Introduction

Enterococcus species are considered as one of the main nosocomial pathogens in the recent years. The urinary tract infection followed by pelvic and intra-abdominal infections, bacteremia, endocarditis, etc. are among the most common nosocomial infections caused by enterococci. Such bacteria are the second leading cause of urinary tract infection and the third in nosocomial infections. Enterococcus spp. are Gram-positive cocci and the intestinal flora of human and some animals (1,2). Enterococcus species show poor pathogenicity due to lack of powerful toxins and remarkable virulence factors, but since they are intrinsically insensitive to penicillins, aminoglycosides, and glycopeptides,
and show high competence in receiving resistance genes; can transfer antibiotic resistance genes to other bacterial genera and species through mutations and/or receiving genetic elements via plasmids or transposons, Enterococcus spp. can cause severe problems in diagnosis, treatment, and control of the associated infections (3).

Nowadays, the multi-drug resistance and insensitivity of such bacteria to antibiotics is of great importance (4). Glycopeptides-resistant Enterococcus spp. are serious and alarming problem worldwide, which affect patients’ general health. Glycopeptides such as vancomycin and teicoplanin are the selective and usually the last-resort choice for the hospital-acquired multidrug-resistant (MDR) Gram-positive infections (5). Inappropriate administration and indiscriminate use of broad-spectrum beta-lactams, aminoglycosides, and carbapenems as well as long-term hospitalization influence the spread of MDR bacteria (6).

Administration of proper antibiotics should always rely on the antibiotic resistance patterns because the treatment of nosocomial infections caused by such bacteria is very difficult; hence, periodic evaluation of the anti-microbial activity of different antibiotics and understanding the proper drug regimen to treat the infection and control its spread is of great importance because the antibiotic resistance pattern may change within short intervals (7). Transfer of the resistance genes among bacteria via transposons/plasmids, and genetic mutations are among the major causes of the prevalence and spread of antibiotic-resistant bacteria. Since a plasmid or transposon can be the carrier for several resistance elements, resistance to several antimicrobial agents can be acquired simultaneously; it is considered as the reason for the emergence of multidrug-resistant bacteria. Nowadays, increasing multidrug-resistant species and the associated complications are among the great concerns of medical community. Such infections are difficult-to-treat and even in some cases threaten the patients’ lives. In addition, due to long-term hospitalization, the treatment is costly; hence, the infections can be significantly controlled and the prevalence can be remarkably limited by the application of cost-effective methods and hospital hygiene standards, as well as microbiologic methods. Identification of Enterococci resistance patterns to commonly used antibiotics to determine therapeutic policy in the initial encounter and effectiveness of controlling programs are essential (8).

In the recent years, molecular techniques such as polymerase chain reaction (PCR) are developed; such techniques are used to identify enterococci as they are very sensitive and benefit from high speed and specificity, compared with the culturing methods (9). Employment of phenotypic methods parallel to genotypic PCR-based methods can provide reliable data. In the current study, both classic and molecular methods were used to identify genus and species. In addition, the frequency, antibiotic resistance pattern, and the prevalence of multidrug-resistance were also studied in Enterococcus species isolated from nosocomial infections in Tehran, Iran.

**Materials and methods**

**Sampling**

The current descriptive-cross sectional study was conducted on 300 samples including urinary tract, blood, wound infections, as well as ascites and bronchoalveolar lavage (BAL) collected from Baqiatallah, Milad, and some other hospitals in Tehran, 2015.

**Identification of Enterococcus species by phenotypic and genotypic methods**

To identify bacteria isolated from clinical samples, Gram staining method as well as the evaluation of the biochemical characteristics such as catalase reaction, growth in 6.5% NaCl, and bile-esculin hydrolysis were performed. Besides, to identify the bacteria at the species level, the sugar fermentation test (lactose, arabinose, etc.) was conducted using a sugar-based media containing phenol red reagent and incubation at 37°C for 24 hours. All isolations were stored at -70°C in brain heart infusion (BHI) broth plus 50% glycerol until molecular analyses.

Bacterial genome was extracted using boiling methods; then, to confirm *E. faecalis* and *E. faecium*, PCR was amplified using specific primers. PCR reaction was performed in a total volume of 25 µL containing 1 µL DNA pattern (0.2 µg), 1 µL
each of the primers (10 pmol), 12 µL 2X Master mix (purchased from Amplicon III, Denmark including 20 mM dNTP and 1.5 mM MgCl₂), and 11 µL double distilled water. Then, the following PCR program was set using a Eppendorf thermocycler (Hamburg; Germany): early denaturation for 1 minute at 94°C, 35 cycles of denaturation for 1 minute at 94°C, and annealing for 1 minute at 55°C and early extension for 2 minutes at 72°C. The final extension was done for 5 minutes at 72°C. The PCR product was electrophoresed on 1.5% gel agarose in a Gel Documentation (Table 1).

<table>
<thead>
<tr>
<th>Primer</th>
<th>Primer Sequence</th>
<th>Size of the Fragment</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>ddl E. faecalis</td>
<td>F- 5’ ATCAAGTACAGTTAGTCT 3’</td>
<td>941 bp</td>
<td>10</td>
</tr>
<tr>
<td>R- 5’ ACGATTCAAAGCTAACTG 3’</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ddl E. faecium</td>
<td>F- 5’ TAGAGACATTGAATATGCC 3’</td>
<td>550 bp</td>
<td>10</td>
</tr>
<tr>
<td>R- 5’ CTAACATCGTGAAGCT 3’</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Antibiotic profile
The disk diffusion method was used to determine the antibiotic sensitivity pattern of the isolates on Muller-Hinton Agar (Merck), according to the Clinical and Laboratory Standards Institute (CLSI) 2015 guidelines; results were reported as resistant, semi-sensitive, and sensitive for each antibiotic (11).

Vancomycin 30 µg, erythromycin 15 µg, quinupristin / dalfopristin 15 µg, tetracycline 30 µg, ciprofloxacin 5 µg, teicoplanin 30 µg, linzolide 30 µg, fosfomycin 200 µg, chloramphenicol 30 µg, gentamicin 120 µg, ampicillin 10 µg, nitrofurantoin and 300 µg (Mast; UK), as well as E. faecalis ATCC 29212 and E. faecium BM 4147 were used as the quality control species in the current study.

The minimum inhibitory concentration (MIC) for the isolates resistant to vancomycin was conducted based on the microdilution method. The isolation showed resistance to 3 or more antibiotic lines were considered as MDR species.

Results
Out of 300 samples collected in the current study, 140 enterococcus species were identified, which constituted 68% of all urinary tract isolated species (Table 2).

Results of the phenotypic-based identification methods were confirmed by PCR amplification using specific primers; accordingly, out of 140 identified species 125 (89.28%) were E. faecalis and 15 (10.72%) E. faecium (Figure 1).
Antibiotic susceptibility testing

The highest antibiotic resistance in the studied isolates was observed against quinupristin / dalfopristin, followed by tetracycline and erythromycin. Results of antibiogram testing for the current study isolates, according to CLSI guidelines, are shown in Table 3.

Table 3. Results of Antibiotic Susceptibility Testing for the Study Isolates, Based on the Disc Diffusion Method

<table>
<thead>
<tr>
<th>antibiotic</th>
<th>Enterococcus faecalis</th>
<th>Enterococcus faecium</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitive, N (%)</td>
<td>Resistant, N (%)</td>
</tr>
<tr>
<td>Tetracycline</td>
<td>23 (18.88)</td>
<td>102 (81.12)</td>
</tr>
<tr>
<td>Gentamicin</td>
<td>80 (64.51)</td>
<td>23 (18.29)</td>
</tr>
<tr>
<td>Ampicillin</td>
<td>115 (92)</td>
<td>0</td>
</tr>
<tr>
<td>Vancomycin</td>
<td>113(90.04)</td>
<td>9(6.8)</td>
</tr>
<tr>
<td>Fosfomycin</td>
<td>25 (20)</td>
<td>47(37.45)</td>
</tr>
<tr>
<td>Linzolid</td>
<td>116(92.8)</td>
<td>8 (6.27)</td>
</tr>
<tr>
<td>Nitrofurantoin</td>
<td>120 (96)</td>
<td>3 (2.4)</td>
</tr>
<tr>
<td>Ciprofloxacin</td>
<td>38(30.04)</td>
<td>44(35.65)</td>
</tr>
<tr>
<td>Erythromycin</td>
<td>19(15.2)</td>
<td>37(29.6)</td>
</tr>
<tr>
<td>Teicoplanin</td>
<td>119(95.2)</td>
<td>4(3.51)</td>
</tr>
<tr>
<td>Chloramphenicol</td>
<td>85(68)</td>
<td>21(16.8)</td>
</tr>
<tr>
<td>Quinupristin/dalfopristin</td>
<td>11(8.8)</td>
<td>5(4)</td>
</tr>
</tbody>
</table>

Table 4. The Frequency of Multidrug-resistant Enterococcus faecalis and Enterococcus faecium Species Isolated in the Current Study

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of isolates resistant to one or more antibiotics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enterococcus faecalis</td>
<td>3.16% showed resistance to vancomycin. MIC of the isolated species to vancomycin was ≥ 256 µg/mL. All vancomycin-resistant isolates showed MDR; in such a way that 1 vancomycin-resistant Enterococcus faecalis isolate showed resistance to 4 other antibiotics, 1 Enterococcus faecium isolate was resistant to 12 antibiotics, 1 isolate of Enterococcus faecalis was resistant to 7 antibiotics, 1 isolate of Enterococcus faecium was resistant to 9 antibiotics, 3 isolates of Enterococcus faecalis were resistant to 8 antibiotics, and 2 Enterococcus faecalis isolates showed resistance to 6 antibiotics.</td>
</tr>
</tbody>
</table>
researchers showed that although the level of general health enhanced in the communities, the bacterial infections, particularly enterococcal infections, increase, which mainly results from intrinsic resistance of *Enterococcus* spp. to antibiotics and the linear transfer of resistant genes, transposons, and plasmids among enterococci and/or other bacterial genera. Besides, indiscriminate and improper administration of antibiotics is another reason for the spread of antibiotic resistance in different geographical regions. Uncontrolled consumption of broad-spectrum beta-lactams as well as long-term hospitalization influenced the spread of multidrug-resistant bacteria; the treatment of such infections is difficult and may leads to mortality (3, 5, 6).

*Enterococcus faecalis* is the most Enterococcus species isolated from clinical samples in the majority of the studies. In the current study, out of 140 isolated enterococci, 125 (89.28%) were *E. faecalis* and 15 (10.72%) *E. faecium*. In the studies by Dadfarma, Kafil, and Comerlato, most of the clinically isolated species were *E. faecalis*, consistent with the results of the current study (13-15). However, in another study by Bibalan and Oskuie, most of the isolated enterococci were *E. faecium*, inconsistent with the results of the current study; the difference between the results may be attributed to the type of samples and the type of commonly administered antibiotics (16, 17). In the current study, similar to those of Padmasini and Behnood, most of the enterococcal species were isolated from urinary tract samples. The dominance of enterococci among the species isolated from urinary tract samples is another reason for the prevalence of enterococci in the urinary tract infections. The bacterial multidrug-resistance has various frequencies in different countries, which may be attributed to genetic changes in bacterial species, different normal flora, and different antibiotic prescription patterns, as well as different rates of antibiotic consumption in the communities (18, 19).

In the current study, *E. faecalis* isolates showed the highest resistance to tetracycline, quinupristin / dalfopristin, erythromycin, and fosfomycin, respectively. In addition, *E. faecium* isolated species were mostly resistant to tetracycline, ciprofloxacin, erythromycin, and quinupristin / dalfopristin. The results of the current study were similar to those of Seifi and Talebi (20, 21).

In the current study, out of 140 enterococci isolates, 2 isolates (*E. faecalis* and *E. faecium*) were resistant to linzolaide, similar to the results of Yaslan and Bhatt (22, 23). But, in the studies by Kafil, Bibalan, Mahesh, and Wang, all isolated species were sensitive to linzolaide; the difference can be attributed to the type of study, geographical region, type of antibiotic, and the employed methods (14, 16, 24, 25). The resistance to gentamicin and ampicillin in the current study was similar to the results of Tabatabaie and in contradiction with the results of Yadegarynia (26, 27).

According to the results of the current study, resistance to vancomycin in *E. faecalis* and *E. faecium* was 3.16% and 26.68%, respectively. In the studies by Sanal and Tabatabaie, most of the species were sensitive to vancomycin (26, 28). In addition, studies by Hoseini Zadeh and Kafil reported higher levels of resistance to vancomycin, compared with the current study (14, 29).

The emergence of multidrug-resistant *Enterococcus* spp. is critically important and 69.6% of *E. faecalis* and 80% of *E. faecium* species isolated in the current study showed multidrug-resistance. In the studies by Bibalan and Aleyasin, the frequency of MDR species was lower than that of the current study (16 vs. 2 MDR species) (36, 16). Results of the studies by Wang et al. and Sharifi et al., showed that more than 80% and 79% of the enterococci isolates were MDR, respectively (15, 31). In addition, results of the studies by Dadfarma, Behnood, and Deshpande reported 45.7%, 49.59%, and 57% of the isolated enterococci as MDR, respectively (14, 19, 32).

Also, results of the studies by Telkar, Mira, and Mahesh reported the prevalence of MDR species (24, 33, 34).

**Conclusion**

Results of the current study indicated that *E. faecalis* was the most common isolated species in the clinical samples. The majority of enterococcal species were isolated from urinary tract samples. In addition, results of the current study showed that the isolated species of *E. faecalis* were more resistant...
against tetracycline, quinupristin / dalfopristin, erythromycin, and fosfomycin, but *E. faecium* showed more resistance against tetracycline, ciprofloxacin, erythromycin, and quinupristin / dalfopristin. Most of the isolated Enterococcus spp. were resistant against 3 or more antibiotics and accordingly were considered as MDR bacteria. Hence, administration of proper antibiotics based on the results of timely and meticulous antibiogram plays a significant role in the treatment and prevention of the MDR bacteria spread. Accordingly, it is recommended to compile more detailed and distinct instructions for more logical administration of antimicrobial agents and prevent infections, particularly nosocomial infections.

**Acknowledgments**

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