In-Vitro Antimicrobial Drug Susceptibility Pattern of Methicillin Resistant Staphylococcus Aureus (MRSA)

Rabia Mubariz, Shahina Yasmin, Shazia Taj, Tariq Butt, Ayesha Ellahi*, Uzma Mussarat**

Islamic International Medical College, Rawalpindi, Pakistan *National University of Medical Sciences (NUMS), Rawalpindi, Pakistan, **Islamic International Dental College Islamabad, Pakistan

ABSTRACT

Objective: To determine the in-vitro antimicrobial susceptibility pattern of Methicillin-resistant Staphylococcus aureus (MRSA) isolates using an automated VITEK-2 compact system.

Study Design: Cross-sectional study.

Place and Duration of Study: Pakistan Railway Hospital (PRH) Rawalpindi collaborates with the Armed Forces Institute of Pathology (AFIP) Rawalpindi, from Sep 2018 to Aug 2019.

Methodology: 100 MRSA samples were isolated from tissue, pus, urine, blood, high vaginal swabs (HVS) and ear swabs using standard microbiological techniques. MRSA isolates' antimicrobial susceptibility pattern was made using an automated VITEK-2 compact system.

Results: Among 100 MRSA isolates, 63% were obtained from pus and 17% from tissue, respectively. MRSA isolates showed 100% sensitivity to Vancomycin, Teicoplanin and Linezolid. Susceptibility to other drugs has shown wide variation, i.e., Tigecycline 97%, Rifampicin 95%, Clindamycin 86%, Tetracycline 79%, and Cotrimoxazole 78%. The minimum inhibitory concentration (MICs) of Vancomycin and Linezolid against MRSA isolates revealed that 41% had 0.5 µg/ml, 46% had one µg/ml, and 13% had two µg/ml for Vancomycin. Whereas for Linezolid, 38 isolates had MIC 1 µg/ml, then 62 isolates had MIC 2 µg/ml.

Conclusion: All the isolates showed 100% sensitivity to Vancomycin, Teicoplanin and Linezolid. Moreover, being less costly, Clindamycin, Tetracycline and Cotrimoxazole are good oral choices for empirical therapy against minor MRSA infections.

Keywords: Antibacterial agents, Automated vitek-2 compact, Linezolid, MRSA, Minimum inhibitory concentration, Vancomycin.

How to Cite This Article: *Mubariz R, Yasmin S, Taj S, Butt T, Ellahi A, Mussarat U. In-Vitro Antimicrobial Drug Susceptibility Pattern of Methicillin Resistant Staphylococcus Aureus (Mrsa). Pak Armed Forces Med J 2022; 72(2): 662-667. DOI: https://doi.org/10.51253/pafmj.v72i2.7083*

INTRODUCTION

Staphylococcus aureus is a gram-positive bacterium ubiquitous in the environment and is expected in the human body on the surface of the skin and in the upper respiratory tract mucosa.[1] It is responsible for skin, mucous membranes and fatal invasive infections, including septicemia, necrotizing pneumonia, endocarditis, urinary tract infections and septicemia.[2]

MRSA is a clinical isolate of Staphylococcus aureus, showing in-vitro resistance to Methicillin and all betalactams drugs. In the 1960s, this strain emerged in health care settings known as hospital-acquired MRSA (HA-MRSA). Later in the 1990s, another strain responsible for causing severe skin infections known as community-acquired MRSA (CA-MRSA) initially appeared in the United States and emerged world-wide.[3]

The resistance to penicillin develops due to the production of Penicillinase by the microorganism that hydrolyzes the beta ring of antimicrobials. In the 1950s, this Penicillin resistance has led to the development of other antimicrobials, including Erythromycin, Chloramphenicol, and Tetracycline.[4] The emergence of MRSA was accompanied by the development of resistance to most of these newly developed non beta-lactam antimicrobials involving different mechanisms.[5]

MRSA expresses resistance to Methicillin when the previously susceptible strain acquires the mecA gene in the Staphylococcal cassette chromosome (SCCmec) that codes for penicillin-binding protein-2a (PBP2a) with low affinity for beta-lactam antibiotics such as Penicillin, Cephalosporin and Carbapenems.[6]

In the 1990s, MRSA and Vancomycin-resistant Enterococci (VRE) showed multidrug resistance and became a severe global challenge for clinicians. Feasibly, the development of newer antimicrobials to treat MRSA infections has improved the situation. However, the cause of concern of Vancomycin-resistant Staphylococcus aureus (VRSA) may develop from Enterococcus faecalis by transferring the VanA gene encoding for high-level glycoprotein.[7]

Correspondence: Dr Rabia Mubariz, Lecturer Pathology, Islamic International Medical College, Rawalpindi, Pakistan

Received: 13 Jul 2021; revision received: 18 Jul 2021; accepted: 19 Jul 2021

Health care personnel (HCP) play a vital role in the epidemiology and pathogenesis of MRSA. Since they act as a bridge for transmission of infection between hospital and community due to poor infection control practices, especially through colonized hands.[8]

At present, multi-drug resistant (MDR) 'superbug' MRSA isolates are a cause of concern because they will demand the development of new and more expensive agents for treating these infections. The competent way to stop the healing crisis is by performing well planned regular periodic studies to evaluate the current susceptibility patterns. It will help select empirical the-rapy resulting in better and cost-effective treatment of minor MRSA infections, ultimately preventing the development of early resistance to Vancomycin, Teicoplanin and Linezolid, which are considered drugs of choice, particularly for critically ill patients of MRSA infections globally. There is a high variance of MRSA prevalence in different countries and regions.

METHODOLOGY

This cross-sectional study was carried out at the Microbiology section of the Pathology Department, Pakistan Railways Teaching Hospital (PRH) in collaboration with the Microbiology section of the Pathology Department, Armed Forces Institute of Pathology (AFIP), Rawalpindi, with the approval of Ethical Review Committee of Islamic International Medical College (Ref # Riphah/IIMC/ERC/18/0281) (Appl # Riphah/ERC/18/0303). The duration of the study was one year, from September 2018 to August 2019. The sample size was calculated using the WHO sample size calculator, taking a confidence level of 95%, margin of error as 6%, and reported prevalence of 10%.

Inclusion Criteria: Consecutive MRSA samples isolated from clinical specimens (blood, tissue, urine, high vaginal swabs (HVS), pus and ear swabs) irrespective of age and gender were included in the study.

Exclusion Criteria: Duplicate samples and patients taking antibiotics before specimen collection were excluded from the study. Consecutive

Blood agar and MacConkey agar were used for inoculation. All the samples were incubated at 37°C for 24 hours, and in case of non-sufficient growth, the culture plates were re-incubated for another 24 hours. Microscopic morphology was done by gram staining and standard biochemical tests like Catalase test, Coagulase test (test tube method) and DNase test. Methicillin resistance was detected by disc diffusion method using 30µg Cefoxitin disc and Oxacillin minimal inhibitory concentration (MIC) using an automated Vitek 2 Compact System. All MRSA isolates were stored in brain heart infusion (BHI) broth with 15% Glycerol at -20˚C for a more extended period as MICs were run in batches using an automated VITEK 2 compact system. Thawing of preserved MRSA isolates was done at room temperature. All the isolates were subcultured on Blood agar and MacConkey agar plates incubated at 35–37°C for 12-48 hours. Antibiotic susceptibility testing (AST) and minimum inhibitory concentrations (MICs) were done by using an automated VITEK 2 Compact system with gram-positive AST cards containing the dehydrated form of Gentamicin, Tobramycin, Levofloxacin, Moxifloxacin, Erythromycin, Clindamycin, Linezolid, Teicoplanin, Vancomycin, Tetracycline, Tigecycline, Fusidic Acid, Rifampicin and Cotrimoxazole according to the Clinical and Laboratory Standards Institute (CLSI) recommended breakpoints.

Statistical Package for Social Sciences (SPSS) version 21.0 was used for the data analysis. For qualitative variables (gender of the patient, type of samples, organisms isolated, ward, antimicrobial susceptibility and their MICs), frequencies and percentages were calculated. Descriptive continuous variable of age was calculated in terms of Mean ± SD.

RESULTS

Out of one hundred MRSA isolates, 53% were recovered from male patients and 47% from female patients. According to the age group, the patients' highest range was recovered from 20-39 years of age group (40%), and the lowest range was recovered from 1-19 years of age group (12%).

Table-I: Distribution of isolated MRSA in different samples from various wards.

Wards	Specimens				
	Pus	Tissue	Blood	HVS	Ear swab
Surgery (n=52)	40 (80.7%)	12(23%)	-	-	-
Orthopaedics (n=24)	19 (79.1%)	5 (20.8%)	-	-	-
Medicine (n=5)	1(20%)	-	4(80%)	-	-
Paediatrics (n=6)	1 (16.7%)	-	5(83.3%)	-	-
Gynaecology (n=10)	2(20%)	-	-	8(80%)	-
ENT (n=3)	-	-	-	-	3(100%)
Total (n=100)	63 (63%)	17 (17%)	9(9%)	8(8%)	3(3%)

Most MRSA isolates were recovered from the Surgery ward (52%), followed by Orthopaedics (24%) and the Gynaecology ward (10%). The distribution of isolated MRSA in different specimens from various wards

was presented in the Table-I. Out of the samples, the highest percentages of isolates were from pus (63%), followed by tissue (17%) and blood specimens (9%). Antibiotic sensitivity testing by automated Vitek-2 compact system for MRSA showed that all the isolates (100%) were sensitive to Vancomycin, Teicoplanin, and Linezolid, followed by a wide susceptibility variation to other antimicrobials as shown in the Table-II.

The maximum resistance was observed against Erythromycin (75%). As per CLSI recommendations, the susceptibility for Vancomycin and Linezolid was confirmed by MIC testing using an automated Vitek-2 compact system.

Table-III and Table-IV displayed the MICs of

Table-II: Antibiogram of MRSA isolated from different body specimen against selected antibiotics.

Antibiotics	Pus		Tissue		Blood		HVS		Ear swab		Average %	
	S	R	S	R	S	R	S	R	S	R	S	R
GEN	32 (54.2%)	27 (45.7%)	8 (53.3%)	7 (46.6%)	8 (100%)	-	2 (40%)	3 (60%)	2 (66.6%)	1 (33.3%)	57	43
TOB	31 (65.9%)	16 (34%)	7 (50%)	7 (50%)	7 (87.5%)	1 (12.5%)	4 (57.1%)	3 (42.8%)	1 (33.3%)	2 (66.6%)	63	36
LEVO	22 (34.9%)	41 (65%)	5 (29.4%)	12 (70.5%)	4 (44.4%)	5 (55.5%)	1 (12.5%)	7 (87.5%)	2 (66.6%)	1 (33.3%)	34	66
MOX	20 (52.6%)	18 (47.3%)	5 (62.5%)	3 (37.5%)	4 (57.1%)	1 (12.5%)	1 (100%)	-	2 (100%)	-	59	40
E	15 (23.8%)	48 (76.1%)	5 (29.4%)	12 (70.5%)	2 (22.2%)	7 (77.7%)	1 (12.5%)	7 (87.5%)	2 (66.6%)	1 (33.3%)	25	75
DA	52 (82.5%)	11 (17.4%)	15 (88.8%)	2 (11.7%)	8 (88.8%)	1 (11.1%)	8 (100%)	-	3 (100%)	-	86	14
LZ	63 (100%)	-	17 (100%)	-	9 (100%)	-	8 (100%)	-	3 (100%)	-	100	-
TEC	63 (100%)	-	17 (100%)	-	9 (100%)	-	8 (100%)	-	3 (100%)	-	100	-
VAN	63 (100%)	-	17 (100%)	-	9 (100%)	-	8 (100%)	-	3 (100%)	-	100	-
TET	49 (77.7%)	14 (22.2%)	15 (88.2%)	2 (11.7%)	8 (88.8%)	1 (11.1%)	5 (62.5%)	3 (37.5%)	2 (66.6%)	1 (33.3%)	79	21
TGC	62 (98.4%)	1 (1.5%)	17 (100%)	-	8 (88.8%)	1 (11.1%)	8 (100%)	-	2 (66.6%)	1 (33.3%)	97	3
FUS	36 (57.1%)	27 (42.8%)	13 (76.4%)	4 (23.5%)	6 (66.6%)	3 (33.3%)	8 (100%)	-	1 (33.3%)	2 (66.6%)	64	36
RIF	59 (93.6%)	4 (6.3%)	16 (94.1%)	1 (5.8%)	9 (100%)	-	8 (100%)	-	3 (100%)	-	95	5
COT	49 (77.7%)	14 (22.2%)	12 (70.5%)	5 (29.4%)	8 (88.8%)	1 (11.1%)	8 (100%)	-	1 (33.3%)	2 (66.6%)	78	22

R: Resistance, S: Sensitive, GEN (Gentamicin), TOB (Tobramycin), LEVO (Levofloxacin), MOXI (Moxifloxacin), E (Erythromycin), DA (Clindamycin), LZ (Linezolid), TEC (Teicoplanin), VAN (Vancomycin), TET(Tetracycline), TGC (Tigecycline), FUS (Fusidic acid) and RIF (Rifampicin), COT (cotrimoxazole).

Table-III: The MICs of selected antibiotics for isolated MRSA.

Antibiotics	Minimum Inhibitory Concentration (µg/ml)									Cut off Value
	0.12	0.25	0.5	1	2	4	8	16	32	
	No. of Isolates									
Gentamicin	-	-	49	-	-	-	24	27	-	0.5-16
Tobramycin	-	-	-	42	-	9	19	30	-	1-16
Levofloxacin	9	17	-	7	-	52	15	-	-	0.12-8
Moxifloxacin	-	25	8	47	15	5	-	-	-	0.25-8
Erythromycin	-	25	-	3	12	7	53	-	-	0.25-8
Clindamycin	-	100	-	-	-	-	-	-	-	0.25-8
Linezolid	-	-	-	38	62	-	-	-	-	0.5-8
Teicoplanin	-	-	79	8	-	8	5	-	-	0.5-32
Vancomycin	-	-	41	46	13	-	-	-	-	0.5-32
Tetracycline	-	-	-	67	4	8	-	21	-	1-16
Tigecycline	95	-	5	-	-	-	-	-	-	0.12-2
Fusidic Acid	-	-	82	13	-	-		-	9	0.5-32
Rifampicin	-	-	49	-	-	-	24	27	5	0.5-32

selected antibiotics for isolated MRSA. The sensitivity of MRSA isolates against Clindamycin was 86% with a maximum MIC of ≥0.25 µg/ml, and the resistance frequency of MRSA isolates was 75% to Erythromycin with a maximum MIC of ≥8 µg/ml.

Table-IV: The MICs of Cotrimoxazole antibiotic for isolated MRSA.

Antibiotic	Minimum Inhibitory Concentration (µg/ml)					Cut off value
	<10	20	40	160	>320	
	No. of isolates					
Cotrimoxazole	48	16	16	9	11	<10 - >320

All MRSA isolates were sensitive to Linezolid (100%, MICs 1, 2, 4 µg/ml). The isolates were also sensitive to Vancomycin and Teicoplanin (100%) having MICs (0.5, 1, 2 µg/ml) and (0.5, 1,2,4, 8 µg/ml) respectively.

DISCUSSION

In the present study, it was found that Vancomycin, Teicoplanin and Linezolid were the most effective drugs like all MRSA isolates were found to be 100% susceptible to them. A wide variation in susceptibility to other drugs was found.

The increasing frequency of HA-MRSA and CA-MRSA infections has become a burden for both patients and healthcare providers because it is associated with increased morbidity and mortality and overall hospitalization cost.[10]

This study aimed to determine the in-vitro antimi-crobial susceptibility pattern of MRSA and their MICs. The male to female ratio of 1.3:1 found in our study was similar to those observed by Al-zoubi *et al*, and Hussain *et al*,[2,10] While Ullah *et al,* reported a high prevalence in females.[11]

Our study found the highest percentage of MRSA isolates in the 20 to 39 years of age-group. Siddiqui *et al*, have reported almost similar results. (30%).[12] Our results were contrary to Ullah *et al*, who reported the highest percentage in the 50 to 59 years of age group (60.71%).[11] These percentages may vary depending on the study population, patient's immunity, method of specimen collection, duration of the study period, etc.

In the present study, MRSA isolates were mostly yielded from pus. Garoy *et al*, reported different findings. The isolation rate was highest in discharges from wounds and abscesses (100%).[13] The observed variation in the proportion of Staphylococcus aureus isolates has been attributed to differences in study design and study population.

In our study, most isolates were recovered from patients admitted in surgery wards, followed by Orthopaedics, Obstetrics and Gynaecology wards. It is comparable with another study conducted by Garoy *et al*, who reported almost the high prevalence of isolates in the surgical wound, diabetic, and burn patients.[13] This variation may be due to types of skin microbiota, collection procedures of the specimen and the total number of specimens.

The 100% sensitivity of all MRSA isolates to Vancomycin, Teicoplanin and Linezolid found in our study was in line with other studies by Omuse *et al*,[14] Varying results were found by Kejela *et al,* who reported 87.2% sensitivity to Vancomycin.[15] Al-zoubi reported 96.5% sensitivity to Linezolid, followed by Tigecycline at 97% and Rifampicin at 95%.[2]

As recommended by CLSI, the confirmation of susceptibility by MIC testing of all isolates for Vancomycin and Linezolid.[16] In the present study, MICs for Vancomycin against isolated MRSA did not fall into the Vancomycin-resistant category according to CLSI. Almost the same results have been reported by Cervera *et al*,[17] No Vancomycin intermediate Staphylococcus aureus (VISA) or Vancomycin-resistant Staphylococcus aureus (VRSA) strain of MRSA was isolated during our study period.

The Clindamycin sensitivity results similar to our study were reported by Omuse *et al*, as 80%.[14] Similarly, Kejela *et al,* reported sensitivity to Tetracycline and Cotrimoxazole of about 66% and 82.1%, respectively.[15] Although MRSA sensitivities vary worldwide, Clindamycin, Tigecycline or Cotrimoxazole are still the effective oral empirically therapy against MRSA infections.[18]

The Studies by Hussain *et al,* reported 70% resistance to Levofloxacin, and Ullah *et al,* reported 80% resistance to Quinolones.[10,11] The resistance to Erythromycin was high in our study (75%). Similar findings have been reported by Hussain *et al.* (69.10%).[10] These percentages might be observed due to different factors like age, immune status, site of infection, the severity of the infection and geographical variation.

This study made an effort to use a quick and precise automated VITEK 2 compact system (V2C) version: 08.01 for antimicrobial drug susceptibility and interpretation of their MIC based on Clinical Laboratory Standard Institute (CLSI) guidelines. It was inten-

ded to know the resistance patterns of MDR MRSA pathogens as they have become a significant problem in hospitals, causing nosocomial infections.

The VITEK-2 compact system is one of the most widely used automated antimicrobial susceptibility testing systems.[19] It combines several advantages that may be of clinical interest for routine testing of Staphylococcus aureus isolated from clinical samples like rapid identi-fication, a simple methodology, a high level of automa-tion and taxonomically updated databases. Other stu-dies have shown that rapid iden-tification and suscep-tibility testing results in earlier switches in antibiotic therapy, narrowing the spectrum and reducing total antibiotic consumption. This will help control the sp-read of MRSA infections by making timely decisions and their application.

To overcome the threat of developing early resistance against available drugs of choice, active surveillance of local MRSA isolate's antimicrobial susceptibility patterns should be regularly done. Effective empirical therapy should be formulated for the rational use of antimicrobials. Other measures like institutional drug policy, antibiotic stewardship and good infection control practices should be promoted.

Our study showed that the irrational use of antimicrobials against MRSA infections leads to the development of early resistance to effective and low-cost drugs available for minor MRSA infections. This study shows a rapid identification and susceptibility pattern testing technique by using an automated VITEK-2 Compact system that may help in the early selection and switching of antibiotics treatment to decrease the total cost. All MRSA isolates were sensitive to drugs of choice Vancomycin, Teicoplanin and Linezolid. So, these drugs are still preserved for critically ill patients with MRSA infections. Clindamycin and Tigecycline show better sensitivity, and Cotrimoxazole is a good choice against MRSA infections in non-critically ill patients.

STUDY LIMITATIONS

Our study was conducted in the laboratory on clinical samples and had no connection with the clinical results. Some information such as clinical history, previous antibiotics use, duration of patient stay in the hospital and outcome of the therapy were missing.

Due to limited resources, isolates were recruited from only two centres, namely AFIP and PRH Rawalpindi. A multicenter study should involve all leading hospitals in the city to establish MDR patterns in MRSA pathogens. Despite this, our study will help doctors in our locale decide on antimicrobial options for treating infectious diseases.

CONCLUSION

All the isolates showed 100% sensitivity to Vancomycin, Teicoplanin and Linezolid. Moreover, being less costly, Clindamycin, Tetracycline and Cotrimoxazole are good oral choices for empirical therapy against minor MRSA infections.

Conflict Of Interest: None.

Author's Contribution

RM:, SY:, TB: Conception, design, analysis, ST:, AE:, UM: Conception, interpretation of data.

REFERENCES

1. Guo Y, Song G, Sun M, Wang J, Wang Y, et al. Prevalence and therapies of antibiotic-resistance in Staphylococcus aureus. Front Cell Infect Microbiol 2020; 10(1): 107.
2. Al-zoubi MS, Al-tayyar IA, Hussein E, Jabali A Al, Khudairat S, et al. Antimicrobial susceptibility pattern of Staphylococcus aureus isolated from clinical specimens in Northern area of Jordan. Iran J Microbiol 2015; 7(5): 265-272.
3. El Amin NM, Faidah HS. Methicillin-resistant Staphylococcus aureus in the western region of Saudi Arabia: prevalence and antibiotic susceptibility pattern. Ann Saudi Med 2012; 32(5): 513-516.
4. Boswihi SS, Udo EE. Methicillin-resistant Staphylococcus aureus: An update on the epidemiology, treatment options and infection control. Curr Med Res Pract 2018; 8(1): 18-24.
5. Asif A, Javed I, Mushtaq S, Anwar S. Nasal carriage of Methicillin resistant Staphylococcus aureus among tertiary care hospital employees in a non-outbreak setting. Pak J Pathol 2017; 28(4):171–175.
6. Gould IM. Clinical activity of anti-Gram-positive agents against methicillin-resistant Staphylococcus aureus. J Antimicrob Chemother 2011; 66(4): 17-21.
7. Gitau W, Masika M, Musyoki M, Museve B, Mutwiri T. Antimicrobial susceptibility pattern of Staphylococcus aureus isolates from clinical specimens at Kenyatta National Hospital. BMC Res Notes 2018; 11(1): 1-5.
8. El Aila NA, Al Laham NA, Ayesh BM. Nasal car-riage of methicillin resistant Staphylococcus aureus among health care workers at Al Shifa hospital in Gaza Strip. BMC Infect Dis 2017; 28(1): 1–7.
9. Spagnolo AM, Orlando P, Panatto D, Amicizia D, Perdelli F, Cristina ML, et al. Staphylococcus aureus with reduced susceptibility to vancomycin in healthcare settings. J Prev Med Hyg 2014; 55(4): 137-144
10. Hussain M, Basit A, Khan A, Rahim K, Javed A, Junaid A, et al. antimicrobial sensitivity pattern of methicillin resistant Staphylococcus aureus isolated from hospitals of Kohat district. Pakistan. J Inf Mol Biol 2013; 1(1): 13-16.
11. Ullah A, Qasim M, Rahman H, Khan J, Haroon M, Muhammad N, et al. High frequency of methicillin-resistant Staphylococcus aureus in Peshawar Region of Pakistan. Springerplus. Springer International Publishing 2016; 5(1): 600
12. Siddique SG, Bhalchandra MH, Wyawahare AS, Bansal VP, Mishra JK, Naik SD, et al. Prevalence of MRSA, ESBL and Carbapenemase producing isolates obtained from endotracheal and tracheal tubes secretions of ICU patient at tertiary care centre. Int J Curr Microbiol App Sci 2017; 6(4): 288-299.
13. Garoy EY, Gebreab YB, Achila OO, Tekeste DG, Kesete R, Ghirmay R, et al. Methicillin-Resistant Staphylococcus aureus (MRSA): Prevalence and antimicrobial sensitivity pattern among Patients-A Multicenter Study in Asmara, Eritrea. Can J Infect Dis Med Microbiol 2019; 2019(1): 8321834.

14. Omuse G, Kabera B, Revathi G. Low prevalence of methicillin resistant Staphylococcus aureus as determined by an automated identification system in two private hospitals in Nairobi , Kenya : a cross sectional study. BMC Infect Dis 2014; 14(1): 1-6.
15. Kejela T, Bacha K. Prevalence and antibiotic susceptibility pattern of methicillin-resistant Staphylococcus aureus (MRSA) among primary school children and prisoners in Jimma Town, Southwest Ethiopia. Ann Clin Microbiol Antimicrob 2013; 12(1): 1-11.
16. Siddiqui T, Muhammad IN, Khan MN, Naz S, Bashir L, Sarosh N, et al. MRSA: Prevalence and susceptibility pattern in health care setups of Karachi. Pak J Pharm Sci 2017; 30(6): 2417-2421.
17. Cervera C, Castañeda X, de la-Maria CG, del Rio A, Moreno A, Soy D, et al. Effect of vancomycin minimal inhibitory concentration on the outcome of methicillin-susceptible Staphylococcus aureus endocarditis. Clin Infect Dis 2014; 58(12): 1668-1675.
18. Ruzbahani M, Rahdar HA, Babaei Z, Rezaeyan MH, Jafari M, Identification of antibiotic resistance patterns of methicillin-resistant Staphylococcus aureus isolates from patients in selected hospitals in Isfahan. Glob J Med Res Stud 2014; 1(2): 37-40.
19. De-Angelis G, Posteraro B, Menchinelli G, Liotti FM, Spanu T, Sanguinetti M, et al. Antimicrobial susceptibility testing of pathogens isolated from blood culture: a performance comparison of Accelerate Pheno™ and VITEK® 2 systems with the broth microdilution method. J Antimicrob Chemother 2019; 74(1): 24-31.