Research Article

Prevalence of \(bla_{\text{NDM}}\), \(bla_{\text{PER}}\), \(bla_{\text{VEB}}\), \(bla_{\text{IMP}}\), and \(bla_{\text{VIM}}\) Genes among Acinetobacter baumannii Isolated from Two Hospitals of Tehran, Iran

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Background and Objectives. The aim of this study was to determine the frequency of \(bla_{\text{NDM}}\), \(bla_{\text{PER}}\), \(bla_{\text{VEB}}\), \(bla_{\text{IMP}}\), and \(bla_{\text{VIM}}\) type genes among \(A.\) baumannii isolates from hospitalized patients in two hospitals in Tehran, Iran. Patients and Methods. Antibiotic susceptibility tests were performed by Kirby-Bauer disc diffusion and Broth microdilution methods. The frequency of MBL (metallo-beta-lactamase) and ESBL (extended-spectrum-beta-lactamase) producers was evaluated by CDDT. The \(\beta\)-lactamases genes were detected by PCR and sequencing methods. Results. The resistance of \(A.\) baumannii isolates against tested antibiotics was as follows: 103 (95.4%) to ceftazidime, 108 (100%) to cefotaxime, 105 (95.7%) to cefepime, 99 (91.7%) to imipenem, 99 (91.7%) to meropenem, 87 (80.6%) to amikacin, 105 (97.2%) to piperacillin, 100 (92.6%) to ciprofloxacin, 103 (95.4%) to piperacillin/tazobactam, 44 (40.7%) to gentamicin, 106 (98.1%) to ampicillin/sulbactam, 106 (98.1%) to co-trimoxazole, 87 (80.6%) to tetracycline, and 1 (1.8%) to colistin. Using combined disk diffusion test, 91 (84.2%) and 86 (86.86%) were ESBL and MBL producers, respectively. The prevalence of \(bla_{\text{PER}}\), \(bla_{\text{VEB}}\), \(bla_{\text{IMP}}\), and \(bla_{\text{VIM}}\) genes was 71 (78.03%), 36 (39.5%), 3 (3.48%), and 15 (17.44%), respectively. Conclusions. The prevalence of ESBLs and MBLs-producing \(A.\) baumannii strains detected in this study is a major concern and highlights the need of infection control measures.

1. Background

Multidrug-resistant bacterial strains have emerged as the causes of nosocomial infections worldwide. Recently, pandrug-resistant (PDR) bacterial strains, which are resistant to all antibacterial agents except the polymyxins and tigecycline, and extensively drug-resistant (XDR) bacterial strains, which are resistant to all antibacterial agents, were isolated from hospital-acquired infections. There is a huge risk of these “superbugs” extending into the community and threatening public health [1]. \(A.\) baumannii is an important cause of nosocomial infections and a leading cause of mortality and morbidity among hospitalized patients and has been associated with a wide variety of diseases in hospitalized patients in the intensive care units (ICU) [2]. Nowadays, increasing drug resistant rate among \(A.\) baumannii strains is a major concern worldwide [3]. The most common mechanism of resistance is the production of \(\beta\)-lactamases, including enzymes of Ambler classes A, D, and B, with their genes being often associated with mobile genetic elements such as plasmids [4]. Carbapenem resistance caused by acquiring the MBLs is considered to be more serious than other resistance mechanisms because MBLs can almost hydrolyse all beta-lactam antibiotics except monobactams [3]. Furthermore, the MBL-encoding genes located on integrons can be disseminated easily from one bacterium to another. Many MBLs have been found in \(A.\) baumannii, including imipenemase (IMP), São Paulo metallo (SPM), Verona integron-encoded metallo-beta-lactamases (VIM), Seoul imipenemase (SIM), Japan, Kyorin University Hospital...
imipenemase (KHM), German imipenemase (GIM), New-Delhi metallo-beta-lactamase (NDM-1), and Australian imipenemase (AIM) [5, 6]. The IMP-type enzymes, first detected in Japan in the late 1980s, have since been reported worldwide in Enterobacteriaceae and in Gram-negative nonfermenters (mostly in P. aeruginosa and Acinetobacter spp.). More than 20 different IMP allotypes have been described, belonging to various sublineages [4]. The different IMP types often have a defined area in the globe, however, some of which (e.g., IMP-1, IMP-4, and IMP-7) were discovered in different areas which their potential for intercontinental dissemination. The VIM-type β-lactamase (Verona integron-encoded metallo-β-lactamases) was first described in a multidrug-resistant P. aeruginosa strain in Italy during the 1990s and has since been reported worldwide. More than 33 different VIM allotypes are described [4].

New-Delhi-metallo-beta-lactamase (NDM-1), a new type of MBL, was first detected in two K. pneumoniae and Escherichia coli strains isolated from a Swedish patient who was admitted to a hospital in New Delhi, India. In recent years, the emergence and dissemination of NDM-1-producing isolates have been reported in several countries, including USA, Canada, Sweden, UK, Austria, Belgium, France, The Netherlands, Germany, Japan, Africa, Oman, and Australia [4]. NDM-producing bacteria are commonly resistant to almost all groups of antibiotics, including fluoroquinolones, aminoglycosides, and β-lactams (especially carbapenems) but are susceptible to colistin and sometimes tigecycline. The blaNDM-1 gene has been detected on different large plasmids, which were readily transferable among bacteria, making NDM-1-producing bacteria a serious clinical and public health threat [7]. Extended spectrum β-lactamases (ESBLs) are a rapidly evolving group of β-lactamase enzymes produced by some bacteria. These enzymes have the ability to hydrolyze cephalosporins and aztreonam but are inhibited by β-lactamase inhibitors such as clavulanic acid [8]. ESBL genes are often located on plasmids and many of them are derived from mutations in TEM (Temoneira) genes and SHV (Sulphhydryl variable) detected by amino acid substitutions around the active site. Apart from TEM and SHV ESBL types, isolates may additionally produce CTX-M (Cefotaximase-Munchen) β-lactamase [8]. Other clinical types include blaKPC, blaVEB, blaPER, blaBEL-1, blaGES-1, blaFOI, blaTIA, and blaHIC [9]. But in recent years, new families of extended-spectrum-beta-lactamases have also emerged all over the world, including PER (for Pseudomonas extended resistance) and VEB (for Vietnamese extended-spectrum-beta-lactamase) families [10].

3. Patients and Methods

3.1. Bacterial Identification. From June 2012 to May 2013, one hundred and eight nonduplicate nonconsecutive isolates of A. baumannii were recovered from blood, wound, urine, sputum, and respiratory tract of patients from 2 hospitals (fifty-eight isolates belonged to Loghman Hakim and fifty isolates to Milad hospitals) in Tehran, Iran. The isolates were identified by conventional biochemical methods [2] and also confirmed for blaOXA-51 gene by PCR.

3.2. Antimicrobial Susceptibility Testing. Antimicrobial susceptibility test to imipenem (IPM: 10 µg), meropenem (MEM: 10 µg), ceftazidime (CAZ: 30 µg), cefotaxime (CTX: 30 µg), amikacin (AK: 30 µg), piperacillin/tazobactam (PTZ: 100/10 µg), piperacillin (PIP, 100 µg), ampicillin (AMP, 10 µg), tetracycline (TE, 10 µg), colistin sulphate (CT, 10 µg), ciprofloxacin (CIP: 5 µg), cefepime (FEP: 30 µg), trimethoprim-sulfamethoxazole (TS, 2.5 µg), and gentamicin (GEN: 10 µg) (Mast, UK) was performed by the Kirby-Bauer disk diffusion method on Mueller Hinton agar (Merck, Germany) based on Clinical Laboratory Standards Institute (CLSI) Guidelines 2012 [11]. Escherichia coli ATCC 25922 was used as the quality control strain.

3.3. Minimum Inhibitory Concentration (MIC). Strains resistant to imipenem, meropenem, ceftazidime, cefepime, cefotaxime, and colistin were rechecked by the broth microdilution method according to the guidelines of the CLSI 2012 [11].

3.4. Phenotypic Detection of MBL. Combined disk diffusion test (CDDT) was performed for identification of MBLs by imipenem and meropenem (Mast Group, Merseyside, UK) alone and in combination with EDTA. An increase in zone diameter of ≥7 mm around the Imipenem+EDTA and Meropenem+EDTA disks compared to that of Imipenem and Meropenem disks alone, respectively, was considered positive for MBL production [12].

3.5. Phenotypic Detection of ESBL. Detection of ESBLs was tested for all the isolates by combination disk diffusion test (CDDT) containing ceftazidime (CAZ) and cefotaxime (CTX) alone and with CAZ 30 µg + clavulanic CA 10 µg and CTX 30 µg + clavulanic CA 10 µg per disc (Mast Group, Merseyside, UK). The zones of inhibition were compared with the CTX and CAZ discs alone and compared with the CAZ 30 µg + clavulanic (CA) 10 µg and CTX 30 µg + CA 10 discs. An increase in zone diameter of ≥5 mm in the presence of clavulanic acid indicated the presence of ESBL in the test organism. Escherichia coli ATCC 25922 and Klebsiella pneumoniae ATCC700603 were used as negative and positive controls for ESBL production, respectively [11].

3.6. DNA Extraction. Total DNAs of the different bacterial isolates were extracted by the DNA extraction kit (Bioneer Company, Korea, Cat. number K-3032-2).

2. Objectives

The aim of this study was to determine the frequency of the blaOXA-51, blaPER, blaVEB, blaIMP, and blaTEM type genes among A. baumannii strains isolated from patients admitted to Loghman Hakim and Milad hospitals, Tehran, Iran, from year 2012 to 2013.
3.7. Detection of bla\text{NDM}, bla\text{PER}, bla\text{VEB}, bla\text{IMP}, and bla\text{VIM} Genes by PCR. PCR was used for screening of the bla\text{NDM}, bla\text{PER}, bla\text{IMP}, bla\text{VIM}, and bla\text{VEB} genes. The primers used for bla\text{NDM}, bla\text{PER}, bla\text{VEB}, bla\text{IMP}, and bla\text{VIM} were as follows: NDM-F (5’-GTGTGGCAGTCTGGTTTTC-3’) and NDM-R (5’-CGGAATGGCCTACACGTGACG-3’) for bla\text{NDM}; PER-F (5’-CTGACACTGCTGCATATCCTG-3’) and PER-R (5’-ATGGTGCCACCGATGAGT-3’) for bla\text{PER}; VEB-F (5’-GGACTTCCATTTCCTCCAGTGC-3’) and VEB-R (5’-GGACCTCTGAAACAAATACGC-3’) for bla\text{VEB}; IMP-F (5’-GGAGGCTGTATTGTCATA-3’) and IMP-R (5’-GTAAGTTCAAGTGATGCA-3’) for bla\text{IMP}; VIM-F (5’-GATGTTGTGTTGCTCGATA-3’) and VIM-R (5’-CGGAATGGCTCATCACGATC-3’) for bla\text{VIM}. The PCR mixture contained the DNA template, forward/reverse primers, and Amplification was carried out with the following thermal cycling conditions: 5 minutes at 94°C, 45 cycles of amplification consisting of 1 minute at 94°C, 1 minute at 56°C, and 1 minute at 72°C, with 5 minutes at 72°C for the final extension. PCR product bands were analyzed after electrophoresis on a 1% agarose gel at 95 V for 45 minutes in 1X TBE containing ethidium bromide and the result was checked under UV irradiation.

3.8. Sequencing Method. The PCR purification kit (Bioneer Co., Korea) was used to purify PCR products and sequencing was performed by the Bioneer Company (Korea). The nucleotide sequences were analyzed with the Chromas 1.45 software and the BLAST program from the National Center for Biotechnology Information website (http://www.ncbi.nlm.nih.gov/BLAST).

3.9. Statistical Analysis. This research was a descriptive-application study. MINITAB16 software was used for statistical analyses. The P value and confidence of intervals were <0.05 and 95%, respectively.

4. Results

Fifty-eight strains were isolated from Loghman Hakim Hospital (53.7%) and fifty from Milad Hospital (46.29%). Fifty-one strains were isolated from female patients (47.2%) and fifty-seven from males (52.8%). Of the 108 isolates, 29 (26.9%) were isolated from urine, 4 (3.7%) from wound, 57 (52.8%) from tracheal tube, 8 (7.4%) from blood, 8 (7.4%) from pleural fluid, and 2 (1.9%) from other samples. The age range of the patients was 1 to 90 years. The isolates were obtained from patients in different age groups: 2–29 years (n = 10), 30–39 (n = 14), 40–49 years (n = 21), 50–59 years (n = 16), 60–69 (n = 24), and 70–79 years (n = 17), and six isolates were isolated from patients of more than eighty years of age. The resistance of A. baumannii isolates to tested antibiotics was 108 (100%) to cefotaxime, 103 (95.4%) to ceftazidime, 99 (91.7%) to meropenem, 99 (91.7%) to imipenem, 44 (40.7%) to gentamicin, 87 (80.6%) to amikacin, 100 (92.6%) to ciprofloxacin, 105 (95.7%) to cefepime, 105 (97.2%) to piperacillin, 103 (95.4%) to piperacillin/tazobactam, 106 (98.1%) to ampicillin/sulbactam, 106 (98.1%) to cotrimoxazole, 87 (80.6%) to tetracycline, and 1 (1.8%) to colistin (Table 1). The results of MIC test of different antibiotics on A. baumannii isolates are shown in Table 2. By using the combined disk diffusion test (CDDT), it was found that among 99 imipenem nonsusceptible A. baumannii strains, 86 (86.86%) were MBL producers and out of 108 ceftazidime-nonsusceptible A. baumannii strains, 91 (84.2%) were ESBL producers. The prevalence of bla\text{PER-1} and bla\text{VEB-1} genes among 91 ESBL-producing A. baumannii isolates was 71 (78.03%) and 36 (39.5%), respectively, and for IMP-1 and VIM-1 genes among metallo-beta-lactamase-producing A. baumannii isolates it was 3 of 86 (3.48%) and 15 of 86 (17.44%), respectively. bla\text{OXA-51} has been investigated and was detected in all isolates. Fortunately, bla\text{NDM} gene was not detected in isolates. Sequencing of PCR products showed conserved regions for the restriction sequence bla\text{PER-1}, bla\text{IMP-1}, bla\text{VEB-1}, and bla\text{VIM-1} genes which was confirmed by BLAST in NCBI. The nucleotide sequence data reported in this paper have been submitted to the GenBank sequence database and assigned accession numbers KF723587, KF723588, KF723589, and KF723590 for bla\text{PER-1} gene, KF723586 for bla\text{VEB-1} gene, and KF723585 for bla\text{IMP-1-}

| Antibiotic            | Resistant, number (%) | Intermediate, number (%) | Sensitive, number (%) |
|-----------------------|-----------------------|--------------------------|-----------------------|
| Gentamicin            | 44 (40.7)             | 7 (6.5)                  | 57 (52.8)             |
| Amoxicillin/sulbactam | 106 (98.1)            | 0 (0.0)                  | 2 (1.8)               |
| Amikacin              | 87 (80.6)             | 4 (3.7)                  | 17 (15.7)             |
| Imipenem              | 99 (91.7)             | 3 (2.8)                  | 6 (5.6)               |
| Cefotaxime            | 108 (100)             | 0 (0.0)                  | 0 (0.0)               |
| Cefepime              | 105 (95.7)            | 2 (1.8)                  | 1 (0.9)               |
| Piperacillin          | 105 (97.2)            | 2 (1.8)                  | 1 (0.9)               |
| Ciprofloxacin         | 100 (92.6)            | 1 (0.9)                  | 7 (6.5)               |
| Meropenem             | 99 (91.7)             | 0 (0.0)                  | 9 (8.3)               |
| Piperacillin/tazobactam | 103 (95.4)           | 1 (1.8)                  | 4 (3.7)               |
| Ceftazidime           | 103 (95.4)            | 0 (0.0)                  | 5 (4.7)               |
| Co-trimoxazole        | 106 (98.1)            | 0 (0.0)                  | 2 (1.8)               |
| Tetracycline          | 87 (80.6)             | 9 (8.3)                  | 12 (11.1)             |
| Colistin              | 2 (1.8)               | 0 (0.0)                  | 106 (98.2)            |

| Antibiotics            | Range | MIC\text{50} | MIC\text{90} |
|------------------------|-------|--------------|--------------|
| Meropenem              | 1–256 | 32           | 128          |
| Imipenem               | 2–256 | 128          | 256          |
| Ceftazidime            | 2–512 | 256          | 512          |
| Cefepime               | 1–256 | 64           | 128          |
| Cefotaxime             | 2–512 | 256          | 512          |
| Colistin               | 0.25–128 | ≤1              | 2               |
The sequences of $\text{bla}_{\text{PER-1}}$ gene in $A. \text{baumannii}$ strains isolated from Loghman Hakim hospital were 100% the same but were not similar to the sequences of $\text{bla}_{\text{PER-1}}$ gene in $A. \text{baumannii}$ strains isolated from Milad hospital (http://multalin.toulouse.inra.fr/multalin/multalin.html) (Figure 1).

5. Discussion

$A. \text{baumannii}$ is responsible for hospital-acquired infections and has recently become one of the most important healthcare-associated infections in hospitals. Infection caused by this bacterium often leads to significant mortality and morbidity [13]. Many researchers have reported the outbreak of PDR $A. \text{baumannii}$. Although $A. \text{baumannii}$ is an increasingly common nosocomial pathogen that can cause serious infections in intensive care units [14], resistance rates of isolates were as follows: 103 (95.4%) to ceftazidime, 99 (91.7%) to meropenem, 99 (91.7%) to imipenem, 44 (40.7%) to gentamicin, 87 (80.6%) to amikacin, 100 (92.6%) to ciprofloxacin, 105 (95.7%) to cefepime, 103 (95.4%) to piperacillin/tazobactam, 106 (98.1%) to ampicillin/sulbactam, 106 (98.1%) to cotrimoxazole, 87 (80.6%) to tetracycline, and 1 (1.8%) to colistin. Also, no susceptible isolate to cefotaxime was identified recently and reported from New Delhi, India, for the first time and after that from other countries including Pakistan. The close distance of these countries to Iran and large number of trips between the countries on one side and the ease of resistance transfer among bacteria on the other hand led us to think that it may be probable for our isolates to have the same gene. These kinds of studies are valuable to prevent distribution of resistant bacteria to other parts of the world. Finally, by accurate MBL enzyme screening and further precise supervision of the hospital practitioners it will be possible to control the spread of multidrug resistant $A. \text{baumannii}$ strains and decrease related infections especially in ICU patients. Based on the available data, $A. \text{baumannii}$ are growing to become the most important common ESBL producing bacteria and consequently making their eradication difficult. In this study, 91' (84.2%)
of *A. baumannii* were identified as ESBL producers by phenotypic tests, which was more than Owlia et al.’s study (21%), Farajnia et al.’s study in Iran (70%), and another study in Poland (20%) [15, 21]. The high rate of ESBL prevalence in Iran and its widespread dissemination is cause of worry. In this study, the prevalence of *bla*<sub>PER-1</sub> genes among 91 of ESBL-producing *A. baumannii* isolates was 71 (78.03%). According to the present study PER-1 is the most common ESBL genotype among *A. baumannii* strains which is inconsistent to other studies that showed different prevalence of PER-1. The prevalence of this genotype was reported 51% in Iran, 46% in Turkey and 54.6% in South Korea. Screening for VEB genotype revealed that 36 (39.5%) of *A. baumannii* isolates contained VEB-1 gene. The prevalence of this gene was reported to be 10% in Iran and 47.61% in the USA [10]. The prevalence of β-lactamase-producing isolates and their isolation from life-threatening infections is dramatically increasing worldwide. Intensity pressure for usage of antimicrobial drugs by patients resulted in eradication of normal flora and situation of MDR isolates substitution. This study showed that β-lactamase producing *A. baumannii* strains are an emerging threat in ICUs and should be supervised by implementation of timely identification and strict isolation methods that will help to reduce their severe outcomes and mortality rate of patients.

### Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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