A three-year survey of the antimicrobial resistance of microorganisms at a Chinese hospital

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Abstract. The present retrospective study aimed to investigate the antibiotic susceptibility of bacteria at Shanghai First People's Hospital (Shanghai, China) between 2009 and 2011. An increasing trend of antibiotic resistance was observed in this hospital between 2009 and 2011. *Escherichia coli*, *Acinetobacter baumannii* and *Staphylococcus aureus* were the most prevalent resistant strains. Antimicrobial susceptibility was detected using standard Kirby-Bauer disk diffusion and analyzed using World Health Organization software. *E. coli* was demonstrated to be the most prevalent bacterium in the present survey between 2009 and 2011 (16.2, 20.0 and 19.6%, respectively); followed by *A. baumannii* (13.5, 13.3 and 10.6%, respectively) and *S. aureus*. Notably, >70% of *E. coli* and 70% of *S. aureus* were resistant to common antibiotics; whereas 60% of *A. baumannii* and 20% of *Pseudomonas aeruginosa* were resistant to the majority of the antibiotics investigated. In 2011, *Enterococcus faecalis* exhibited a resistance rate of 55.6% against levofloxacin and *E. faecium* exhibited a 53.2% resistance rate. The present survey demonstrated an increasing trend in bacterial resistance against antibiotics; therefore, more stringent guidelines for antibiotics should be advocated.

Introduction

Surveillance of antibiotic resistance is the most effective method for obtaining accurate data regarding bacterial resistance transitions and epidemiology. This data informs the formulation of guidelines for the use of antibiotics, and helps control the spread of resistant bacteria (1). In recent years, microbial resistance to antibiotics has been increasing, particularly in China (2-5). If this trend continues there will be fewer antibiotics to choose from when treating patients (6,7). Formulating policy for the use of antibiotics and the improved management of patients depends on up-to-date knowledge of the prevalent strains of bacteria in particular locales or regions of a country, and their likely patterns of antibiotic resistance. To this end, in the present retrospective study, enabled by the routine practice of monitoring clinical bacterial isolates and recording corresponding antibiograms, the clinical bacterial profiles of patients were collected and analyzed between 2009 and 2011 at Shanghai First People's Hospital (Shanghai, China). Patterns of antibiotic resistance were determined in order to ascertain an accurate representation of local bacterial resistance and to help improve the efficacy of empirical antibiotic therapy.

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Materials and methods

Clinical survey. The present study retrospectively investigated the antibiotic susceptibility of bacteria between 2009 and 2011 at Shanghai First People's Hospital affiliated with Shanghai Jiaotong University. The study included a total of 5,209 patients (63% male), from whom were collected sputum, blood and wound culture samples. The present study was approved by the ethics committee of Shanghai First People's Hospital. Written informed consent was obtained from all participants.

Bacterial strains and tests for antimicrobial susceptibility. The quality control bacterial strains included *Staphylococcus aureus* (ATCC25923), *Escherichia coli* (ATCC25922), *Pseudomonas aeruginosa* (ATCC27853), *Enterococcus faecalis* (ATCC29212), and *Klebsiella pneumoniae* (ATCC700603; Shanghai Center for Clinical Laboratory, Shanghai, China). Mueller-Hinton agar, which was used for susceptibility testing, and antibiotic susceptibility disks were purchased from Oxoid (Thermo Fisher Scientific Inc., Waltham, MA, USA). Antimicrobial susceptibility testing data were generated as part of a surveillance program conducted by the Shanghai First People's Hospital between 2009 and 2011. Drug susceptibility tests were performed using the Kirby-Bauer antibiotic testing disk diffusion method (8), and the data were interpreted in accordance with the 2010 guidelines outlined by the Clinical and Laboratory Standards Institute (8).

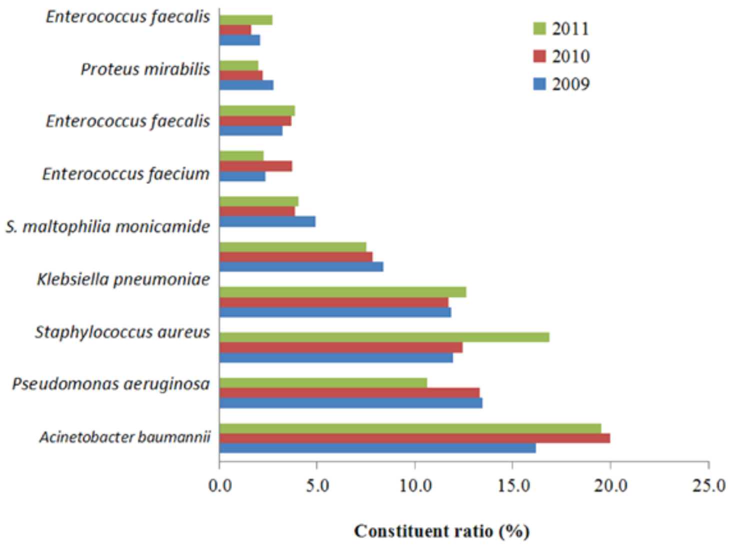

Figure 1. Prevalence of bacterial pathogens at Shanghai First People's Hospital (Shanghai, China) between 2009 and 2011.

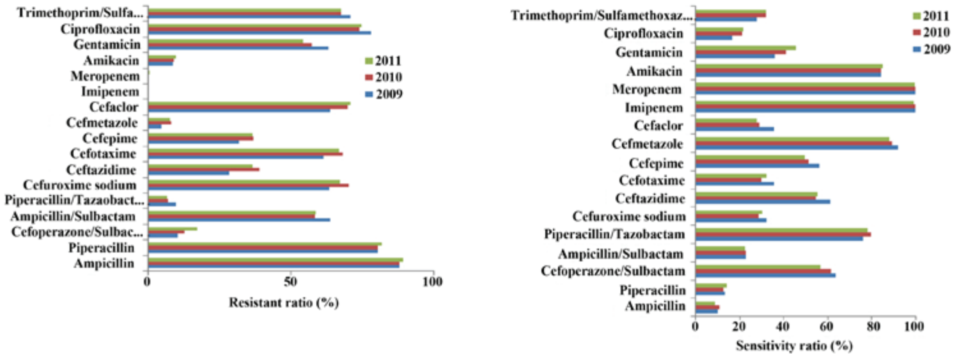

Figure 2. Resistance and sensitivity rates of *Escherichia coli* to penicillins, including ampicillin, piperacillin and ampicillin/sulbactam, cephalosporins and other antibiotics between 2009 and 2011.

Statistical analyses. WHONET 5.5 software, which was provided by the Antimicrobial Resistance Monitoring Center of the World Health Organization (Geneva, Switzerland), was utilized for statistical analyses.

Results

Distribution of the pathogenic bacteria. Between 2009 and 2011, *E. coli* was the most prevalent bacterial pathogen detected in the present hospital, with the following detection rates: 2009, 305/1883 (16.2%); 2010, 346/1730 (20%); 201, 408/2082 (19.6%) (Fig. 1). The next most prevalent was *Acinetobacter baumannii*: 2009, 225/1875 (12.0%); 2010, 216/1728 (12.5); and 2011, 253/1497 (16.9%), and *S. aureus* was the third most prevalent pathogenic bacterium by 2011.

Sensitivity and resistance rates of the bacterial strains

E. coli. Susceptibility testing of *E. coli* indicated >60% resistance against the following antibiotics: Penicillins, including ampicillin, piperacillin and ampicillin/sulbactam; certain cephalosporins, including cefuroxime, cefotaxime and cefaclor; and other antibiotics, including ciprofloxacin, trimethoprim, sulphamethoxazole and gentamicin. Imipenem and meropenem were demonstrated to be the most effective antibiotics against *E. coli*. By 2011, the resistance rate of *E. coli* against meropenem had increased to 0.2% and since then the trend for resistance against imipenem and meropenem has increased, with the susceptibility break point increasing from 14-15 to 20-22 (Fig. 2).

S. aureus. The resistance of *S. aureus* to the most commonly used antibiotics, including: Penicillin, cefazolin, gentamicin, clindamycin, erythromycin and levofloxacin, was demonstrated to be >70%. *S. aureus* exhibited minimal resistance to linezolid, vancomycin and teicoplanin in the three consecutive years (Fig. 3).

A. baumannii. For the majority of the antibiotics investigated, the resistance rates of *A. baumannii* were >60%. Cefoperazone/sulbactam was demonstrated to be the most effective antibiotic treatment against this bacterium; however, its resistance rate increased from 26.1 to 44.6% between 2009 and 2011 (Fig. 4).

P. aeruginosa. For the majority of the antibiotics investigated against *P. aeruginosa,* the resistance rates were ~20%, including cefoperazone/sulbactam and piperacillin, whereas the resistance rates against amikacin were ~10% (Fig. 5).

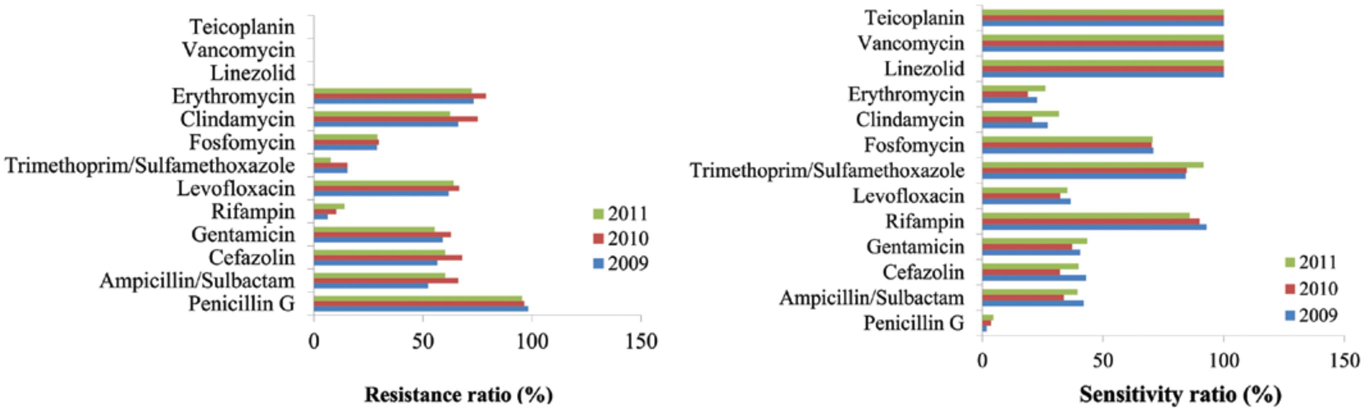

Figure 3. Resistance and sensitivity rates of *Staphylococcus aureus* to common antibiotics: Penicillin, cefazolin, gentamicin, clindamycin, erythromycin, levofloxacin, linezolid, vancomycin and teicoplanin between 2009 and 2011.

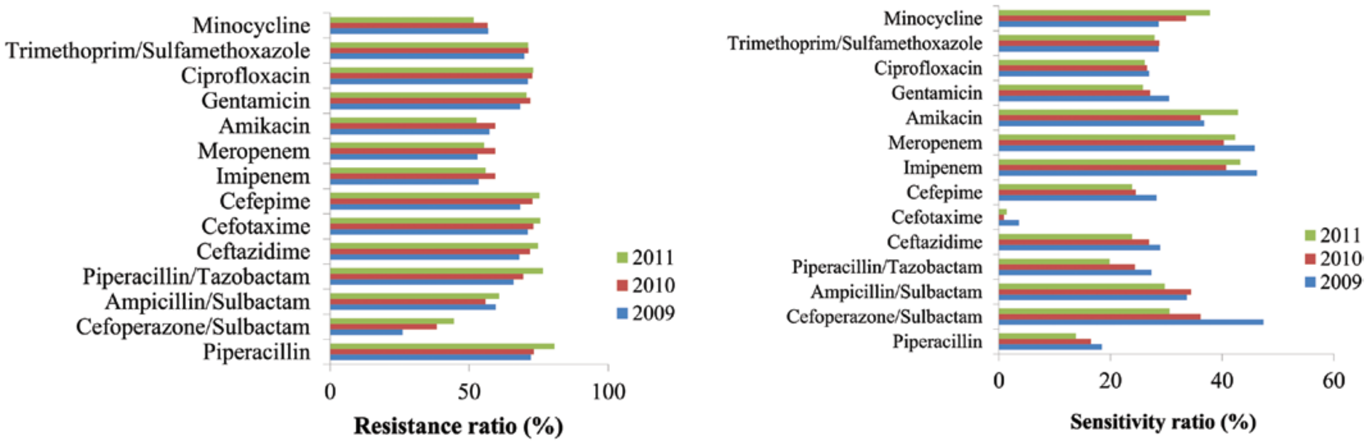

Figure 4. Resistance and sensitivity rates of *Acinetobacter baumannii* to various antibiotics between 2009 and 2011.

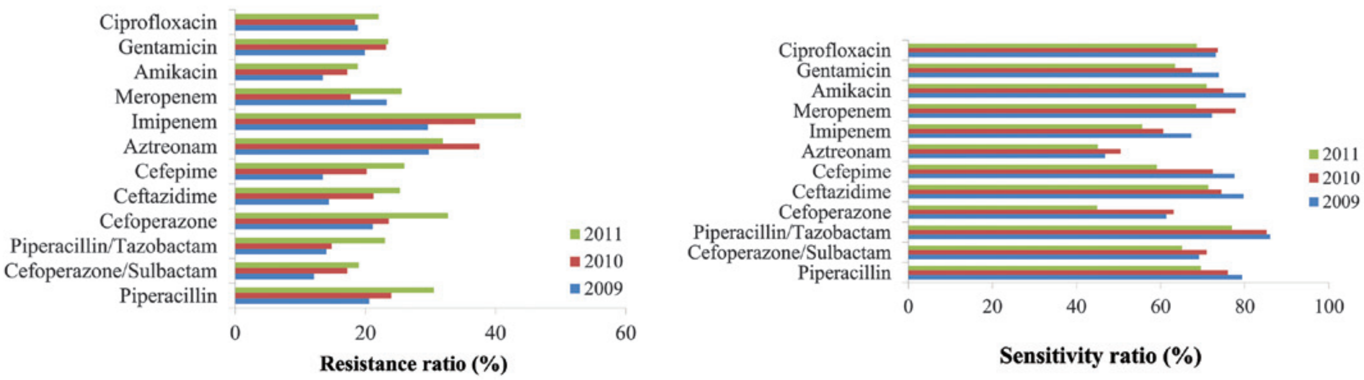

Figure 5. Resistance and sensitivity rates of *Pseudomonas aeruginosa* to various antibiotics between 2009 and 2011.

K. pneumoniae. With sensitivity rates of 100% to imipenem and meropenem in 2009 and 2010, *K. pneumoniae* was the most highly sensitive bacterium; however, *K. pneumoniae* had developed a small degree of resistance to these antibiotics by 2011 (Fig. 6).

Stenotrophomonas maltophilia monicamide. *S. maltophilia monicamide* was demonstrated to be sensitive to cefoperazone/sulbactam (Fig. 7), with no change demonstrated over the three years.

E. faecalis. In 2011, *E. faecalis* exhibited a resistance rate of 55.6% against levofloxacin, which was a notable increase compared with previous years. *E. faecalis* was demonstrated to be 100% sensitive to linezolid, vancomycin and teicoplanin (Fig. 8).

Proteus. mirabilis. *P. mirabilis* was initially 100% sensitive to cefoperazone/sulbactam, imipenem, meropenem and gentamicin; however, this sensitivity decreased by 0.0, 21.4, 4.8 and 31.0%, respectively, over three years (Fig. 9).

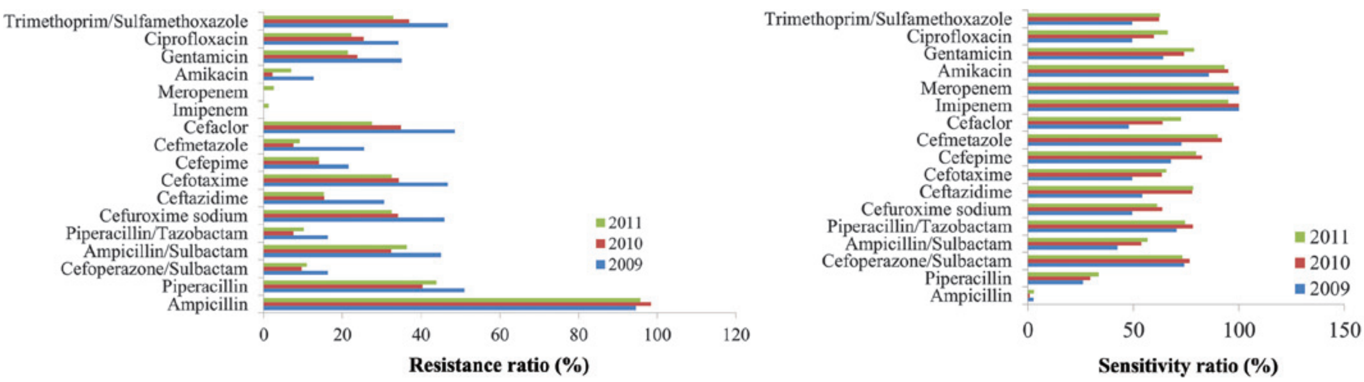

Figure 6. Resistance and sensitivity rates of *Klebsiella pneumoniae* to various antibiotics between 2009 and 2011.

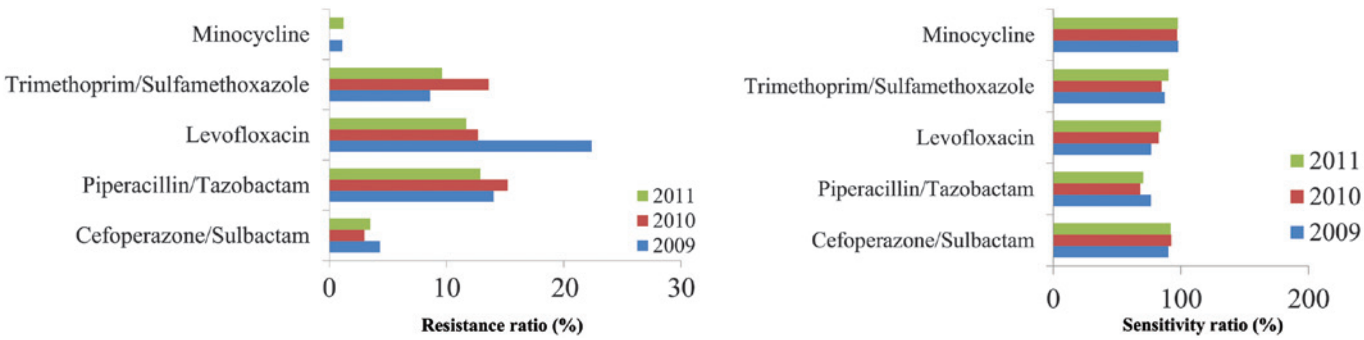

Figure 7. Resistance and sensitivity rates of *Stenotrophomonas maltophilia monicamide* to various antibiotics between 2009 and 2011.

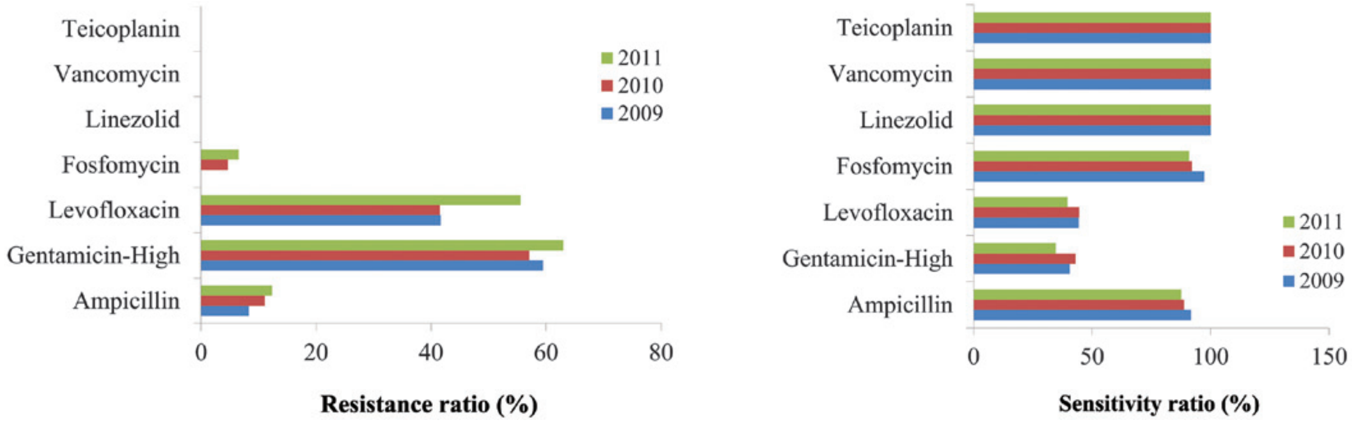

Figure 8. Resistance and sensitivity rates of *Enterococcus faecalis* to various antibiotics between 2009 and 2011.

Methicillin-resistant S. aureus. Between 2009 and 2011, the detection rates for methicillin-resistant *S. aureus* were 63.2, 65.8 and 60.1%, respectively (Fig. 10); whereas the detection rates for methicillin-resistant coagulase-negative staphylococci were 68.0, 71.6 and 68.5%, respectively between 2009 and 2011.

Discussion

The results of the present study demonstrated that the most common pathogen detected between 2009 and 2011 at Shanghai First People's Hospital was *E. coli*, followed by *A. baumannii*, *P. aeruginosa*, *S. aureus*, *K. pneumoniae*, *S. maltophilia*, *E. faecium*, *E. faecalis*, *P. mirabilis* and *E. cloacae*. The percentage of Gram-negative bacteria detected was significantly higher, as compared with that of Gram-positive bacteria. Furthermore, non-fermenting Gram-negative bacteria were more prevalent than *Enterobacteriaceae*, and *A. baumannii* was more prevalent than *P. aeruginosa*, which was demonstrated to be the most prevalent pathogen at the hospital since 2011.

At present, antibiotic consumption in China is high, with various quantities and classes of antibiotics being prescribed, depending on the type of hospital (9-11). Given that the worldwide spread of multidrug-resistant bacteria is threatening the availability of safe and effective antibiotic treatment for patients (12), strong infection control measures and alternative therapeutic agents are required. Methicillin-resistant *S. aureus* remains the primary Gram-positive bacterium of concern in

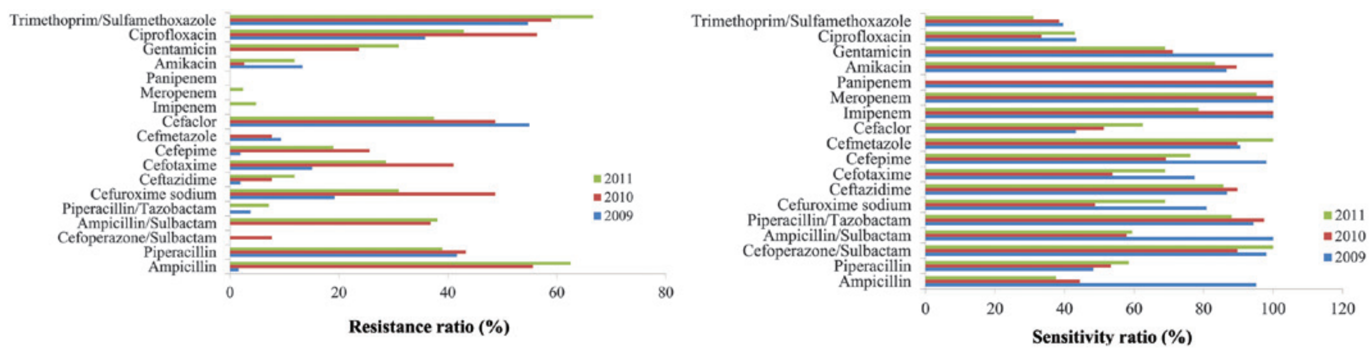

Figure 9. Resistance and sensitivity rates of *Proteus mirabilis* to various antibiotics between 2009 and 2011.

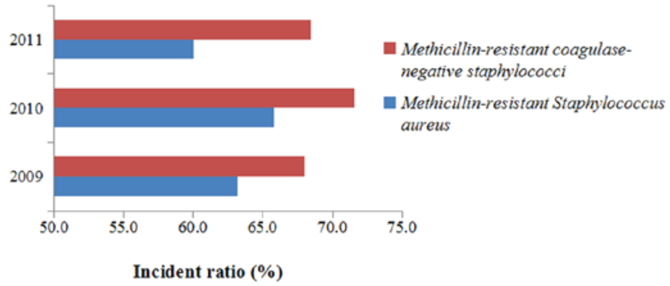

Figure 10. Detection rates of methicillin-resistant *Staphylococcus aureus* and methicillin-resistant coagulase-negative staphylococci between 2009 and 2011.

public hospitals (13,14). Strains of this bacterium are resistant to β-lactams, macrolides, fluoroquinolones and aminoglycosides; therefore, glycopeptide antibacterial agents remain the last line of antimicrobial defense.

Antibiotic consumption and the development of bacterial resistance are closely associated, and antibiotic resistance rates are increasing in developing countries, as compared with those in developed countries (15). Extensive use of third-generation cephalosporins has caused bacteria under this selective pressure to generate extended-spectrum β-lactamases and AmpC enzymes, which are capable of overcoming the anti-bacterial activities of cephalosporins (16). In the present study, the susceptibility tests demonstrated that the majority of bacteria were highly sensitive to linezolid, vancomycin and teicoplanin; therefore, these remain effective antimicrobial agents against otherwise resistant bacteria. Furthermore, the present study demonstrated that Gram-negative bacilli may be more sensitive to imipenem. All bacteria were 100% sensitive to imipenem and meropenem in 2009 and 2010; however, a small increase in resistance to imipenem was detected in 2011.

In order to mitigate the development of antibiotic resistance and reduce nosocomial infections, clinicians should pay particular attention to clinical indications. Furthermore, clinicians should understand the dynamics of bacterial resistance, the results of bacterial susceptibility tests, and develop appropriate prevention measures that seek to reduce the incidence of nosocomial infections and the spread of resistant bacteria (17,18). *E. coli* remains the most common pathogen at Shanghai First People's Hospital , and the resistance rates of bacteria to conventional and emerging antibiotics are increasing. Previous studies investigating similar control strategies supported the effectiveness of targeted active surveillance (19-21). The present study suggested that clinicians should seek to prescribe medications based on antimicrobial susceptibility results, in order to avoid the misuse of antibiotics and to reduce the probability of resistant strains emerging under the selection pressure.

Acknowledgements

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