

Prevalence and Phenotypic Virulence Characteristics of Bacterial Isolates from Patients with Urological Disorders in Three Tertiary Healthcare Facilities in Port Harcourt, Nigeria

Barinua, D. N.^{*}, Wemedo, S. A., Sampson, T. and Ugboma, C. J.

Department of Microbiology, Rivers State University, Nkpolu-Oroworukwo, Port Harcourt, Rivers State, Nigeria

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Corresponding Author: **Barinua, D. N.**

E-Mail: barinua.nenyiebari@rsu.edu.ng

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ABSTRACT

Bacterial infection is common among patients' with urological disorders, especially in tertiary-owned hospitals, where admission, urinary-instrumentation, persistent infection and continual antibiotic use favour the persistence of opportunistic-organisms. Identifying isolates is only part of the picture, since traits such as biofilm-formation, haemolysis, motility and coagulase- production indicate how well bacteria can colonise persistently and cause disease. This study determined the prevalence and phenotypic virulence characteristics of bacteria isolated from patients with urological disorders at three tertiary-owned healthcare facilities in Port Harcourt, Nigeria. In hospital-based cross-sectional study, urine specimens from 252 patients admitted at Rivers State University Teaching Hospital (RSUTH), University of Port Harcourt Teaching- Hospital (UPTH) and Kelsey-Harrison Hospital (KHH) were respectively cultured and the isolates successively identified using recommended methods. Coagulase production, motility, biofilm-formation and haemolysis were then determined. Bacterial growth was obtained thus; 63 from RSUTH, 57 from UPTH and 22 from KHH from 142 of the 252 specimens (56.3%) collected. *Klebsiella* spp. (n =73)

occurred at all three hospitals (RSUTH, 34; UPTH, 31; KHH, 8). *Staphylococcus aureus* (n = 41) was frequent at all three, whereas *Pseudomonas aeruginosa* was found at KHH. Biofilm-formation was detected among 87 isolates (61.3%), with the highest occurrence recorded in *Escherichia coli* (2/2; 100%), coagulase-negative staphylococci (87.5%), *P.aeruginosa* (83.3%) and *S.aureus* (73.2%). 20 motile isolates (14.1%) and 31 (21.8%) were haemolytic, and isolated every *S. aureus* showed coagulase-positive. The isolates were phenotypically virulence and biofilm forming. The differences in bacterial distribution among the hospitals; alongside biofilm production can be applied in local epidemiological studies, virulence surveillance and in the management of complicated urological infections.

Keywords: urological-disorders; bacterial isolates; biofilm; virulence-factors; haemolysis; motility; *Klebsiella* spp.; *Staphylococcus aureus*; Port Harcourt.

1. Introduction

According to [1], urological disorders affect the smooth function of the urinary system. Bacterial infection complications, and urinary tract infection (UTI) have contributed significantly to the clinical burden among patients globally [4]. UTIs common around hospital environments are caused by Gram-positive cocci [1, 2]. Bacteria linked to urinary infections healthcare environment include; *Klebsiella* spp., *Pseudomonas aeruginosa*, *Enterobacter* spp., *Serratia* spp. and *Staphylococcus aureus* with uropathogenic *Escherichia coli* been the major cause of uncomplicated community-acquired UTI, [2]. Epidemiological studies across diverse geographical regions in Nigeria showed that urinary bacterial infections have shown considerable variation across healthcare settings. Their bacterial predominance may differ between hospitals depending on patient characteristics, referral patterns,

antimicrobial exposure and healthcare-associated risk factors [3, 4]. However, according to [4], hospital-specific surveillance remains important for understanding ecology of urological infections bacteria.

Bacterial pathogenicity stems from exhibition of several phenotypic and molecular characteristics that promote traits like; adhesion, colonization, persistence, tissue damage and evasion of host defence mechanisms [6]. However, prominent among these traits were motile ability, haemolytic tendencies, coagulase-production and biofilm –formation [5, 6].

Biofilm formation is common in healthcare-associated infections. Biofilms are of bacterial communities inhabiting surfaces of an extracellular matrix. Biofilm-grown bacteria exhibit increased tolerance to antimicrobial agents with host defense mechanisms enabling persistence and recurrence of infection [5, 6].

The urinary tract produces biofilm development sites several potential sites in patients under urinary catheters or other urological devices [10]. Biofilm-producing bacteria often resist antimicrobial treatment and can therefore contribute to recurrent bacteriuria resulting to infections difficult to treat. The pathogenic properties of a biofilm are prompted by antimicrobial tolerance necessitated by multiple interacting mechanisms, including extent of antimicrobial penetration, altered bacterial metabolic states and stress responses mechanisms [2, 10].

S. aureus produces coagulase and numerous adhesins and can form biofilm; coagulase also underpins its routine laboratory identification. Together with its other virulence factors, these traits enable the organism to cause both community-onset and hospital-acquired disease [7, 8].

Klebsiella spp. are opportunistic pathogens of growing importance in complicated urinary infection, relying on capsule, adhesins, iron-scavenging systems and biofilm formation [9].

Motility, driven by flagella, helps bacteria reach and settle in favourable sites. Uropathogenic *E. coli* and other Gram-negative uropathogens combine it with several other factors to colonise the urinary tract and withstand host defences [2, 10]. Haemolysins can injure host cells and tissues, yet a non-haemolytic isolate is not necessarily less pathogenic, since virulence rests on many independent mechanisms.

Integrated data on the prevalence and phenotypic virulence of bacteria from patients with urological disorders across tertiary hospitals in Port Harcourt are scarce. This study therefore estimated the prevalence of bacterial isolates at three tertiary hospitals and characterised four phenotypic traits: biofilm formation, motility, coagulase production and haemolysis.

2. Materials and Methods

2.1 Study design and setting

A hospital-based cross-sectional study was carried out among patients with urological disorders attending three tertiary hospitals in Port Harcourt, Rivers State, Nigeria: Rivers State University Teaching Hospital (RSUTH), University of Port Harcourt Teaching Hospital (UPTH) and Kelsey-Harrison Hospital (KHH). In all, 252 patients were enrolled (RSUTH, 112; UPTH, 107; KHH, 33) between September 2024 and August 2025. [Ethical approval: insert the approving committee(s), reference number(s) and a statement on informed consent.]

2.2 Specimen collection and bacterial isolation

A urine specimen was collected from each participant and processed in the laboratory by standard bacteriological methods. Specimens were inoculated onto suitable culture media and incubated under appropriate conditions. Growth of at least 10^5 CFU/mL was taken as significant for midstream urine and at least 10^2 CFU/mL for catheter specimens. Colonies were examined for cultural characteristics, Gram-stained and subjected to conventional biochemical tests [11].

2.3 Identification of bacterial isolates

Isolates were identified from their cultural, microscopic and biochemical properties [11]. Seven groups were recognised: *Klebsiella* spp., *Staphylococcus aureus*, coagulase-negative staphylococci (CoNS), *Enterobacter* spp., *Serratia marcescens*, *Escherichia coli* and *Pseudomonas aeruginosa*.

2.4 Phenotypic virulence characterisation

Four readily observable phenotypes linked to pathogenicity and persistence were examined: coagulase production, motility, biofilm formation and haemolysis [11].

2.4.1 Coagulase production

The coagulase test was applied to the staphylococcal isolates, and visible clotting or clumping was recorded as positive. The result separated *S. aureus* from the coagulase-negative staphylococci [11].

2.4.2 Motility

Isolates were stab-inoculated into semi-solid medium. Diffuse growth spreading away from the stab line indicated motility, whereas growth confined to the line indicated a non-motile organism [11].

2.4.3 Biofilm formation

Biofilm (slime) production was screened on Congo red agar. Isolates forming black, dry, crystalline colonies were scored as biofilm producers, and those without this appearance as non-producers. The method was first described for coagulase-negative staphylococci [12] and has since been applied to clinical isolates in Port Harcourt [13].

2.4.4 Haemolysis

Haemolysis was read on blood agar. A greenish discolouration around colonies was recorded as α -haemolysis, a clear zone as β -haemolysis and no change in the medium as γ -haemolysis [11].

2.5 Data analysis

Data were analysed with the Statistical Package for the Social Sciences (SPSS) version 20.0 and are presented descriptively as frequencies and percentages. Prevalence at each hospital was calculated using the number of specimens examined at that hospital as the denominator. Differences between hospitals are described and were not tested statistically.

3. Results

3.1 Prevalence of bacterial isolates at the three hospitals

Bacterial growth was obtained from 142 of the 252 specimens, an overall rate of 56.3% (Table 1). The rate was highest at KHH (22/33; 66.7%), followed by RSUTH (63/112; 56.3%) and UPTH (57/107; 53.3%). *Klebsiella* spp. was the most frequent isolate, found in 73 specimens (29.0%), with similar rates at RSUTH (30.4%), UPTH (29.0%) and KHH (24.2%). *Staphylococcus aureus* came second, in 41 specimens (16.3%): 21.2% at KHH, 16.8% at UPTH and 14.3% at RSUTH. CoNS accounted for 8 specimens (3.2%), occurring at KHH (6.1%) and RSUTH (5.4%) but not at UPTH. *Enterobacter* spp., *S. marcescens* and *P. aeruginosa* were each found in 6 specimens (2.4%). *Enterobacter* spp. rates were 3.0% at KHH, 0.9% at RSUTH and 3.7% at UPTH; *S. marcescens* was absent at KHH and found in 3.6% at RSUTH and 1.9% at UPTH; and *P. aeruginosa* was commonest at KHH (12.1%), absent from RSUTH and found in 1.9% at UPTH. *E. coli* was the least frequent, with two isolates (0.8%), both from RSUTH (1.8%).

Table 1: Prevalence of bacterial isolates at the three hospitals (N = 252 specimens)

Isolate	KHH n (%) (N = 33)	RSUTH n (%) (N = 112)	UPTH n (%) (N = 107)	Overall n (%) (N = 252)
<i>Klebsiella</i> spp.	8 (24.2)	34 (30.4)	31 (29.0)	73 (29.0)
<i>Staphylococcus aureus</i>	7 (21.2)	16 (14.3)	18 (16.8)	41 (16.3)
Coagulase-negative <i>Staphylococcus</i> spp.	2 (6.1)	6 (5.4)	0 (0)	8 (3.2)
<i>Enterobacter</i> spp.	1 (3.0)	1 (0.9)	4 (3.7)	6 (2.4)
<i>Serratia marcescens</i>	0 (0)	4 (3.6)	2 (1.9)	6 (2.4)
<i>Escherichia coli</i>	0 (0)	2 (1.8)	0 (0)	2 (0.8)
<i>Pseudomonas aeruginosa</i>	4 (12.1)	0 (0)	2 (1.9)	6 (2.4)
Total	22 (66.7)	63 (56.3)	57 (53.3)	142 (56.3)

N = number of specimens examined; n = number of specimens positive for the isolate; percentages are of specimens examined at each hospital (or overall). KHH, Kelsey-Harrison Hospital; RSUTH, Rivers State University Teaching Hospital; UPTH, University of Port Harcourt Teaching Hospital; CoNS, coagulase-negative staphylococci.

3.2 Phenotypic virulence characteristics

Table 2 summarises the phenotypic traits of the 142 isolates. Biofilm formation was the commonest: 87 isolates (61.3%) were producers and 55 (38.7%) were not. Twenty isolates (14.1%) were motile, and 31 (21.8%) were haemolytic, of which 11 (7.7%) showed α -haemolysis and 20 (14.1%) β -haemolysis.

Table 2: Phenotypic virulence characteristics of the bacterial isolates

Isolate (n)	Coagulase positive n (%)	Motile n (%)	Biofilm positive n (%)	Haemolysis n (%)		
				α	β	no
<i>Klebsiella</i> spp. (73)	0 (0)	0 (0)	42 (57.5)	0 (0)	0 (0)	73 (100)
<i>Staphylococcus aureus</i> (41)	41 (100)	0 (0)	30 (73.2)	5 (12.2)	10 (24.4)	26 (63.4)
Coagulase-negative <i>Staphylococcus</i> spp. (8)	0 (0)	0 (0)	7 (87.5)	2 (25.0)	6 (75.0)	0 (0)
<i>Enterobacter</i> spp. (6)	0 (0)	6 (100)	0 (0)	0 (0)	0 (0)	6 (100)
<i>Serratia marcescens</i> (6)	0 (0)	6 (100)	1 (16.7)	0 (0)	0 (0)	6 (100)
<i>Escherichia coli</i> (2)	0 (0)	2 (100)	2 (100)	0 (0)	2 (100)	0 (0)
<i>Pseudomonas aeruginosa</i> (6)	0 (0)	6 (100)	5 (83.3)	4 (66.7)	2 (33.3)	0 (0)
Total (142)	41 (28.9)	20 (14.1)	87 (61.3)	11 (7.7)	20 (14.1)	111 (78.2)

Values in brackets after each isolate are the number of isolates tested; percentages are of that number. α , α -haemolysis; β , β -haemolysis; γ , no haemolysis.

Among biofilm producers, both *E. coli* isolates were positive (100%), followed by CoNS (7/8; 87.5%), *P. aeruginosa* (5/6; 83.3%), *S. aureus* (30/41; 73.2%) and *Klebsiella* spp. (42/73; 57.5%). One *S. marcescens* isolate (16.7%) produced biofilm, and no *Enterobacter* isolate did.

All *Enterobacter* spp., *S. marcescens*, *E. coli* and *P. aeruginosa* isolates were motile, whereas *Klebsiella* spp., *S. aureus* and CoNS were non-motile.

All 41 *S. aureus* isolates were coagulase-positive and no other group produced coagulase, so this trait was confined to *S. aureus*.

Haemolysis was detected in every CoNS isolate (two α , six β), both *E. coli* isolates (β), all six *P. aeruginosa* isolates (four α , two β) and 15 of the 41 *S. aureus* isolates (five α , ten β ; 36.6%). No *Klebsiella*, *Enterobacter* or *S. marcescens* isolate was haemolytic.

4. Discussion

4.1 Prevalence of bacterial isolates

Bacterial growth in more than half of the specimens (56.3%) shows that bacterial infection contributes considerably to the burden of disease in these patients. Culture-positivity of this order is broadly comparable with hospital-based reports from sub-Saharan Africa, including Nigeria, although patient characteristics, clinical setting, specimen collection, prior antibiotic use and laboratory methods all influence the figures seen in different studies [3, 4, 14, 15]. persistence of bacteria biofilm cross diverse health facilities settings substantiates the relevance of microbiological investigation of patients' with urological disorders [3].

Klebsiella spp. emerged as the leading isolate and occurred at all three hospitals. This departs from the classical picture of uncomplicated community-acquired UTI, in which uropathogenic *E. coli* is the main cause [2]. A likely explanation is the study population: patients with urological disorders at tertiary hospitals tend to have more complicated disease than community patients with uncomplicated infection. *Klebsiella* spp. are well-recognised agents of complicated and healthcare-associated urinary infection, and they possess traits that help them survive in clinical settings [16, 17].

S. aureus was also commonly isolated at every hospital. It is not the usual leading pathogen in uncomplicated UTI, but its presence here is clinically meaningful: the organism is linked with complicated and hospital-acquired infection and may be more frequent where there are structural abnormalities of the urinary tract, instrumentation or other predisposing factors [8].

CoNS were less frequent but were found at two of the three hospitals. They merit attention because they are now regarded as opportunistic pathogens, particularly in hospitalised patients and those with indwelling devices, and adherence to surfaces and biofilm formation may allow them to persist and cause recurrent or device-related infection [18]. Their absence at UPTH reflects only the specimens sampled and should not be read as proof that they are absent from that hospital.

Enterobacter spp., *S. marcescens* and *P. aeruginosa* were less common and showed different patterns across the hospitals. Even so, they are important opportunistic pathogens in complicated and healthcare-associated urinary infection: *Enterobacter* spp. readily acquire resistance determinants, while *Serratia* and *P. aeruginosa* are known for persisting and resisting treatment in hospital environments [19, 20]. The uneven pattern suggests that the bacterial make-up of urological infection was not uniform across the hospitals.

The very low frequency of *E. coli* (two isolates) contrasts with its established dominance in uncomplicated community UTI [2]. The contrast should be read with care, because the patients were hospital attenders with urological disorders rather than a community sample, and the result may reflect that clinical profile instead of any decline in the importance of *E. coli* as a uropathogen. Differences in isolate frequency between the three hospitals indicate that pathogens were not evenly distributed. Variation of this kind may arise from differences in patient mix, referral patterns, clinical practice and other local factors, but none of these was examined here and none can be taken as the explanation.

Overall, the profile was dominated by *Klebsiella* spp., with a substantial contribution from *S. aureus* and a scattering of other Gram-negative and Gram-positive opportunists. This supports hospital-specific surveillance in preference to reliance on a single generalised profile, since local data can inform diagnosis, susceptibility testing and infection-prevention policy.

4.2 Biofilm formation

Biofilm production was the most conspicuous virulence trait, present in 61.3% of isolates. Biofilm allows bacteria to persist in protected communities with greater tolerance of antimicrobials and host defences, which makes infections harder to clear [5, 6]. This matters for patients with urological disorders, who may undergo instrumentation and suffer recurrent infection, because biofilm-producing bacteria could keep an infection going despite conventional treatment.

Among individual groups, CoNS had a high rate (87.5%). CoNS are increasingly seen as true opportunistic pathogens and not merely contaminants, and biofilm lets them attach to indwelling devices and sustain hospital-associated infection [18]. Nearly three-quarters of *S. aureus* isolates (73.2%) formed biofilm, in keeping with the known ability of the species to do so and to persist in clinical settings [6]. The 83.3% rate in *P. aeruginosa* is also expected for a recognised biofilm former, and biofilm-associated infections tend to be chronic and hard to eradicate [5].

Over half of the *Klebsiella* isolates (57.5%) were positive, consistent with a role for biofilm in the persistence of this genus. Biofilm is only one part of its virulence, which also includes capsule, adhesion and iron acquisition [9].

Both *E. coli* isolates formed biofilm, but with only two isolates this must be interpreted cautiously. It is nonetheless plausible, given the many adhesion and colonisation mechanisms of uropathogenic *E. coli* [2, 10]. None of the six *Enterobacter* isolates formed biofilm on Congo red agar; this describes the isolates tested and does not mean that the genus cannot form biofilm.

4.3 Motility, coagulase production and haemolysis

Motility was uncommon overall (14.1%) but was universal among *Enterobacter* spp., *S. marcescens*, *E. coli* and *P. aeruginosa*, and absent from *Klebsiella* spp., *S. aureus* and CoNS. This matches the expected properties of these organisms: *Klebsiella* is characteristically non-motile, and *P. aeruginosa* is typically motile. Motility can help bacteria reach favourable niches and aid colonisation and persistence; uropathogenic *E. coli*, for example, uses flagella together with other virulence structures in the urinary tract [2, 10].

Coagulase was present in all *S. aureus* isolates and absent from every other group, which fits its standard use for identifying *S. aureus*. Coagulase is also a virulence factor, helping the bacterium to shield itself from host defences through interaction with the plasma clotting system [7]. The result therefore both supports the identification of the isolates and shows an established virulence phenotype among them.

Haemolysis was found in 21.8% of isolates, β -haemolysis being more frequent than α -haemolysis. Haemolysins can damage host cells and may release nutrients for the bacterium. Haemolysis was seen in all CoNS, *E. coli* and *P. aeruginosa* isolates, but it should be interpreted trait by trait: its presence does not establish greater clinical severity, and its absence does not rule out pathogenicity.

This applies especially to *Klebsiella* spp., none of which was haemolytic yet which has other virulence mechanisms, including capsule, siderophore-mediated iron uptake, adhesion and biofilm formation [9].

4.4 Limitations

Several limitations apply. The study was cross-sectional and descriptive, and differences between hospitals were not tested statistically. Biofilm was assessed qualitatively on Congo red agar, a method designed for staphylococci [12]; a quantitative assay, such as the microtitre plate method, would be more informative, particularly for Gram-negative isolates. Numbers were small for some species (two *E. coli* and six each of *Enterobacter* spp., *S. marcescens* and *P. aeruginosa*), which limits inference. Phenotypes were not linked to clinical variables such as catheterisation or recurrence, and the genetic basis of the traits was not examined.

5. Conclusion

Bacterial isolates from patients with urological disorders differed in frequency across the three tertiary hospitals in Port Harcourt. *Klebsiella* spp. was the leading organism, and other opportunistic pathogens showed facility-specific patterns. From the results, it was observed that biofilm-formation was the most virulence phenotypic trait, motility behaviours, coagulase-production and haemolysis were amongst other notable traits observed. These findings suggest that the isolates have traits that favour colonisation and persistence, especially in healthcare-associated and recurrent infection. Hospital-specific microbiological surveillance should be strengthened, with particular attention to biofilm-producing and other potentially persistent isolates; virulence phenotypes should be characterised routinely alongside identification; and the management of urinary devices and infection-prevention measures should be reinforced. Future work should include quantitative biofilm assays and molecular analysis of the genes underlying the phenotypes observed.

References

1. Foxman B. Urinary tract infection syndromes: occurrence, recurrence, bacteriology, risk factors, and disease burden. *Infect Dis Clin North Am.* 2014;28(1):1-13.
2. Flores-Mireles AL, Walker JN, Caparon M, Hultgren SJ. Urinary tract infections: epidemiology, mechanisms of infection and treatment options. *Nat Rev Microbiol.* 2015;13(5):269-84.
3. Iregbu KC, Nwajiobi-Princewill PI. Urinary tract infections in a tertiary hospital in Abuja, Nigeria. *Afr J Clin Exp Microbiol.* 2013;14(3):169-73.
4. Onoh RC, Umeora OUJ, Egwuatu VE, Ezeonu PO, Onoh TJP. Antibiotic sensitivity pattern of uropathogens from pregnant women with urinary tract infection in Abakaliki, Nigeria. *Infect Drug Resist.* 2013;6:225-33.
5. Vestby LK, Grønseth T, Simm R, Nesse LL. Bacterial biofilm and its role in the pathogenesis of disease. *Antibiotics (Basel).* 2020;9(2):59.
6. Hall CW, Mah TF. Molecular mechanisms of biofilm-based antibiotic resistance and tolerance in pathogenic bacteria. *FEMS Microbiol Rev.* 2017;41(3):276-301.
7. Foster TJ. The staphylococcal coagulases: virulence factors in *Staphylococcus aureus* infection. *Future Microbiol.* 2020;15:1099-107.
8. Tong SYC, Davis JS, Eichenberger E, Holland TL, Fowler VG Jr. *Staphylococcus aureus* infections: epidemiology, pathophysiology, clinical manifestations, and management. *Clin Microbiol Rev.* 2015;28(3):603-61.

9. Paczosa MK, Mecsas J. *Klebsiella pneumoniae*: going on the offense with a strong defense. Microbiol Mol Biol Rev. 2016;80(3):629-61.
10. Terlizzi ME, Gribaudo G, Maffei ME. Uropathogenic *Escherichia coli* (UPEC) infections: virulence factors, bladder responses, antibiotic, and non-antibiotic antimicrobial strategies. Front Microbiol. 2017;8:1566.
11. Cheesbrough M. District laboratory practice in tropical countries, Part 2. 2nd ed. Cambridge: Cambridge University Press; 2006.
12. Freeman DJ, Falkiner FR, Keane CT. New method for detecting slime production by coagulase-negative staphylococci. J Clin Pathol. 1989;42(8):872-4.
13. Robinson VK, Akani NP, Amadi LO, Wemedo SA. Phenotypic determination of virulence attributes of *S. aureus* and *P. aeruginosa* isolated from clinical specimens in Port Harcourt, Rivers State. J Adv Microbiol Res. 2023;4(2):38-44.
14. Kabugo D, Kizito S, Ashok DD, Kiwanuka J, Nabimba R, Namunana S, et al. Factors associated with community-acquired urinary tract infections among adults attending assessment centre, Mulago Hospital, Uganda. Afr Health Sci. 2016;16(4):1131-42.
15. Derbie A, Hailu D, Mekonnen D, Abera B, Yitayew G. Antibigram profile of uropathogens isolated at Bahir Dar Regional Health Research Laboratory Centre, Northwest Ethiopia. Pan Afr Med J. 2017;26:134.
16. Gajdács M, Ábrók M, Lázár A, Burián K. Comparative epidemiology and resistance trends of *Klebsiella* spp. isolated from urinary tract infections in outpatients and inpatients. Antibiotics (Basel). 2019;8(4):190.
17. Navon-Venezia S, Kondratyeva K, Carattoli A. *Klebsiella pneumoniae*: a major worldwide source and shuttle for antibiotic resistance. FEMS Microbiol Rev. 2017;41(3):252-75.
18. Becker K, Both A, Weißelberg S, Heilmann C, Rohde H. Emergence of coagulase-negative staphylococci. Expert Rev Anti Infect Ther. 2020;18(4):349-66.
19. Davin-Regli A, Lavigne JP, Pagès JM. *Enterobacter* spp.: update on taxonomy, clinical aspects, and emerging antimicrobial resistance. Clin Microbiol Rev. 2019;32(4):e00002-19.
20. Mahlen SD. *Serratia* infections: from military experiments to current practice. Clin Microbiol Rev. 2011;24(4):755-91.