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Serratia infections in a general hospital: characteristics and outcomes

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Abstract We aimed to present our experience regarding infections caused by *Serratia* spp. in a region with relatively high antimicrobial resistance rates. We retrospectively reviewed the databases of the microbiological laboratory of the University Hospital of Heraklion, Crete (2/2004–12/2009). A total of 77 patients [67.5% men, mean age ± standard deviation (SD)=56.9±24.5 years) were identified; 37.7% were outpatients. Sixty-five (84.4%) of the 77 included patients had a *Serratia marcescens* isolate; the remaining 12 patients had a non-marcescens *Serratia* spp. The most frequently observed infections were respiratory tract infection (32.5%) and keratitis/endophthalmitis (20.8%). Seventy-three (94.9%) patients were cured. Four deaths were observed; three of them were considered as attributed to the *Serratia* infection. No difference was found regarding the characteristics and outcomes between patients with *Serratia marcescens* and non-marcescens infections. In addition, antipseudomonal penicillins and their combinations with beta-lactamase inhibitors, as well as carbapenemes, and fluoroquinolones exhibited high antimicrobial activity against both the tested *Serratia marcescens* and non-marcescens isolates. Our study adds useful information regarding the characteristics and outcomes of patients with *Serratia* infection, as well as the susceptibilities of the respective *Serratia marcescens* and non-marcescens isolates, in a region with relatively high levels of antimicrobial resistance.

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Introduction

Serratia spp, particularly *Serratia marcescens*, are mainly encountered as causative pathogens of nosocomial infections and nosocomial outbreaks [1, 2]. Specifically, *Serratia* spp. are incriminated for outbreaks in neonatal intensive care units (NICUs) [3–5]. In addition, due to their ability of biofilm formation and the production of enzymes including gelatinase, elastase and alkaline protease, *Serratia* spp. manage to invade human corneal epithelial cells and cause keratitis, and particularly contact lens-related keratitis [6, 7].

Even though *Serratia* spp. are mainly considered nosocomial pathogens, recently published population-based studies suggested that a considerable percentage of the identified *Serratia* infections is community-acquired [6, 8]. Even though *Serratia marcescens* constitutes the

majority of the identified *Serratia* isolates, many reports regarding infections and outbreaks caused from *Serratia* spp. other than *Serratia marcescens* have also appeared in the literature [7, 9–12]. In addition, another issue that intensified the importance of *Serratia* infections is the emergence of multi-drug resistant *Serratia* isolates, and particularly extended spectrum beta-lactamase-producing (ESBLs) *Serratia* isolates [13–15].

In this regard, the aim of our study was to present our experience regarding the characteristics and outcomes of patients with infections caused from *Serratia* spp. at a university hospital of a region with relatively high levels of antimicrobial resistance [16–20].
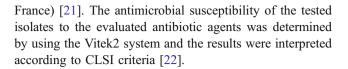
Methods

Study design and patient population

We present a descriptive study based on the retrospective evaluation of a case series. Specifically, we retrospectively reviewed the databases of the microbiological laboratory of the University Hospital of Heraklion, Crete in order to identify patients from whom *Serratia* spp. were isolated, during a 5-year period (February 2004–December 2009). The University Hospital of Heraklion, Crete is a 650-bed tertiary care centre, serving a population of approximately 650,000 individuals, with approximately 65,000–70,000 admitted patients per year. The following data were retrieved from the available medical records of the respective patients: sex, age, department of hospitalization, potential risk factors for acquisition of nosocomial infections (including immunosuppression, treatment with corticosteroids, malnutrition, trauma, surgery, and presence of a urinary catheter), type of *Serratia* infection, antibiotic treatment administered for the infection, duration of hospitalization, as well as the outcome of the infection.

With regard to the evaluated potential risk factors in particular, the objective criteria of *malnutrition* were a BMI <18.5, or unintentional weight loss of more than 5% in the last month, or more than 10% in the last 6 months, whereas *trauma* was defined as any injury or wound infection. When more than one *Serratia* isolates were identified from a patient, we selected the first isolate for inclusion in our study. Moreover, data regarding any other pathogen that was simultaneously identified from the same clinical specimen were also retrieved.

Microbiological testing

Identification of the isolates was performed with the use of standard biochemical methods—the API 20 E system and the Vitek2 automated system (BioMérieux, Marcy l' Etoile,

France) [21]. The antimicrobial susceptibility of the tested isolates to the evaluated antibiotic agents was determined by using the Vitek2 system and the results were interpreted according to CLSI criteria [22].

Statistical analysis

We performed comparisons regarding demographic, clinical characteristics, and outcomes between the included patients with a clinical specimen that yielded a *Serratia marcescens* isolate and those with a clinical specimen that yielded a *Serratia* spp. isolate (other than *Serratia marcescens*). The χ^2 test or the Fisher exact tests were used, when appropriate, in the comparisons regarding categorical variables, whereas the *t*-test was used in the comparisons regarding continuous variables. For non-normally distributed continuous variables, the Mann-Whitney signed-rank test was used. A *p* value of <0.05 was regarded as indicative of statistical significance. The comparisons were performed with the use of the OpenEpi Software [23] and the SPSS software version 13.0 (SPPS Inc, Chicago, Illinois, USA).

Results

Patient characteristics

A total of 77 patients were identified as having a clinical specimen that yielded a *Serratia* spp. isolate during the study period. Detailed data regarding the demographic, clinical characteristics and outcomes of the patients are presented in Table 1. Specifically, the mean age ± standard deviation (SD) of the included patients was 56.9±24.5 years. Two of the 77 patients were infants (7 and 8 months, respectively). The majority (67.5%) of the patients were men. Regarding the department of hospitalization, the majority (59.7%) were admitted in medical wards, whereas 37.7% were outpatients. Seventeen (22.1%) of the 77 patients did not have any comorbidity. Regarding the remaining 60 patients, cardiac diseases were reported most frequently (50%). A total of 32.5% of the patients were immunosuppressed, 24.7% were treated with corticosteroids, 19.5% had undergone surgery, 13% had a urinary catheter, 9.1% were trauma patients, and 7.8% were malnourished. In addition, ten of the evaluated patients were admitted in the ICU; two of them were on mechanical ventilation. None of the evaluated patients had a central venous catheter.

Infections and outcomes

A total of 32.5% of the patients had a respiratory tract infection, followed by 20.8% that had keratitis/endophthal-

Table 1 Baseline characteristics, infections and outcomes of the patients

Characteristics	All	Serratia marcescens (Group A)	Other Serratia spp. (non-marcescens) (Group B)	P value (Group A vs Group B)
Number of patients	n_1=77	n_2=65	n_3=12	
Demographics				
Age (years)	56.9±24.5	56.3±24.5	59.9±25.9	0.7
Sex (male)	52 (67.5)	45 (69.2)	7 (58.3)	0.7
Department of hospitalization				
Medical	46 (59.7)	38 (58.5)	8 (66.7)	0.8
Surgical	13 (16.9)	11 (16.9)	2 (16.7)	>0.9
Pediatric	2 (2.6)	2 (3.1)	0	>0.9
ICU	10 (13.0)	10 (15.4)	0	0.3
Outpatients	29 (37.7)	25 (38.5)	4 (33.3)	>0.9
Transfer from another hospital	2 (2.6)	2 (3.1)	0 (0)	>0.9
Comorbidity				
None	17 (22.1)	13 (20.0)	4 (33.3)	0.5
Diabetes mellitus	12 (15.6)	9 (13.8)	3 (25.0)	0.6
Cardiac diseases	33 (42.9)	27 (41.5)	6 (50.0)	0.8
Pulmonary diseases	14 (18.2)	12 (18.5)	2 (16.7)	>0.9
Renal diseases	7 (9.1)	5 (7.7)	2 (16.7)	0.6
Hepatic diseases	2 (2.6)	2 (3.1)	0	>0.9
CNS diseases	11 (14.3)	11 (16.9)	0	0.3
Orthopedic diseases	9 (11.7)	8 (12.3)	1 (8.3)	>0.9
Malignancies	14 (18.2)	11 (16.9)	3 (25.0)	0.8
Autoimmune diseases	6 (7.8)	4 (6.2)	2 (16.7)	0.5
Hyperurichaemia	3 (3.9)	2 (3.1)	1 (8.3)	0.8
Smoking	11 (14.3)	10 (15.4)	1 (8.3)	0.9
Benign prostate hyperplasia	5 (6.5)	4 (6.2)	1 (8.3)	>0.9
Lipofuscinosis	1 (1.3)	1 (1.5)	0	>0.9
Risk factors				
Corticosteroids	19 (24.7)	16 (24.6)	3 (25.0)	>0.9
Immunosuppression	25 (32.5)	19 (29.2)	6 (50.0)	0.3
Malnutrition	6 (7.8)	3 (4.6)	3 (25.0)	0.1
Urinary catheter	10 (13.0)	8 (12.3)	2 (16.7)	>0.9
Trauma	7 (9.1)	6 (9.3)	1 (8.3)	>0.9
Surgery	15 (19.5)	13 (20.0)	2 (16.7)	>0.9
Type of infection				
RTI	25 (32.5)	20 (30.8)	5 (41.7)	0.7
UTI	10 (13.0)	10 (15.4)	0	0.3
SSTI	13 (16.9)	9 (13.9)	4 (33.3)	0.2
Keratitis/endophthalmitis	16 (20.8)	14 (21.5)	2 (16.7)	>0.9
Cholecystitis	3 (3.9)	2 (3.1)	1 (8.3)	0.8
Sepsis	5 (6.5)	4 (6.2)	1 (8.3)	>0.9
Colonization	8 (10.4)	8 (12.3)	0	0.5
Time to acquisition of the first positive culture for Serratia spp.	Median (range)[a]: 2 (0–158)	Median (range)[b]: 2 (0–158)	Median (range)[c]: 2 (0–5)	0.4
Duration of hospitalization (days)	Median (range)[a]: 6 (1–206)	Median (range)[b] 7 (1–206)	Median (range)[c]: 5 (1–15)	0.3
Outcome				
Cure	73 (94.9)	61 (93.8)	12 (100)	0.9
Death	4 (5.2)	4 (6.2)	0 (0)	>0.9

ICU intensive care unit, *CNS* central nervous system, *RTI* respiratory tract infection, *UTI* urinary tract infections, *SSTI* skin and soft tissue infection

Values given as mean ± standard deviation (SD) or number (%)

[a] NR: 15/77 (19.2%)

[b] NR: 12/65 (18.1%)

[c] NR: 3/12 (25%)

mitis. None of the latter ocular infections was hospital-acquired. Other types of infections observed were skin and soft tissue infections (16.9%), urinary tract infections (13.0%), sepsis (6.5%), and cholecystitis (3.9%). In addition, eight (10.4%) of the patients were considered as colonized with *Serratia* spp. With regard to the patients' outcomes, 73 (94.9%) of the 77 patients were cured. Four deaths were observed during hospitalization in our case series. Three of the four deceased patients had monomicrobial *Serratia* infections, whereas the remaining one patient also had an infection from *Citrobacter freundii*. The four deaths were evaluated by the clinicians that took care of the specific patients as well as the study investigators. Three of these four deaths were considered attributable to the *Serratia* infection and one to other causes.

Comparisons regarding patient subpopulations

Comparative data regarding the patients providing a clinical specimen that yielded a *Serratia marcescens* isolate and those with a clinical specimen that yielded a *Serratia* spp. isolate, other than *Serratia marcescens*, are also presented in Table 1. No difference was found between the compared patient sub-populations regarding the analyzed characteristics and outcomes.

Microbiological characteristics

Types of isolates and sites of isolation

In Table 2 we present data regarding the isolated *Serratia* spp, the respective sites of isolation, as well as any other simultaneously isolated non-*Serratia* species. Specifically, 65 (84.4%) of the 77 patients had a *Serratia marcescens* isolate, whereas the remaining 12 patients had a non-marcescens *Serratia* spp. isolate. These were *Serratia liquefaciens* in five patients, *Serratia rubidaea* in three, *Serratia fonticola* in two, *Serratia plymuthica* in one, and *Serratia ficaria* in one patient. Detailed data regarding the respective sites of isolation are presented in Table 2. Other isolates, including *P. aeruginosa*, *K. pneumoniae*, and *Candida* spp., were identified concurrently to the isolation of the *Serratia* spp. Detailed data regarding the distribution of the concurrently isolated species are also presented in Table 2.

Antimicrobial susceptibility of the tested isolates

The susceptibility rates of the isolated *Serratia* spp. to the 30 analyzed antimicrobial agents are presented in Table 3. Regarding the isolated *Serratia marcescens* that constituted the majority (65/77 [84.4%]) of the identified *Serratia* isolates, the following antibiotic agents exhibited substantial antimicrobial activity against the tested isolates (89.2–100%): antipseudomonal penicillins (specifically, ticarcillin, piperacillin, and ceftazidime), ticarcillin-clavulanic acid, piperacillin-tazobactam, third generation cephalosporins (cefotaxime and ceftriaxone), carbapenems (imipenem and meropenem), aztreonam, tobramycin, netilmicin, nitrofurantoin trimethoprim-sulfonamides, and quinolones (specifically, pefloxacin, ofloxacin, norfloxacin, and ciprofloxacin).

Regarding the 12 tested non-marcescens *Serratia* spp., all of them were found susceptible to the following antimicrobial agents: ticarcillin, piperacillin, ticarcillin-clavulanic acid, piperacillin-tazobactam, ceftazidime, ceftriaxone, cefotaxime, imipenem, meropenem, aztreonam, tobramycin, netilmicin, nitrofurantoin trimethoprim-sulfonamides, pefloxacin, ofloxacin, norfloxacin, and ciprofloxacin. In addition, amikacin, gentamicin, and chloramphenicol exhibited substantial antimicrobial activity against the 12 tested isolates (83.3% each).

Discussion

A total of 77 patients providing a clinical specimen that yielded a *Serratia* spp. isolate were identified in a 650-bed tertiary care hospital during a 5-year period. The majority of the *Serratia* isolates were identified in male patients. This observation is in accordance with the findings of recent population-based studies in which males were considered to be at higher risk for the acquisition of a *Serratia* isolate [8]. In addition, ICU patients were represented by rather low percentages (13%) in this cohort, whereas a considerable percentage (38%) were outpatients. Indeed, population-based studies also reported that the majority of the isolated *Serratia* species [8], including a considerable percentage of *Serratia* bacteremic episodes, were community-acquired [24].

With regard to the observed *Serratia* infections, these were mostly respiratory tract infections, followed by ocular infections, including keratitis and/or endophthalmitis, skin and soft tissue infections, and urinary tract infections. Indeed, due to their ability for biofilm formation, based on the interaction of quorum sensing system and nutrient factors [25, 26], *Serratia* spp frequently colonize medical devices, such as bronchoscopes [27], urinary catheters [28] and water supplies [29], whereas long-term carriage in the hands of healthcare workers has been reported as well [30]. Consequently, *Serratia* spp are frequently incriminated for hospital-acquired bacteremias, nosocomial respiratory and urinary tract infections, and nosocomial outbreaks [31–34]. Specifically, 13% of the included included patients had a urinary catheter. In addition, due to the production of specific enzymes such as gelatinase, elastase and alkaline protease, *Serratia* spp. cause ocular infections including

Table 2 Data regarding the isolated species and sites of isolation

Species identified	n (%)
Serratia spp.	
Serratia marcescens	65 (84.4)
Serratia liquefaciens	5 (6.5)
Serratia rubidaea	3 (3.9)
Serratia fonticola	2 (2.6)
Serratia plymuthica	1 (1.3)
Serratia ficaria	1 (1.3)
Other species	
Staphylococcus spp.	3 (3.9)
Proteus vulgatis	1 (1.3)
Pseudomonas aeruginosa	4 (5.2)
Klebsiella pneumoniae	1 (1.3)
Candida spp	2 (2.6)
Escherichia coli	1 (1.3)
Enterococcus faecalis	1 (1.3)
Mycoplasma pneumoniae	1 (1.3)
Enterococcus faecalis	1 (1.3)
Citrobacter freundii	1 (1.3)
Site of isolation	
Blood	6 (7.8)
Urine	12 (15.6)
BAL	9 (11.7)
Bronchial secretions	8 (10.4)
Pharyngeal aspirate	3 (3.9)
Nasal aspirate	1 (1.3)
Sputum	7 (9.1)
Pus	13 (16.8)
Contact lens	9 (11.7)
Bile	3 (3.8)
Ocular aspirate	6 (7.8)
Conjuctiva	1 (1.3)
Yaloid pus	1 (1.3)
Tracheal tube	1 (1.3)
Number of positive cultures	
One	70 (90.9)
Two	7 (9.1)

BAL bronchoalveolar lavage

ulcerative keratitis, particularly contact lens-related keratitis [6, 35] and endophthalmitis [36, 37]. Moreover, immuno-compromised patients are considered more prone to *Serratia* infections. Of note, a considerable percentage of 32.5% of the included patients were immunosuppressed, and an additional 24.7% received corticosteroids.

Serratia marcescens is the most frequently isolated *Serratia* spp. However, other *Serratia* spp. including *Serratia liquefaciens*, *Serratia plymuthica*, and *Serratia rubidaea*, have been recently identified as the cause of

Serratia nosocomial infections and outbreaks [10, 12, 38, 39]. Furthermore, non-marcescens *Serratia* spp are also incriminated for community-acquired infections [40]. A possible explanation that has been proposed for the relative scarcity of published evidence regarding non-marcescens *Serratia* spp. compared to *Serratia marcescens* is the misidentification of these specific strains by commercially available identification systems [41]. In our study, 12 (15.5%) of the 77 patients provided a clinical specimen of non-marcescens *Serratia* spp (specifically, *Serratia liquefaciens*, *Serratia rubidaea*, *Serratia fonticola*, *Serratia plymuthica*, and *Serratia ficaria*). The majority of the respective infections were respiratory tract infections. It is worth to note that in the comparisons between the patient subpopulations with *S. marcescens* infection and those with non-marcescens *Serratia* infection, no difference was found regarding the demographic characteristics, comorbidity, risk-factors, types of infections, as well as infection outcomes.

As far as mortality is concerned, four of the 77 patients died. Three of these four deaths were considered to have been probably attributed to the *Serratia* infection, after a meticulous evaluation of the respective clinical data from the clinicians as well as the study investigators. Regarding mortality from *Serratia* infections, published evidence report percentages of 5% and 37% for *Serratia* bacteremia 7-day and 6-months mortality, respectively [24]. However, mortality can occur even in less severe *Serratia* infections, such as urinary tract infections. Specifically, female gender and the development of secondary *S. marcescens* bacteremia have been identified as risk factors independently associated with fatality in patients with urinary tract infection due to *S. marcescens* [42]. Moreover, the emergence of ESBL-producing *Serratia* spp. intensifies the importance of the issue of *Serratia* infection-related mortality. Specifically, a 30-day mortality rate of 33% has been reported for nosocomial patients with ESBL-producing *S. marcescens* infections [43].

Serratia spp. exhibit considerable antimicrobial resistance to penicillins and cephalosporins. This is mainly attributed to the fact that AmpC beta-lactamases are encoded in the chromosome of *Serratia* spp. The expression of these genes is inducible in most cases [44, 45]. In our study all the 65 tested *Serratia marcescens* isolates were found resistant to amoxicillin and amoxicillin/clavulanic acid. Similarly, one of the 12 non-marcescens *Serratia* spp was susceptible to the above drugs. This observation was consistent regarding cefalothin, a first generation cephalosporin, whereas with regard to cefuroxime, lower susceptibility rates were observed for the tested *Serratia marcescens* compared to the non-marcescens isolates. Additionally, 35% of the tested *Serratia marcescens* isolates and 50% of the non-marcescens isolates were

Table 3 Susceptibility patterns of *Serratia* isolates tested

Antimicrobial agents	*Serratia marcescens*		*Serratia* spp. (non-*marcescens*)[a]		All *Serratia* isolates tested	
	n_1=65		n_2=12		n=77	
	S (%)	I (%)	S (%)	I (%)	S (%)	I (%)
Ampicillin	0	0	1 (8.3)	0	1 (1.2)	0
Amoxicillin + Clavulanic acid	0	0	1 (8.3)	0	1 (1.2)	0
Ticarcillin	59 (90.8)	0	12 (100)	0	71 (92.2)	0
Ticarcillin + Clavulanic acid	61 (93.8)	1(1.5)	12 (100)	0	73 (94.8)	1 (1.2)
Piperacillin	60 (92.3)	2 (3.1)	12 (100)	0	72 (96.0)	2 (2.5)
Piperacillin/tazobactam	62 (95.4)	0	12 (100)	0	74 (98.6)	0
Cefalothin	0	0	1 (8.3)	0	1 (1.2)	0
Cefuroxime	2 (3.1)	1 (1.5)	3 (25.0)	0	5 (6.4)	1 (1.2)
Cefoxitin	23 (35.4)	29 (44.6)	6 (50.0)	2 (16.7)	29 (37.6)	31 (40.2)
Cefotaxime	62 (95.4)	0	12 (100)	0	74 (98.6)	0
Ceftriaxone	62 (95.4)	0	12 (100)	0	74 (98.6)	0
Ceftazidime	62 (95.4)	0	12 (100)	0	74 (98.6)	0
Imipenem	62 (95.4)	0	12 (100)	0	74 (98.6)	0
Meropenem	64 (98.4)	0	12 (100)	0	76 (98.7)	0
Aztreonam	65 (100)	0	12 (100)	0	77 (100)	0
Tobramycin	60 (92.3)	2 (3.1)	12 (100)	0	72 (93.5)	2 (2.5)
Amikacin	34 (52.3)	5 (7.7)	10 (83.3)	0	44 (57.1)	5 (6.4)
Gentamicin	35 (53.8)	4 (6.2)	10 (83.3)	0	45 (58.4)	4 (5.1)
Netilmicin	58 (89.2)	2 (3.1)	12 (100)	0	71 (92.2)	2 (2.5)
Chloramphenicol	30/61 (49.2)[b]	5 (8.21)	10 (83.3)	0	40/73 (54.7)	5/73 (6.8)
Tetracycline	17/25 (68.0)[c]	3 (12.0)	3/3[d]	0	21/28 (75)	3/28 (10.7)
Trimethoprim	4 (6.2)	0	1 (8.3)	0	5 (6.4)	0
Trimethoprim + Sulfonamides	63 (96.9)	1 (1.5)	12 (100)	0	75 (97.4)	1 (1.2)
Nitrofurantoin	59 (90.7)	0	12 (100)	0	71 (92.2)	0
Nalidixic acid	4 (6.2)	1 (1.5)	1 (8.3)	2 (16.7)	5 (6.4)	3 (3.8)
Pefloxacin	60 (92.3)	0	12 (100)	0	72 (93.5)	0
Ofloxacin	62 (95.4)	1 (1.5)	12 (100)	0	74 (96.1)	1 (1.2)
Norfloxacin	63 (96.9)	0	12 (100)	0	75 (97.4)	0
Ciprofloxacin	63 (96.9)	0	12 (100)	0	75 (97.4)	0

S susceptibility, *I* intermediate susceptibility, *NR* not reported

[a] These include five *Serratia liquefaciens*, three *Serratia rubidaea*, two *Serratia fonticola*, one *Serratia plymuthica*, and one *Serratia ficaria*

[b] NR: 4/66 (6.1%)

[c] NR: 40/66 (60.6%)

[d] NR: 9/12 (75.0%)

found susceptible to cefoxitin. Finally, third generation cephalosporins (ceftazidime and cefotaxime) and ceftriaxone exhibited high susceptibility rates regarding the *Serratia marcescens* and non-marcescens tested isolates (95.4% and 100%, respectively).

Other beta-lactamases, including CTX-M3, IMP-type, as well as TEM-type have also been identified in *Serratia* spp [14, 46–48]. Specifically, the issue of the emergence of carbapenem resistance *Serratia* strains is of major importance. In our study, both imipenem and meropenem

exhibited high antimicrobial activity rates against the tested *Serratia marcescens* and non-marcescens isolates. In addition, among the evaluated antimicrobial agents, tobramycin, netilmicin, nitrofurantoin, as well as the combination of trimethoprim with sulfonamides were also found highly active against the tested *Serratia marcescens* and non-marcescens isolates. On the contrary, amikacin and gentamicin were found to be more active against the tested non-marcescens isolates compared to the tested *Serratia marcescens* isolates. Finally, fluoroquinolones were also

highly active against the tested *Serratia marcescens* and non-marcescens isolates. However, evidence regarding the chromosome-encoded resistance to fluoroquinolones of *Serratia marcescens* has appeared in the literature [49–51].

Our study has specific limitations that should be considered. Firstly, one should bear in mind the intrinsic methodological limitations of retrospective cohort studies before the extrapolation of the study findings. In addition, our findings derive from the evaluation of the clinical and microbiological data of a rather limited number of 77 patients that provided a clinical specimen that yielded a *Serratia* spp. isolate. Moreover, since *Serratia* spp. are often incriminated for nosocomial epidemics, one may consider that the *Serratia* strains included in this study are epidemic strains. Yet, even though genetic identification techniques were not used in this study, the 5-year study period is rather contradictory to the potential of a concurrent nosocomial epidemic. However, one may consider that a proportion of the tested *Serratia* isolates might have been of the same clonal origin. Finally, even though the emergence of ESBL-producing *Serratia* spp. appears to be an issue of increasing importance, microbiological methods for the identification of ESBL-producing isolates, among the evaluated *Serratia* isolates, were also not implemented in this study.

In conclusion, our study aids in the clarification of issues regarding the characteristics and outcomes of patients with *Serratia* infections, as well as the susceptibility patterns of the respective isolates. In the era of alarmingly high antimicrobial resistance, and particularly in the era of ESBL-producing enterobacteriaceae [52], our findings may provide useful information regarding the infections caused from this specific pathogen, as they derive from a clinical setting with relatively high levels of antimicrobial resistance.

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