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Resistance of Clinical Isolates to Generation of Cephalosporins in a Tertiary Hospital in Ogbomoso, South-Western Nigeria

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ABSTRACT

Antibiotics resistance is a major public health concern, antimicrobial resistance possess a great challenge to the community and hospitals. This study was carried out to determine the susceptibility pattern of clinical isolates to different generations of cephalosporins. A total number of 105 isolates made up of 31 *Pseudomonas aeruginosa*, 31 *Escherichia coli*, 19 *Proteus mirabilis* and 24 *Klebsiella* spp., were collected over a period of five months (March to August 2013). These isolates were tested for their sensitivity to antibiotics by means of disc diffusion method using prepared antibiotics discs containing different amounts of antibiotics; cefadroxil (30 μg), cefotaxims (30 μg), cefamandole (30 μg), cefador (30 μg), cefpodoxime (10 μg) and cefixime (5 μg). Out of the 31 (28.2%) *Escherichia coli* isolates obtained from different clinical specimens, 30 (96.8%) showed highest resistant rate to cefador which is a second generation cephalosporin. The resistant of cefotaxims and cefador which are second generation of cephalosporins to the isolates of *Proteus mirabilis* is higher compared to other generations. *Staphylococcus aureus* was resistant to all the antibiotics used. All isolates of *Pseudomonas aeruginosa* were absolutely resistant to cefpodoxime and cefixime which are third generation of cephalosporins but have minimal resistant rate to other antibiotics used. The results from this study provide more and further evidence of resistance of clinical isolates among generations of cephalosporins used.

Key words: Antimicrobial, cephalosporins, clinical isolates, resistance, Ogbomoso

INTRODUCTION

Antimicrobial drugs vary considerably in their range of effectiveness. Many are narrow-spectrum drugs; they are effective only against a limited variety of pathogens. Others are broad-spectrum drug that attacks many different kinds of pathogens.

Commonly used antibiotics include the penicillin, cephalosporins, aminoglycosides, chloramphenicol, tetracyclines, polymyxins and erythromycin and the common synthetic antimicrobials are the sulphonamides, trimethoprim and nalidixic acid (Ochei and Kolhatkar, 2007). Cephalosporins are grouped into generation by their antimicrobial properties, categorized chronically and are therefore divided into first, second and third generation. Each newer generation

of cephalosporin has greater Gram negative antimicrobial properties than the preceding generation. The later generation of cephalosporin has greater effect against resistant bacteria (Forbes *et al*., 1998; Cheesbrough, 2006). Cephalosporins are used to treat, pneumonia, strep throat, staph infections, tonsillitis, bronchitis, otitis media, various types of skin infections and gonorrhea. Cephalosporins are closely related to the penicillin and have a bactericidal effect by inhibiting the synthesis of the bacteria cell wall (Forbes *et al*., 1998; Cheesbrough, 2006). The classification of cephalosporins into generations is a common practice although the exact categorization is often imprecise.

Resistance of Gram negative bacteria to cephalosporins as with other beta-lactam antibiotics is a function of a site (penicillin-binding proteins). Permeation through the outer-membrane is largely governed by the presence and properties of porins which are water filled channels facilitating the movement of hydrophilic molecules across the membrane. The properties of porins vary considerably between wild-type bacteria species and their members (and hence the ability of a bacterial cell to exclude antibiotics) may be reduced in strains with acquired resistance. In the case of cephalosporin, ability to cross the outer membrane is related to physiochemical properties such as molecular size, hydrophobicity and the number and charge of ionized group. Thus, for example, permeability rate than dipolar cephalosporins. The phenotypically expressed susceptibility of a particular bacterial strains to cephalosporin is brought about by a dynamic combination of permeation, the ability of the agent to resist degradation of binding to the beta-lactamase in the periplasmic space which act upon the relatively low concentration of cephalosporin present their and target affinity (Pfeifer *et al*., 2010). Antimicrobial resistance has been reported worldwide and increasing rates of resistance among clinical isolates is a great concern in both developed and developing countries. A rise in bacteria resistance to antibiotics complicates treatments of infections. Because of the prevailing antibiotics resistance in microorganisms, broad spectrum cephalosporins are used empirically and specifically in both developed and developing countries. Therefore, the study was designed to determine the antimicrobial susceptibility pattern of selected clinical isolates to cephalosporin using different antibiotics in various generations.

MATERIALS AND METHODS

Study area: This study was carried out in Ogbomoso, Oyo State, South Western part of Nigeria, in order to determine resistance of clinical isolates to cephalosporins among the patients at Ladoke Akintola University Teaching Hospital Ogbomoso and Bowen University Teaching Hospital Ogbomoso, Oyo State, Nigeria over a period of five months (March to August, 2013).

Bacterial isolates: A total number of 105 isolates made up of 31 *Pseudomonas aeruginosa*, 31 *Escherichia coli*, 19 *Proteus mirabilis* and 24 *Klebsiella* spp., isolated from different clinical specimens including urine, blood culture, wound swab, eyes swab, ear swab, high virginal swab, abscess, catheter tips, aspirate, sputum and cerebrospinal fluid were used for this study. These samples were collected from both Universities with 90 isolates from Ladoke Akintola University Teaching Hospital Ogbomoso and 18 isolates from Bowen University Teaching Hospital Ogbomoso at the Department of Medical Microbiology and Parasitology.

Identification of bacterial isolates: The bacterial isolates were identified based on their morphological behaviour on various differential media. Media were prepared according to the

manufacturer's instructions and sterilized at 121°C for 15 min at 15 lb pressure. Further identification was then carried out by standard biochemical test as described by Jolt *et al*. (1994) and Cheesbrough (2006).

Susceptibility test: The susceptibility test was conducted using the Kirby-Bauer method of sensitivity determination. Petri-dishes of Mueller Hinton agar were prepared according to the manufacturer's instruction. The 0.1 mL of the bacterial isolates equivalent to 0.5 McFarland standard was seeded into each of the Petri-dishes containing Mueller-Hinton agar using sterile swabs. These were allowed to stand for 45 min to enable the inoculated organisms to pre-diffuse. The bacterial isolates were tested for their sensitivity to antibiotics by means of disc diffusion method using prepared antibiotics discs containing different µg of antibiotics; cefadroxil (30 µg), cefotaxim (30 µg), cefamandole (30 µg), cefador (30 µg), cefpodoxime (10 µg) and cefixime (5 µg); all are products of Oxoid, UK. The antibiotic discs were aseptically placed on the surfaces of the sensitivity agar plates. These were incubated for 18-24 h at 37°C and the radial zone of inhibitions were taken. The results were expressed as susceptible, intermediate or resistant according to criteria developed by Clinical Laboratory Standard Institute (CLSI., 2007).

RESULTS

From Table 1 *Escherichia coli* isolates from urine has a low susceptible to cefadroxil, cefotaxims and cefamandole while resistant to cefador and intermediate cefpodoxime and cefixime. *Escherichia coli* isolate from an abscess showed an intermediate effect of cefadroxil, susceptible to cefotaxims and cefpodoxime; resistant to cefamandole, cefador and cefixime. Catheter's tip, aspirate and wound isolates of *E. coli* were resistance to cefadroxil, cefotaxims, cefamandole, cefador, cefpodoxime and cefixime.

Escherichia coli isolates obtained from stool culture were resistant to cefadroxil, cefotaxims, cefamandole, cefador, cefpodoxime and cefixime. One isolate obtained from blood culture was completely resistant to all the antibiotics used. While two isolates obtained from High Vaginal Swab (HVS), was susceptible to cefadroxil but the other was resistant; these two isolates were resistant to cefotaxims, cefamandole, cefador, cefpodoxime and cefixime. The *Escherichia coli* isolated from eyes swab were resistant to cefadroxil but susceptible to cefotaxims and the

Table 1: Susceptibility pattern of *Escherichia coli* to different generations of cephalosporin using CLSI (2007) criteria

	First generation			Second generation									Third generation								
	CFP			CTX			MA			CEC			CPD			CFM			Total		
Isolation site	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R
Urine	4	0	12	3	0	13	3	0	13	0	1	15	3	0	13	2	1	13	15	2	79
Abscess	0	1	0	1	0	0	0	0	1	0	0	1	1	0	0	0	0	1	2	1	3
Catheter's tip	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	6
Wound swab	0	0	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0	5	0	0	30
Stool culture	0	2	0	0	2	0	0	2	0	0	2	0	0	0	2	0	0	2	0	8	4
Blood culture	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	6
HVS	1	0	1	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	1	0	11
Eye swab	0	0	2	1	0	1	0	0	2	0	0	2	0	0	2	0	0	2	1	0	11
Aspirate	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	6
Total	5	1	25	5	0	26	3	0	28	0	1	30	4	0	28	2	1	28	19	11	156
Susceptibility (%)	16.1	3.2	80.6	16.1	0	83.6	9.7	0	90.3	0	3.2	96.8	12.9	0	90.3	6.5	3.2	90.3	10.2	5.9	83.9

CFP: Cefadroxil, CTX: Cefotaxims, MA: Cefamandole, CEC: Cefador, CPD: Cefpodoxime, CFM: Cefixime, S: Sensitive, I: Intermediate, R: Resistant, HVS: High vagina swab, CLSI criteria; for cefotaxims, S: ≥23, I: ≤15-22 and R: ≤14, cefamandole, S: ≥18, I: ≤15-17 and R: ≤14, for cefadroxil, S: ≥18, I: ≤15-17 and R: ≥14, for cefpodoxime, S: ≤21, I: ≥18-20 and R: ≤17, for cefador, S: ≥18, I: ≤15-17 and R: ≤14, for cefixime, S: ≥20, I: ≤17-19 and R: ≤16

remaining were resistant to cefamandole, cefador, cefpodoxime and cefixime. The overall susceptibility rate of *Escherichia coli* to different generations of cephalosporin is 12.9% sensitive, 4.1% intermediate and 82.9% resistant as shown in Table 1.

Table 2 shows the susceptibility of *Pseudomonas aeruginosa* obtained from urine, some were susceptible to cefadroxil and cefamandole but were resistant to cefotaxims, cefador, cefpodoxime and cefixime. The isolates obtained from blood culture were susceptible to cefadroxil while resistant to cefotaxims, cefamandole, cefador, cefpodoxime and cefixime. The isolates obtained from ear swab were susceptible to cefadroxil and cefamandole while resistant to cefador, cefpodoxime and cefixime. Isolate obtained from eyes swab was resistant to cefadroxil and cefotaxims; intermediate for cefamandole, resistant to cefador, cefpodoxime and cefixime while isolate from high vaginal swab were susceptible to cefadroxil and resistant to cefotaxims, cefamandole, cefador, cefpodoxime and cefixime. The *Pseudomonas aeruginosa* isolated from urine were susceptible to cefadroxil, cefotaxims and cefamandole while the remaining isolates were resistance to cefador, cefpodoxime and cefixime. Isolates obtained from sputum and abscess was susceptible to cefadroxil while were resistant to cefotaxims, cefamandole, cefador, cefpodoxime and cefixime. The overall susceptibility pattern of *Pseudomonas aeruginosa* to different generations of cephalosporin is 14.7% sensitive, 3.2% intermediate and 82.2% resistant.

From Table 3 *Proteus mirabilis* isolates obtained from sputum were susceptible to cefadroxil, cefamandole and cefotaxims while resistant to other antibiotics. Isolates from ear swab were

Table 2: Susceptibility pattern of *Pseudomonas aeruginosa* to different generations of cephalosporins using CLSI (2007) criteria

	First generation			Second generation									Third generation								
	CFP			CTX			MA			CEC			CPD			CFM			Total		
Isolation site	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R
Wound swab	4	1	5	0	0	10	3	0	7	0	1	9	0	0	10	0	0	10	7	2	51
Blood culture	2	0	0	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	2	0	10
Ear swab	3	0	3	0	0	6	0	1	5	0	0	6	0	0	6	0	0	6	3	1	32
Eye swab	0	0	1	0	0	1	0	1	0	0	0	1	0	0	1	0	0	1	0	1	6
HVS	3	0	1	0	0	4	0	0	4	0	0	4	0	0	4	0	0	4	3	1	21
Urine	2	0	0	1	0	1	1	0	1	0	0	2	0	0	2	0	0	2	4	0	8
Sputum	1	0	3	0	0	5	0	0	5	0	0	5	0	0	5	0	0	5	4	2	28
Abscess	1	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	1	0	5
Total	16	1	13	1	0	30	4	2	25	0	1	30	0	0	31	0	0	31	24	7	161
Susceptibility (%)	56.6	3.3	41.9	3.2	0	96.8	12.9	6.5	80.6	0	3.2	96.8	0	0	100	0	0	100	12.5	3.6	83.9

CFP: Cefadroxil, CTX: Cefotaxims, MA: Cefamandole, CEC: Cefador, CPD: Cefpodoxime, CFM: Cefixime, S: Sensitive, I: Intermediate, R: Resistant, CLSI criteria; for cefotaxims, S: ≥23, I: ≤15-22 and R: ≤14, cefamandole, S: ≥18, I: ≤15-17 and R: 14, for cefadroxil, S: ≥18, I: ≤15-17 and R: ≤14, for cefpodoxime, S: ≥21, I: ≤18-20 and R: ≥17, for cefador, S: ≥18, I: ≤15-17 and R: ≤14, for cefixime, S: ≥20, I: ≤17-19 and R: ≤16

Table 3: Susceptibility pattern of *Proteus mirabilis* to different generations of cephalosporin using CLSI (2007) criteria

	First generation			Second generation									Third generation								
	CFP			CTX			MA			CEC			CPD			CFM			Total		
Isolation site	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R
Sputum	3	1	4	1	0	7	3	0	5	0	1	7	2	0	6	2	0	6	11	2	34
Ear swab	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	6
Total	3	1	5	1	0	8	3	0	6	0	1	8	2	0	7	2	0	7	11	2	34
Susceptibility (%)	33.3	11.1	55.6	11.1	0	88.9	33.3	0	66.7	0	11.1	88.9	22.2	0	77.8	22.2	0	77.8	23.4	4.3	72.3

CFP: Cefadroxil, CTX: Cefotaxims, MA: Cefamandole, CEC: Cefador, CPD: Cefpodoxime, CFM: Cefixime, S: Sensitive, I: Intermediate, R: Resistant, CLSI criteria; for cefotaxims, S: ≥23, I: ≤15-22 and R: ≤14, cefamandole, S: ≥18, I: ≤15-17 and R: ≤14, for cefadroxil, S: ≥18, I: ≤15-17 and R: ≥14, for cefpodoxime, S: ≥21, I: ≤18-20 and R: ≤17, for cefador, S: ≥18, I: ≤15-17 and R: ≤14, for cefixime, S: ≥20, I: ≤17-19 and R: ≤16

Table 4: Susceptibility pattern of *Klebsiella* spp., to different generations of cephalosporin using CLSI (2007) criteria

	First generation			Second generation									Third generation								
	CFP			CTX			MA			CEC			CPD			CFM			Total		
Isolation site	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R
Urine	3	1	6	2	0	8	2	0	8	0	1	9	3	0	7	2	1	7	12	3	45
Wound swab	1	0	5	1	0	5	1	0	5	1	0	5	1	0	5	1	0	5	6	0	30
Sputum	1	0	4	1	0	4	0	0	5	0	0	5	0	1	4	0	0	5	5	2	28
HVS	1	0	1	0	0	2	0	0	2	0	0	2	0	0	2	0	0	2	1	0	11
Ear swab	3	0	3	1	0	5	1	0	5	1	0	5	1	0	5	1	0	5	8	0	28
Stool culture	0	1	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	1	5
Eye swab	1	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	1	0	5
Throat swab	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	6
Cather's tip	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	6
CSF	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	6
Total	10	2	22	5	0	29	4	0	30	2	1	31	5	1	28	4	1	29	33	6	170
Susceptibility (%)	29.4	5.9	64.7	14.7	0	85.3	11.8	0	88.2	5.9	2.9	91.2	14.7	2.9	82.4	11.8	2.9	85.3	15.8	2.9	81.3

CFP: Cefadroxil, CTX: Cefotaxims, MA: Cefamandole, CEC: Cefador, CPD: Cefpodoxime, CFM: Cefixime, S: Sensitive, I: Intermediate, R: Resistant, CSF: Cerebrospinal fluid, HVS: High vagina swab, CLSI criteria; for cefotaxims, S: ≥23, I: ≤15-22 and R: ≤14, cefamandole, S: ≥18, I: ≤15-17 and R: ≤14, for cefadroxil, S: ≥18, I: ≤15-17 and R: ≥14, for cefpodoxime, S: ≥21, I: ≤18-20 and R: ≤17, for cefador, S: ≤18, I: ≥15-17 and R: ≤14, for cefixime, S: ≥20, I: ≤17-19 and R: ≤16

resistant to all antibiotics. The overall susceptibility rate of *Proteus mirabilis* to different generations of cephalosporins is 20.6% sensitive, 4.8% intermediate and 74.6% resistant.

From Table 4 isolates of *Klebsiella* spp., obtained from urine were susceptible to cefadroxil, cefotaxims, cefpodoxime and cefamandole while some were resistant to cefador and cefixime. Isolates obtained from wound swab has a low susceptibility to each of cefotaxims, cefamandole, cefador, cefpodoxime and cefixime. Sputum isolates was susceptible to both cefadroxil and cefotaxims while resistant to other antibiotics. Isolates obtained from High Vaginal Swab (HVS), stool culture, eyes swab and ear swab was susceptible to cefadroxil and were resistant to cefotaxims, cefamandole, cefador, cefpodoxime and cefixime. The isolates obtained from catheter's tip, Cerebrospinal Fluid (CSF) and throat swab were resistant to all the antibiotics used. The overall susceptibility rate of *Klebsiella* spp., to different generations of cephalosporin is 18.1% sensitive, 2.9% intermediate and 79.0% resistant.

DISCUSSION

Cephalosporin is one of the most widely used antibiotics in the treatment of both Gram positive and Gram negative organisms. In this study, *Escherichia coli* isolates showed a highest resistant to cefador, followed by cefamandole, cefpodoxime and cefixime which are second and third generation of cephalosporins, this agree with the study by Jawetz *et al*. (2010) that second generations agents are active against organisms covered by first generation drugs. Also in support with observation made on third generations that they have broad spectrum of activity and further increased activity against Gram-negative rods (Jawetz *et al*., 2010). From this study the organism showed a highest susceptibility rate to cefadroxil which is a first generation, this confirmed its effectiveness over the others.

Result from this study also revealed that *Pseudomonas aeruginosa* showed a highest resistant rate to cefpodoxime and cefixime which are third generation cephalosporins followed by cefador, cefamandole and cefotaxims which are second generation. This organism showed minimal resistance rate to cefadroxil a first generation cephalosporin.

This agrees with Jawetz *et al*. (2010), that second generation agents are active against organisms covered by first generation drugs but have extended coverage against Gram-negative

rods including *Klebsiella* spp., but not *Pseudomonas aeruginosa* but disagree with the study of Pichichero (2006) that reported that third generation have a broad-spectrum of activity and further increased activity against Gram-negative organisms which may be due to the fact that microorganisms may lose the specific target structure for a drug for several generations and thus be resistant (Jawetz *et al*., 2010).

Pseudomonas aeruginosa showed highest susceptibility rate to cefadroxil which is first generation and this may occur due to the abuse use of various generations of cephalosporins which leads the mutation in the genetic make-up of pathogens and thus drug resistant. In line with this study, *Proteus mirabilis* have a highest inhibitory concentration to cefotaxims and cefador followed by cefpodoxime and cefixime which are second and third generations, respectively. This disagrees with the observation of Jawetz *et al*. (2010) that second generation agents are active against organisms covered by first generation drugs but have extended coverage against Gram-negative rods including *Klebsiella* spp., but not *Pseudomonas aeruginosa*.

It also disagrees with the study of Pichichero (2006), that third generation cephalosporins have a broad-spectrum of activity and further increased activity against Gram-negative organisms and this may be due to the fact that Gram-negative bacteria pursue various molecular strategy the presence and properties for development of resistance to these antibiotics (Pfeifer *et al*., 2010). The most effective of all this antibiotics is cefadroxil which is a first generation and cefamandole have moderate effects on this organism than the rest of the antibiotics expect cefadroxil which it may be due to the misuse or abuse use of different generations of cephalosporins.

As it is revealed from the result of this study, the resistant of *Klebsiella* spp., increased according to different generations of antibiotics used. Cefadroxil also showed high rate of effectiveness than the rest of all the generations of cephalosporins used. This study is not in support with the study of Jawetz *et al*. (2010) that second generation agents are active against organisms covered by first generation drugs but have extended coverage against Gram-negative rods including *Klebsiella* spp., but not *Pseudomonas aeruginosa*. It also disagrees with the study by Jawetz *et al*. (2010) that third generations have a broad-spectrum of activity and further increased activity against Gram-negative organisms.

Analysis from this study showed that, a significant difference was observed in the mean effect of the first generation cephalosporin on the clinical isolates; with a mean value ranging between 1.94 effect on *Pseudomonas aeruginosa* and this may be due to the ability of the different isolates to produce beta-lactamase that reduced the activity of the first generation cephalosporin. This result agrees with the study of Jawetz *et al*. (2010), who from a study noted that the first generation cephalosporins are only moderately effective against some aerobic rod and anaerobic cocci. With no significant different observed in the mean effect of the second generation cephalosporin on the isolates, this result disagrees with the claims of Jawetz *et al*. (2010) that these agents are active against *Klebsiella* spp., *Proteus mirabilis* but not *Pseudomonas aeruginosa*. There is no significant difference in the mean effect of fourth generation cephalosporin used on clinical isolates tested; this may be due to misuse and abuse of cephalosporins which leads the mutations in the genetic makeup of pathogens and thus drug resistant. The resistance of clinical isolates to different generations of cephalosporins could be as a result of abuse of the antibiotics and there should be proper monitoring by qualified personnel in the field to curb the trends of antibiotics misuse. There should be proper monitoring of antimicrobial susceptibility both in the community and hospital settings.

Despite the resistance of bacteria to first and second generation cephalosporins they could still be used if appropriate laboratory sensitivity testing done on the isolates. However, in the absence

of that, third generation cephalosporins should be recommended. In order to avoid the crisis of drug resistance, the efficacy of antibiotic should be checked from time to time by carrying out comparative studies as done in this study.

REFERENCES

CLSI., 2007. Performance standards for antimicrobial susceptibility testing; seventeenth informational supplement. M100-S17, Vol. 27, No. 1, Clinical and Laboratory Standards Institute (CLSI), Wayne, PA., USA.

Cheesbrough, M., 2006. District Laboratory Practice in Tropical Countries. 1st Edn., Cambridge University Press, Cambridge, UK., ISBN-10: 0521665450, pp: 434.

Forbes, B.A., D.F. Sahm and A.S. Weissfeld, 1998. Baily and Scoot's Diagnostic Microbiology. 10th Edn., Mosby Inc., St Louis, Pages: 234.

Jawetz, E., G.E. Melnick and C.A. Adelberg, 2010. Medical Microbiology. 25th Edn., McGraw-Hill, New York, USA., ISBN-13: 978-0071624961.

Jolt, J.G., N.R. Krieg, P.H.A. Sneath, J.T. Stanley and S.T. Williams, 1994. Bergey's Manual of Determinative Bacteriology. 9th Edn., The Williams and Wilkins Co., Maryland, Pages: 786.

Ochei, J. and A. Kolhatkar, 2007. Medical Laboratory Science Theory and Practice. 5th Edn., McGram-Hill, New Delhi, India, pp: 788-812.

Pfeifer, Y., A. Cullik and W. Witte, 2010. Resistance to cephalosporins and carbapenems in Gram-negative bacterial pathogens. Int. J. Med. Microbiol., 300: 371-379.

Pichichero, M.E., 2006. Cephalosporins can be prescribed safely for penicillin-allergic patients. J. Family Pract., 55: 106-112.