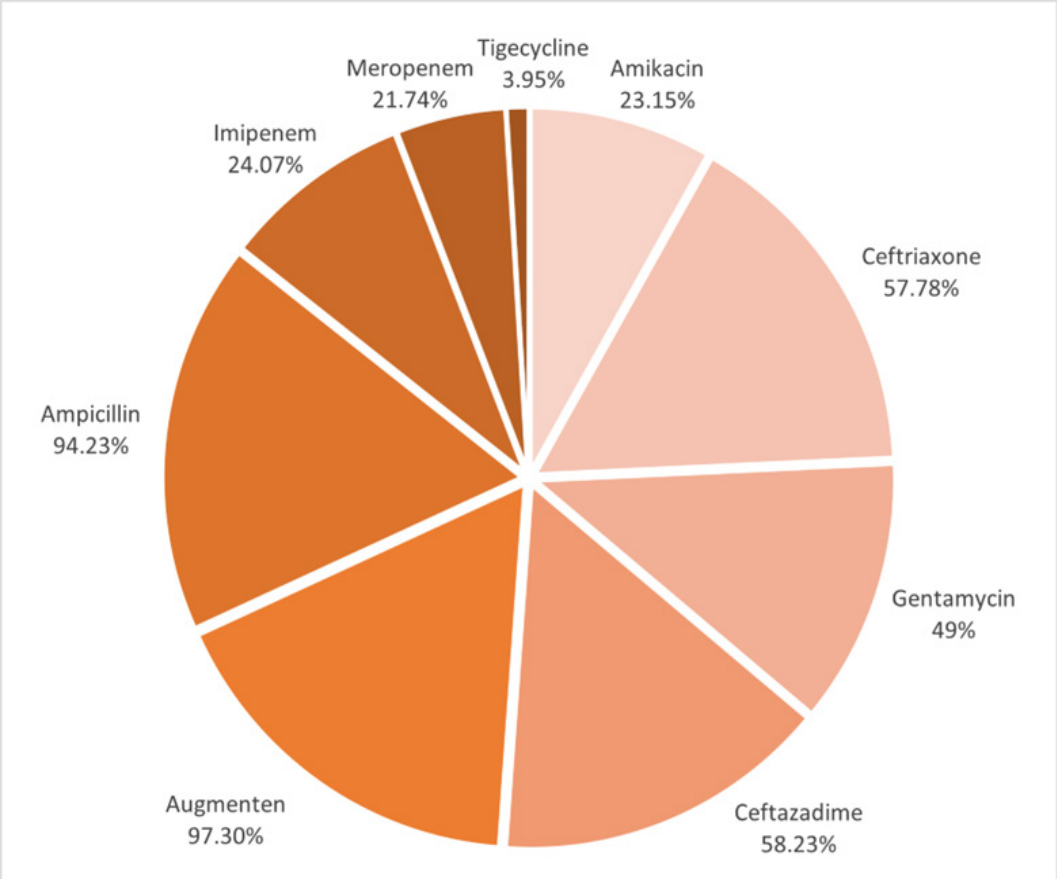

Figure 1: Resistance percentages of Serratia marcescens to various antibiotics. The highest resistance was observed to Augmentin (97.30%) and Ampicillin (94.23%), while the lowest was to Tigecycline (3.95%).

Among carbapenems, imipenem and meropenem exhibited better activity, with sensitivity rates of 74.07% and 75.36%, respectively. However, the detection of resistance in approximately one-fourth of the isolates to these last-resort antibiotics is concerning, suggesting emerging resistance even in this potent class.

In the aminoglycoside class, amikacin demonstrated moderate efficacy with a 76.85% sensitivity rate, whereas gentamicin showed nearly equal proportions of sensitivity (50.93%) and resistance (49.07%). Minocycline and tigecycline were among the most effective agents, with sensitivity rates of 87.18% and 94.74%, respectively.

Fluoroquinolones such as ciprofloxacin showed only 56.48% sensitivity, and levofloxacin was completely ineffective in the single isolate tested. Resistance to miscellaneous agents such as Polymyxin B and Colistin was also high, at 77.78% and 60%, respectively. Fosfomycin showed equal distribution between resistance and intermediate sensitivity.

Discussion

Serratia are comparatively low-virulent, often identified as prevalent nosocomial opportunistic bacteria during the past three decades, and have demonstrated an upsurge in the prevalence of antibiotic resistance. They are prone to a variety of healthcare-associated infections (HAIs), particularly in patients who are extremely ill or immunocompromised [1,2]. Serratia can contaminate medical devices and equipment since they are common in the environment. It does not induce primary invasive illnesses and is comparatively less virulent. However, if they enter an immunocompromised host, they cause infection, which is generally severe. Inadequate infection control techniques along with the rise in the frequency of contemporary medical operations are contributing reasons to the emergence of nosocomial infections. Healthcare workers' contaminated hands and contact with poorly sterilized central venous lines, hemodialysis units, urine catheters, injection needles, and surgical procedures increase the risk of infection transmission [3,4]. We investigated the antibiotic resistivity of Serratia marcescens at Fauji Foundation Hospital, Rawalpindi. Our research sheds important light on antibiotic resistance and emphasizes the necessity of focused intervention techniques to control Serratia marcescens infections better.

We collected a total of 108 isolates, and out of them, 43 were from the Medicine department, 34 from Surgery, 8 from Gynecology, and 23 from the intensive care unit (ICU). Our study shows quite high resistance to aminoglycosides. 23.15% of Serratia strains were resistant to Amikacin, which is considerably higher compared to the survey by Simsek et al., which reported only 6.3% resistance [5], and another study held in Oman showing 91.5% susceptibility [6]. Our study shows 49.07% of Serratia strains are resistant to Gentamycin, which is also higher compared with the survey of Simsek et al. showing only 0.6% [5] and the survey in Oman showing 91.2% susceptibility [6]. However, Serratia strains were only 18.5% resistant to gentamicin and 14.8% resistant to amikacin, according to research by Ferriera et al. [7] Another study conducted in Lahore shows 5.9% resistant strains, which is also low compared with our study. These variations in antibiotic resistance may be due to differences in prescribing practices, infection control measures, and antibiotic use in different regions or healthcare settings.

Through our study, we found out that Serratia is showing a very high level of resistance to beta-lactam antibiotics, including ampicillin (94.23%), amoxicillin plus clavulanic acid (97.30%), aztreonam (80%), imipenem (26%), and penicillin (75%). This aligns with other studies showing the same resistance pattern [5,7,8]. The finding for ampicillin resistance also aligns with another conducted in the USA, which shows 94% resistance [9]. This is because the Serratia have intrinsic resistance to beta-lactam antibiotics. This intrinsic resistance is due to the resistant genes on their chromosomes.

Our study showed high resistance of Serratia marcescens to cephalosporins, including cefepime (35.71%), cefotaxime (52.94%), ceftazidime (58.23%), ceftriaxone (57.78%), and cephradine (51.35%). These are comparatively very high, as a study showed resistance rates to ceftriaxone and ceftazidime were 22.7% and 19.6%, respectively [5]. Our finding contradicts another study showing low levels of resistance to these cephalosporins, with cefepime showing good efficacy against Serratia marcescens [10].

Among tetracyclines, Serratia marcescens showed less resistivity to tigecycline and minocycline, which were 3.95% and 12.82%, respectively. But Serratia showed high resistance to doxycycline (56.44%). These findings are also supported by another study [6]. The reason may be that Serratia marcescens has well-documented intrinsic and acquired resistance mechanisms

In the aminoglycoside class, amikacin demonstrated moderate efficacy with a 76.85% sensitivity rate, whereas gentamicin showed nearly equal proportions of sensitivity (50.93%) and resistance (49.07%). Minocycline and tigecycline were among the most effective agents, with sensitivity rates of 87.18% and 94.74%, respectively.

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Discussion

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are genetically encoded, they tend to appear consistently across different regions and studies.

Our study showed considerable resistance of Serratia marcescens to co-trimoxazole (50.93%), ciprofloxacin (42.59%), chloramphenicol (25%), meropenem (21.74%), and imipenem (24.07%). However, Serratia strains were only 18.5% resistant to ciprofloxacin, according to research by Ferriera et al. [7]. And Serratia was only 7% resistant to chloramphenicol, according to a study in the USA [9]. The higher resistance rates in our study compared to the USA study (e.g., chloramphenicol resistance of 25% vs. 7%) can indicate greater antibiotic misuse or different bacterial strains circulating in our region. Another study in Bulgaria shows a similar resistance pattern to co-trimoxazole (53.3%) and ciprofloxacin (44.5%). Frequent and inappropriate use of certain antibiotics in a given area can lead to increased resistance. For example, if ciprofloxacin is widely used in our region, resistance may be higher (42.59%) than in the study by Ferriera et al. (18.5%). The similarity of our co-trimoxazole and ciprofloxacin resistance rates to the Bulgarian study suggests similar prescribing habits.Our research demonstrates that in order to confirm treatment decisions, it is necessary to conduct routine surveillance and resistance monitoring of local resistance trends. Additionally, data exchange with regional and international networks is necessary to monitor new resistance patterns. Furthermore, we need to raise public awareness about the dangers of self-medication and incomplete antibiotic courses.

Strengths and limitations

Strengths

This study spans seven years, offering long-term insight into antimicrobial resistance trends of Serratia marcescens in a tertiary care setting. It includes diverse specimen types from multiple departments and uses standardized microbiological methods and CLSI guidelines for accurate susceptibility profiling.

Limitations

Being a single-center, retrospective study, findings may not reflect broader national trends. Molecular resistance mechanisms were not analyzed, and clinical outcome data were unavailable. Additionally, some antibiotics were tested on limited isolates, reducing generalizability for those agents.

Conclusion

This seven-year surveillance study reveals a concerning rise in antimicrobial resistance among Serratia marcescens isolates in a tertiary care setting in Rawalpindi, Pakistan. The pathogen demonstrated high resistance to multiple first-line antibiotics, including β-lactams and fluoroquinolones, with emerging resistance even to carbapenems. The increasing prevalence, particularly in critical care units, underscores the urgent need for comprehensive infection control policies and the rational use of antibiotics. Tigecycline and minocycline showed the most promise among the tested agents, offering potential therapeutic alternatives. However, without prompt implementation of robust antimicrobial stewardship programs, enhanced diagnostic capabilities, and sustained epidemiological surveillance, the threat of multidrug-resistant S. marcescens may continue to escalate. Future research should focus on molecular characterization of resistance mechanisms and evaluating the effectiveness of targeted interventions in curbing resistance trends in local healthcare settings.

Appendices

Author Contributions

Human Ethics

Consent: Informed consent was obtained from all participants, and they were enlightened about the purpose of the research.

Data Protection: The participants' information was kept anonymous and will not be shared with unauthorized entities.

Confidentiality: Participant data will be secured, and their identities will not be exposed.

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Animal Ethics

All authors have verified that this research did not include animal subjects or tissue.

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