

Full Length Research Paper

## Extended-spectrum-beta-lactamase producing uropathogenic *Escherichia coli* infection in Dhaka, Bangladesh

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Received 9 February, 2014; Accepted 23 December, 2014

Extended-spectrum-beta-lactamase (ESBL) producing *Escherichia coli* that cause urinary tract infection (UTI) is a burning issue. This study was carried out to detect extended spectrum beta lactamase producing *E. coli* isolated from patients presented with UTI. This cross sectional study was conducted in the Department of Microbiology at Dhaka Medical College, Dhaka from January to December 2005, a period of one year. Clinically diagnosed cases of infected (UTI) patients were included in this study. The clean catch mid-stream (CCMU) technique was employed to collect urine sample. Microscopical examination of urine was done and pus cell  $\geq 5$ /HPF was included in the study. Urine samples were inoculated into blood agar and MacConkey agar media. All the organisms were identified by their colony morphology, staining character, pigments production, haemolysis, motility and other relevant biochemical tests as per standard methods. Antibiogram for all bacterial isolates were done by disc diffusion method of modified Kirby-Bauer technique using Mueller Hinton agar plates. Detection of ESBL producers was performed by double disc diffusion test. Phenotypic confirmatory test was done by E test. A total of 250 samples of urine were collected and within this, 103 (41.2%) samples were shown in positive culture. Out of 103 positive urine samples, majority were *E. coli* (67.0%) followed by *Klebsiella* species (19.4%), *Pseudomonas* species (7.8%) and *Proteus* species (5.8%). Out of 69 *E. coli* isolates, ESBL producers were found in 22 (31.9%) urine samples. The difference between the rate of isolation of *E. coli* with ESBL and other than *E. coli* with ESBL is statistically significant ( $p=0.0001$ ). *E. coli* strains showed 100.0% resistance to amoxicillin, aztreonam, cefotaxim, ceftazidime, ceftriaxone and cephradine. However, more than 80.0% resistant was observed in cotrimoxazole, amikacin and nalidixic acid. Nitrofurantoin and mecillinam were more than 50.0% resistant. All strains were sensitive to imipenem. A considerable number of ESBL producing *E. coli* was detected from UTI cases, indicating it as the major challenge for future antibiotic therapy.

**Key words:** Extended-spectrum-beta-lactamase (ESBL), bacterial agents, urinary tract infection, antimicrobial susceptibility.

## INTRODUCTION

Drug resistance is a burning problem in the field of medicine (Altoparlak et al., 2004). There are many ways to mediate resistance, among them beta-lactamases play a major role in developing resistance against Gram negative organisms (Siro, 1995). During the last three decades many betalactam drugs have been used against the hydrolytic action of betalactamases for the treatment of Gram negative bacterial infections. Microorganisms are gradually developing resistance to these beta-lactam antibiotics by producing betalactamases (Altoparlak et al., 2004). Due to increased spectrum of activity of betalactamases especially against the oxyimino cephalosporins, they are called extended spectrum betalactamases (ESBLs) (Siro, 1995).

ESBL was first reported in 1983 from Germany in isolates of *Klebsiella pneumoniae* (Shukla et al., 2004). Gradually, many more ESBLs have been described (Bradford, 2001). ESBL producing bacteria are *Escherichia coli*, *Klebsiella* spp., *Salmonella* spp., *Morganella morganii*, *Proteus mirabilis*, *Serratia marcescens*, *Pseudomonas aeruginosa* and many more. Frequency of ESBL production is high among *E. coli* and *Klebsiella* species (Nathisuwan et al., 2001). This has created a worldwide problem resulting in treatment failure. ESBLs are enzymes that mediate resistance to extended spectrum (3<sup>rd</sup> generation) cephalosporins like ceftazidime, ceftriaxone, cefotaxime and monobactams like aztreonam but do not affect 2<sup>nd</sup> generation cephalosporins such as cephamecin (CDC, 1999).

In United States, occurrence of ESBL production in Enterobacteriaceae ranges from 0 to 25.0% depending on institutions (Bradford, 2001). In Europe, the prevalence is 23.0-25.0% for *Klebsiella* spp. and 5.4% for *E. coli* (Foury and Araj, 2003). In Asia, the proportion of ESBL production in *E. coli* varies from 4.8% in Korea to 8.5% in Taiwan and up to 12.0% in Hongkong (Bradford, 2001). In Singapore, 16.1% *E. coli* are ESBL producers (Chlebicki and Oh, 2004). In India, 58.1% *E. coli* are ESBL producers (Anathakrishnan et al., 2000). In Bangladesh, 26.9-43.2% *E. coli* are ESBL producers (Rahman et al., 2004; Alim, 2005).

This study has been designed to isolate ESBL producing *E. coli* from urine samples by double disc diffusion method and to confirm them by E-test ESBL method. Susceptibility pattern of ESBL producing *E. coli* were also observed.

## METHODOLOGY

This cross sectional study was conducted in the Department of Microbiology at Dhaka Medical College, Dhaka from January to

December, 2005, a period of one year. Clinically diagnosed cases of infected (UTI) patients were included in this study.

### Urine collection

The clean catch mid-stream (CCMU) technique was employed to collect urine sample. Urine was collected into two sterile containers of which one for microscopy and another for culture (Cheesbrough, 2000). In the case of catheterized patients, urine was collected from the catheter by sterile disposable syringe after proper cleaning of the catheter. Approximately 20 ml of urine was collected aseptically (Cheesbrough, 2000). The containers were properly labeled with patient's name and ID number. The specimens were then transported to the laboratory as quickly as possible.

### Microscopical examination

Urine was transferred into a clean and dry 15 ml centrifuge tube and was centrifuged at 1000 rpm for 5 min. The supernatant was discarded and one drop of sediment was taken into a clean glass slide, a cover slip was placed over it and then examined for pus cells under light microscope using 10 and 40x objectives. Samples with pus cell  $\geq 5$ /HPF were included in the study (Colle et al., 1996).

### Culture of urine

Urine samples were inoculated into Blood agar and Mac Conkey agar media by calibrated loop technique (Colle et al., 1996; Hoeprich, 1960).

### Isolation and identification of organisms

All the organisms were identified by their colony morphology, staining character, pigments production, haemolysis, motility and other relevant biochemical tests as per standard methods (Cheesbrough, 2000; Colle et al., 1996).

### Antimicrobial susceptibility test (Bauer et al., 1966)

Antibiogram for all bacterial isolates were done by disc diffusion method of modified Kirby-Bauer technique using Mueller Hinton agar plates and commercially available antimicrobial disc (Oxoid Ltd. UK). For *E. coli*, the following discs were used amoxicillin (Amx), co-trimoxazole (SXT), gentamicin (CN), amikacin(AK), nalidexic acid (Na), nitrofurantoin (Nf), netilmycin (NET), ciprofloxacin (CIP), cephradine (CL), ceftriaxone (CRO), ceftazidime (CAZ), imipenem (I) and aztreonam (ATM).

### For ESBL producers

To see the susceptibility against quinolones, fluoroquinolones and cephamycin, the following discs were used: ciprofloxacin (CIP), gatifloxacin (GTX), levofloxacin (LEV), ofloxacin (OFX), sparfloxacin (Sp), lornefloxacin (LOM), pefloxacin (PEF) and cephamycin (CF).

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### Quality control

Discs from each batch were first standardized by testing against reference strain of *E. coli* ATCC-25922 and zones of inhibition were compared with standard value (Cheesbrough, 2000; Jeong et al., 2004).

### Inoculum standardization

With a sterile wire loop, three isolated colonies were transferred to screw-capped tube containing 4 ml of sterile normal saline and standardized with 0.5 Mac Farland standards by adding more organisms or more saline, the solution approximately corresponds to  $1.5 \times 10^8$  organisms/ml (Cheesbrough, 2000).

### Inoculation of test plate and disc placement

Before use, the Mueller-Hinton agar plates were dried in an incubator at 37°C for 30 min. Within 15 min after standardization of inoculums, a sterile cotton swab was immersed into the bacterial suspension. The excess broth was removed by retaining the swab with firm pressure against the inner side of the tube above fluid level. The swab was then streaked evenly on the surface of the plate in 3 different planes by rotating the plate approximately 60° each time to get a uniform distribution of inoculum. The inoculum was allowed to dry for 10-15 min at room temperature keeping the lid closed. The discs were then placed on the inoculum surface by a disposable niddle 15 mm away from the edge of the Petridish and having 20-25 mm gap between the discs. The plates were incubated at 37°C for 24 h (Cheesbrough, 2000).

### Reading of the sensitivity tests

After over right incubation, each plate was examined and diameter of the complete zones of inhibition was measured in mm with the help of scale placed under surface of the Petridish. Zones of inhibition were measured in two directions of right angles to each other through the center of each disc and the average of the two readings was taken and compared with the standard (Washington, 1985).

### Interpretation of zone

The zone of inhibition in growth produced by each antimicrobial agent on the test organisms was compared with that produced on the control organisms (CLSI, 2007).

### Detection of ESBL producers by double disc diffusion test (Jarlier et al., 1988)

Synergy between a disc of augmentin (amoxicillin and clavulamic acid) and 3<sup>rd</sup> generation cephalosporins was detected as clavulamic acid in augmentin inhibits  $\beta$ -lactamases around 3<sup>rd</sup> generation cephalosporin disc in agar plate.

### Procedure

Mueller-Hinton agar plates were prepared and inoculated with standardized inoculum (compared with 0.5 McFarland standards) by sterile cotton swab. Augmentin disc (20  $\mu$ g amoxicillin+10  $\mu$ g clavulamic acid) was placed in the center of the plate. 3<sup>rd</sup> generation cephalosporins (ceftazidime, ceftriaxone, cefotaxime) and aztreonam

discs were placed 20-30 mm apart (center to center) from the augmentin disc. The plate was observed after over night incubation at 37°C (Linscott and Brown, 2005).

### Interpretation

Inhibition around the 3<sup>rd</sup> generation cephalosporins or aztreonam disc were increased towards the augmentin disc or neither disc were inhibitory alone but bacterial growth was inhibited where two antibiotics diffuse together, interpreted as ESBL positive (Shukla et al., 2004).

### Quality control

*E. coli* ATCC-25922 were used as negative control and *K. pneumoniae* ATCC 700603 were used as positive control collected from BSMMU (Jeong et al., 2004).

### Phenotypic confirmatory test (Chaudhary and Aggarwal, 2004)

#### E test ESBL

**Principle:** E-test ESBL strip consists of a thin, inert and non-porous plastic carrier (5x60 mm). One side of the strip is calibrated with MIC reading scales in  $\mu$ g/ml while the reverse surface carries two predefined exponential gradients. TZ code for ceftazidime (0.5-32  $\mu$ g/ml) gradient and TZL for ceftazidime (0.064-4  $\mu$ g/ml) plus 4  $\mu$ g/ml clavulanic acid. The test is set up like a standard E test MIC procedure, two inhibition ellipses in opposing alignment appears at the end of the strip. The presence of ESBL was confirmed by the appearance of a phantom zone or deformation of the TZ ellipse or when TZ MIC was reduced by >3 log (8 times) dilutions in the presence of clavulanic acid.

**Reagents:** E-test ESBL strips containing (0.5-32  $\mu$ g/ml) ceftazidim alone and (0.064-4  $\mu$ g/ml) ceftazidim plus (4  $\mu$ g/ml) clavulanic acid were collected from AB BIODISK, Solna, Sweden.

**Procedure:** Inoculum was prepared and standardized with 0.5 McFarland standard and streaked by sterile swab over the entire agar surface of Mueller Hinton agar plates three times, rotating the plate approximately 60° each time to ensure even distribution of inoculum and kept for 15 min to absorb excess moisture.

**Application of E test ESBL strip:** With a forcep the ESBL strip was gripped at areas labeled TZ or TZL and placed at the middle of the inoculated plate in such a manner that the whole length of the strip was in complete contact with the agar surface, so that no bubble appeared under the strip and incubation was done at 35°C for 16-18 h.

**Reading and interpretation (AB BIODISK, Solna, Sweden):** After over night incubation, the plates were examined to see the values. TZ and TZL MIC values were recorded where the respective inhibition ellipses intersect the strip. Growth along the entire gradient, that is no inhibition ellipse indicates that the MIC was greater than the highest value on the reading scale. An inhibition ellipse below the gradient indicates a MIC less than the lowest value on the scale. When mutant colonies are present in the inhibition ellipse, MIC value was read where the colonies were completely inhibited. ESBL production was determined by a  $\geq 2$  two

**Table 1.** Rate of isolation of bacteria from urine samples (n=250)

Isolated bacteria	Frequency	Percentage
Growth of bacteria	103	41.2
No Growth	147	58.8
Total	250	100.0

**Table 2.** Isolation rate of different bacterial species from urine samples (n=250).

Isolated bacteria	Frequency	Percentage
<i>Esch. coli</i>	69	67.0
<i>Klebsiella</i> species	20	19.4
<i>Pseudomonas aeruginosa</i>	8	7.8
<i>Proteus</i> species	6	5.8
Total	103	100.0

fold concentration decrease in the MIC of TZ in presence of clavulanic acid (Linscott and Brown, 2005). Occasionally a 'rounded' zone (phantom zone) was seen below the TZL gradients while no ellipse was seen around the TZ end. The TZ inhibition ellipse may also be deformed at the tapering end. Presence of a phantom zone or ellipse deformation also indicates ESBL production due to synergy between TZ and clavulanic acid diffusing across from the TZL sections.

**Interpretation:** ESBL was positive if  $TZ \geq 1$  and  $TZ / TZL \geq 8$  or phantom zone or deformation of TZ ellipse and ESBL producer and resistant to all penicillins, cephalosporins and aztreonam (NCCLS M 100-S series). ESBL was negative if  $TZ < 1$  or  $TZ / TZL < 8$ . ESBL non-producer and report actual MIC of all relevant drugs as determined by an MIC method. ESBL was non-determinable (ND) if  $TZ > 32$  or  $TZL > 4$ . ESBL non-determinable and report actual MIC of all relevant drugs as determined by an MIC method. If ESBL is suspected, this was confirmed by CLSI methods and genotyping.

**Quality control:** *E. coli* ATCC 25922 as negative control and *K. pneumonia* ATCC 700603 as positive control collected from BSMMU were used.

## RESULTS

A total of 250 samples of urine were collected and within this, 103 (41.2%) samples were shown in positive culture (Table 1).

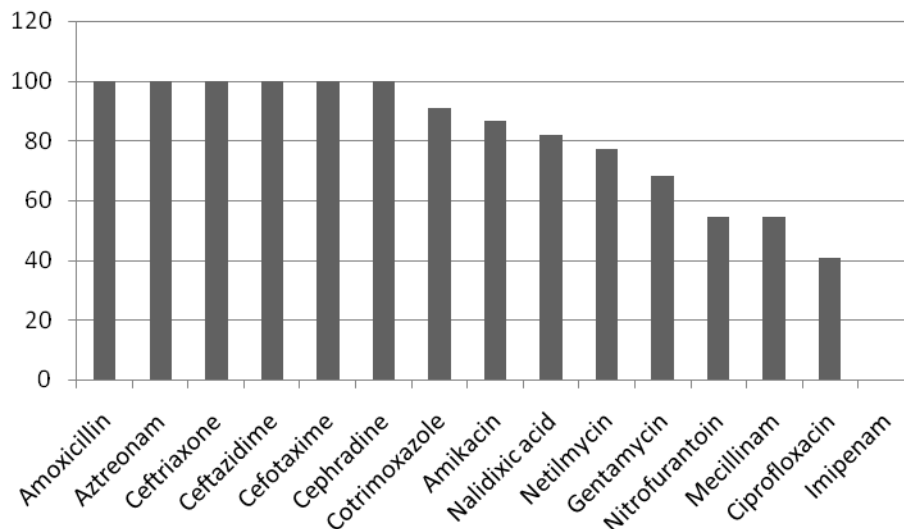
Out of 103 positive urine samples majority were *E. coli* (67.0%) followed by *Klebsiella* species (19.4%), *Pseudomonas* species (7.8%) and *Proteus* species (5.8%) (Table 2). Out of 69 *E. coli* isolates, ESBL producers were found in 22 (31.9%) urine samples. The difference between the rate of isolation of *E. coli* with ESBL and other than *E. coli* with ESBL is statistically significant ( $p=0.0001$ ) (Table 2).

*E. coli* strains showed 100.0% resistance to amoxicillin, aztreonam, cefotaxim, ceftazidime, ceftriaxone and cephadrine. However, more than 80.0% resistant was observed in cotrimoxazole, amikacin and nalidixic acid. Nitrofurantoin and mecillinam were more than 50.0% resistant. All strains were sensitive to imipenem (Figure 1).

## DISCUSSION

ESBLs are the enzymes produced by a variety of organisms like enterobacteriaceae as well as *P. aeruginosa* (Bradford, 2001). Failure to detect these enzymes has contributed to their uncontrolled spread and therapeutic failure (Thomson, 2001). In this study, ESBL producing *E. coli* was isolated and the sensitivity pattern was recorded. Regarding that issue, a total number of 250 urine samples were analyzed and among these 103 (41.2%) samples was yielded bacterial growth. A study was conducted at Bangabandhu Sheikh Mujib Medical University by Mostaqim (2007) who found 69.4% bacteria from various samples which is not consistent with the present study. The reason of low bacterial growth in this study may be use of urine sample only; on the other hand, culture of different samples was performed by the the previous author. In addition to that, majority of the patients with UTI usually take the antibiotic from the pharmacy before coming to hospital and this irrational use of antibiotic may hinder the growth of bacteria from urine (Table 3).

In this study, majority of isolated bacteria were *E. coli* (67.0%) followed by *Klebsiella* species (19.4%), *Pseudomonas* species (7.8%) and *Proteus* species (5.8%). In the present study, *E. coli* were the predominant



**Figure 1.** Antimicrobial drug resistance among the ESBL producing *E. coli*.

**Table 3.** Rate of isolation of ESBL among *Escherechia coli* isolates (n=69).

Isolated bacteria	ESBL producer		Total	p value
	Positive	Negative		
<i>Escherechia coli</i>	22(31.9)	47(68.1)	69(100.0)	
Other bacteria	9(25.0)	25(75.0)	34(100.0)	0.0001
Total	31(30.1)	72(69.9)	103(100.0)	

\*Chi-square test has been performed. \*Figure within parenthesis indicates percentage.

bacteria isolated from urine samples. From this result, it has been cleared that *E. coli* are the most prevalent bacteria isolated from urine. Similar result was reported by Mansour et al. (2009) and stated that *E. coli* is still the most common cause of UTI. Ferry et al (1988) published that *E. coli* were the most common isolated bacteria from the urine samples of the patients presented with UTI. This result also corresponds with the result obtained by other investigator (Jakobsen et al., 2012). Some have shown, however, that the percentage of *E. coli* is slowly declining, being replaced by other members of the Enterobacteriaceae and enterococci (Weber et al., 1997).

Out of all *E. coli* isolates, ESBL producers were found in 31.9% urine samples. The difference between the rate of isolation of *E. coli* with ESBL and other than *E. coli* with ESBL is statistically significant ( $p=0.0001$ ). Mostaqim (2007) found 56.7% *E. coli* and among them, 34.1% were ESBL producers which correlate with the findings of the present study. Again, Rahaman et al. (2004) reported that *E. coli* was the predominant organism in urine and among them majority were ESBL producers which are similar to this present study. In another study, Alim (2005) found that 26.9% *E. coli* isolates from urine were ESBL

producers which are more or less similar to the present result. In Bangladesh Rahaman et al (2004b) found that 43.20% *E. coli* were ESBL producer which is higher than the present study. The explanation regarding high rate is that they are isolated from pus samples.

In this study, sensitivity pattern of ESBL producing *E. coli* was done against different antibiotics and has shown that *E. coli* strains have 100.0% resistance to amoxicillin, aztreonam, cefotaxim, ceftazidime, ceftriaxone and cephadrine (Table 4). However, more than 80.0% resistant was observed in cotrimoxazole, amikacin and nalidixic acid. Nitrofurantoin and mecillinam were more than 50.0% resistant. All strains were sensitive to imipenem. Higher resistance to other antibiotics like cephadrine, cotrimoxazole, gentamycin, amikacin against ESBL producing *E. coli* was observed in this study which indicates that ESBL producing organisms are multidrug resistant and genes that code for ESBL are linked to other resistance genes (Ahmed and Salam, 2002). ESBL strains were 100% sensitive to imipenem. According to CDC, ESBL are defined as enzymes which hydrolyze 3<sup>rd</sup> generation cephalosporins and aztreonam but sensitive to cephamycin and imipenem (CDC, 1999). Nakamura

**Table 4.** Antimicrobial susceptibility profiles of ESBL *E. coli* and non ESBL *E. coli* isolates.

Antibiotic name	ESBL <i>E. coli</i> (n=22)	Non ESBL <i>E. coli</i> (n=47)	OR (95% CI)	P value
Amoxicillin	22 (100.0%)	38 (80.8%)	1.24 (1.08-1.40)	0.049
Aztreonam	22 (100.0%)	26 (55.3%)	1.81 (1.40-2.34)	0.0001
Ceftriaxone	22 (100.0%)	28 (59.6%)	1.68 (1.33-2.12)	0.0001
Ceftazidime	22 (100.0%)	29 (61.7%)	1.62 (1.29-2.03)	0.0001
Cefotaxime	22 (100.0%)	30 (63.8%)	1.57 (1.26-1.94)	0.001
Cephadrine	22 (100.0%)	42 (89.4%)	1.12 (1.12-1.23)	0.169
Cotrimoxazole	19 (86.4%)	33 (70.2%)	0.37 (0.095-1.46)	0.231
Amikacin	11 (50.0%)	41 (87.2%)	6.83 (2.06-22.61)	0.001
Nalidixic Acid	18 (81.8%)	28 (59.6%)	0.327 (0.096-1.12)	0.058
Netilmycin	16 (72.7%)	33 (70.2%)	0.884 (0.286-2.73)	0.830
Gentamycin	15 (68.2%)	24 (51.1%)	0.487 (0.168-1.41)	0.181
Nitrofurantoin	12 (54.5%)	17 (36.2%)	0.472 (0.169-1.32)	0.150
Mecillinum	12 (54.5%)	18 (38.3%)	0.517 (0.186-1.44)	0.205
Ciprofloxacin	8 (36.4%)	18 (38.3%)	1.09 (0.380-3.10)	0.887
Imipenem	0 (0.0%)	0 (0.0%)	NA	NA

and Komatsu (2005) found that 61.1% *E. coli* were ciprofloxacin resistant among the ESBL producers which is similar to the present study.

When ESBL producing organisms are confirmed by NCCLS guidelines, results should be reported as resistance to all penicillins, aztreonam and cephalosporins excluding cephamycin (CDC, 1999). Treatment of ESBL producing *E. coli* can be done by imipenem or cephamycin. Imipenem is costly and not within the reach of the people of developing country like Bangladesh. But quinolone (ciprofloxacin) and fluoroquinolones (levofloxacin, gatifloxacin etc) are cheap, available and single dose drug which may be used in the treatment against ESBL producing organisms. So early correct detection of ESBL producing *E. coli* by E test ESBL method and rational use of antibiotics can limit the spread of multidrug resistant pathogens (Medeiros, 1993).

## Conclusion

A considerable number of ESBL producing *E. coli* from urine samples were isolated. Sensitivity was higher in the case of imipenem as these are expensive and dose inconvenient so may be used for reserve antibiotics. Awareness regarding proper identification of ESBL producing *E. coli* should be carried out for appropriate antibacterial agent against them can reduce the hospital stay and sufferings of the patients.

## Conflict of Interests

The author(s) have not declared any conflict of interests.

## REFERENCES

- Ahmed I, Salam A (2002). Extended Spectrum  $\beta$ -lactamases and Bacterial Resistance. Pak. J. Med. Sci. 18(2):151-155.
- Alim R (2005). Detection of Extended Spectrum  $\beta$ -Lactamases (ESBL) Producing Bacteria. [M.Phil Thesis, Microbiology] BSMMU, Dhaka.
- Altöparlak U, Erol S, Aklay MN, Celebi F, Kadanali A (2004). Time related changes of antimicrobial resistance patterns and predominant bacterial profiles of burn wounds and body flora of burned patients. Burns 30:660-664.
- Anathakrishnan AN, Kanungo R, Kumar A, Badrinath S (2000). Detection of Extended Spectrum  $\beta$ -lactamase producers among Surgical wound infections and Burn Patients in Jipmer. Indian J. Med. Microbiol. 18(4):160-165.
- Bauer AW, Kirby WMM, Sherris JC, Turck S (1966). Antibiotic susceptibility testing by a standardized single disc method. Am. J. Clin. Path 36:493-496
- Bradford PA (2001). Extended spectrum  $\beta$ -lactamases in the 21<sup>st</sup> century: Characterization, epidemiology and detection of this important resistance threat. Clin. Microbiol. Rev. 14(4):933-951.
- CDC (1999). Laboratory Detection of Extended Spectrum  $\beta$ -lactamases (ESBL). <http://www.cdc.gov/ncidod/hip>
- Chaudhary U, Aggarwal R (2004) Extended spectrum  $\beta$ -lactamases (ESBL) – An emerging threat to clinical therapeutics. Indian J. Microbiol. 22(2):75-80.
- Cheesbrough M (2000). District laboratory practice in tropical countries, ELBS, Cambridgeshire, England, 2:175-180.
- Chlebicki MP, Oh HML (2004). Extended Spectrum Beta-Lactamases in Clinical Isolates of *Escherichia coli* and *Klebsiella* spp. in a Singapore Hospital: clinical spectrum. Ann. Acad. Med. 33(3):302-306.
- CLSI (2007). Performance standards for antimicrobial susceptibility testing. NCCLS approved standard. M100-S9.; Wayne, P A.
- Colle JG, Miles RS, Watt B (1996). Tests for the identification of bacteria. In: Collee JG, Fraser AG, Marmion BP, Simmons A, editors, Mackie and McCartney Practical Medical Microbiology, 14th ed. 1996; Churchill Livingstone, New York. pp. 553-559.
- Ferry S, Burman LG, Holm SE (1988). Clinical and bacteriological effects of therapy of urinary tract infection in primary health care: relation to *in vitro* sensitivity testing. Scandinavian J. Infect. Dis. 20(5):535-44.
- Foury K, Araj GF (2003). Recent developments in  $\beta$ -lactamase and Extended spectrum  $\beta$ -lactamases. Bangladesh Med. J. 327:1209-1213.

- Hoeprich PD (1960). Culture of the urine. *J. Lab. Clin. Med.* 56(6):899-906.
- Jakobsen L, Cattoir V, Jensen KS, Hammerum AM, Nordmann P, Frimodt-Møller N. (2012). Impact of low-level fluoroquinolone resistance genes *qnrA1*, *qnrB19* and *qnrS1* on ciprofloxacin treatment of isogenic *Escherichia coli* strains in a murine urinary tract infection model. *J. Antimicrob. Chemother.* 67(10):2438-2444.
- Jarlier V, Nicolas MH, Fournier G, Philippon A (1988). ESBLs conferring Transferable resistance to newer  $\beta$ -lactam agents in *Enterobacteriaceae*: hospital prevalence and susceptibility patterns. *Rev. Infect. Dis.* 10:867-878.
- Jeong SH, Bae KII, Lee JH, Sohn SG, Kang GH, Jeon GJ, Kim YH, Jeong BC, Lee SH (2004). Molecular Characterization of Extended Spectrum  $\beta$ -Lactamase Produced by Clinical Isolates of *Klebsiella pneumoniae* and *E. coli* from Korean Nationwide Survey. *J. Clin. Microbiol.* 2902-2906.
- Linscott AJ, Brown WJ (2005). Evaluation of Four Commercially Available Extended Spectrum Beta-Lactamase Phenotypic Confirmation Tests. *J. Clin. Microbiol.* 43(3):1081-1084.
- Mansour A, Manijeh M, Zohreh P (2009). Study of bacteria isolated from urinary tract infections and determination of their susceptibility to antibiotics. *Jundishapur J. Microbiol.* 2(3):118-23.
- Medeiros AA (1993). Nosocomial outbreaks of multiresistant bacteria: extended-spectrum beta-lactamase have arrived in North America. *Ann. Intern. Med.* 119(5):428-429.
- Mostaqim R (2007). Rapid Detection of Extended Spectrum Beta-Lactamases (ESBL) Production Directly From Primary Culture. M.Phil.Thesis, BSMMU
- Nakamura T, Komatsu M (2005). Susceptibility of ESBL producing *E. coli* and *Klebsiella pneumoniae* to various antibacterial agents. *Japanese J. Antibiot.* 58(1):1-10.
- Nathisuwan S, Burgess DS, Lewis IJS (2001). ESBLs: Epidemiology, Detection and Treatment. *Pharmacother.* 21(8):920-928.
- Rahman M, Haq JA, Hossain MA, Sultana R, Islam F, Islam S (2004). Prevalence of extended-spectrum  $\beta$ -lactamase-producing *Escherichia coli* and *Klebsiella pneumoniae* in an urban hospital in Dhaka, Bangladesh. *Int. J. Antimicrob. Agents* 24:508-510.
- Rahman M, Shoma S, Rashid H, Siddique AK, Nair GB, Sack DA (2004b). Extended-spectrum  $\beta$ -lactamase-mediated third-generation cephalosporin resistance in *Shigella* isolates in Bangladesh. *J. Antimicrob. Chemother.* 54(4):846-847.
- Shukla I, Tiwari R, Agrawal M (2004). Prevalence of Extended Spectrum  $\beta$ -Lactamase-Producing *Klebsiella pneumoniae* In Tertiary Care Hospital. *Indian J. Med. Microbiol.* 22(2):87-91.
- Sirot D (1995). Extended-spectrum plasmid-mediated  $\beta$ -lactamases. *J. Antimicrob. Chemother.* 36:Suppl A S19-34.
- Thomson KS (2001). Controversies about Extended-spectrum and AmpC  $\beta$ -lactamases, *Emerg. Infect. Dis.* 7(2):333-336.
- Washington JAll (1985). Susceptibility tests. In: Lennette E H, Balows A, Hausser WJ. Eds. *Manual of clinical microbiology*. 4th ed. American Society of Microbiology. Washington D C. pp. 967-971.
- Weber G, Riesenberk K, Schlaeffer F, Peled N, Borer A, Yagupsky P (1997). Changing trends in frequency and antimicrobial resistance of urinary pathogens in outpatient clinics and a hospital in Southern Israel, 1991-1995. *European J. Clin. Microbiol. Infect. Dis.* 16(11):834-838.