Original paper

Antibiotic resistance features in Klebsiella pneumoniae and Escherichia coli strains isolated from hospital and community acquired urinary tract infections

AL SHAIKHLI NAWFAL HAITHAM¹,²,³, VIOLETA CORINA CRISTEA⁴, IRINA GHEORGHE¹,², SAJJAD MOHSIN IRRAYIF¹,², HAMZAH BASIL MOHAMMED¹,², OMAR SADIK⁵, GRIGORE MIHAESCU¹

¹University of Bucharest, Faculty of Biology, Dept. of Botanics and, Bucharest, Romania
²Research Institute of the University of Bucharest, Earth, Environmental and Life Sciences Section-ICUB, Bucharest, Romania
³University of Baghdad, College of Education for Pure Science (Ibn Al-Haitham), Department of Biology, Iraq
⁴Central Reference Synevo-Medicover Laboratory, Bucharest, Romania
⁵Middle Technical University – College of Health and Medical Technology, Baghdad, Iraq

All authors have equally contributed to this paper as main authors

Abstract

A total number of 35 strains (n=23 of K. pneumoniae and n=12 of E.coli) were isolated in May 2017 from patients with UTI, hospitalized in the National Institute for Cardiovascular Diseases Prof. C.C. Iliescu and from community infections (CA) diagnosed in Central Reference Synevo-Medicover Laboratory from Bucharest. The hospital strains were identified by BD Phoenix and the CA ones by mass spectrometry using MALDI Biotyper. The antibiotic susceptibility was determined by agar disk diffusion (CLSI, 2017) and automated methods (BD Phoenix and Vitek II system). For molecular characterization, all strains were analyzed be using PCR amplification. The investigated strains revealed the presence of tetracycline resistance gene, i.e. tet(A) (67% in E. coli and 45% of K. pneumoniae strains), tet(D) (8% of E. coli and 5% of K. pneumoniae strains), carbapenemase genes (blaOXA-48 in 40% of the K. pneumoniae strains); blaTEM (25% of E. coli strains and 10% of K. pneumoniae strains).

Keywords

Community-acquired infections (CA), UTIs, Escherichia coli.

To cite this article: HAITHAM ASN, CRISTEA VC, GHEORGHE I, IRRAYIF SM, MOHAMMED HB, SADIK S, MIHAESCU G. Antibiotic resistance features in Klebsiella pneumoniae and Escherichia coli strains isolated from hospital and community acquired urinary tract infections. Rom Biotechnol Lett. 2021; 26(1): 2244-2248. DOI: 10.25083/rbl/26.1/2244.2248

*Corresponding author: IRINA GHEORGHE, University of Bucharest, Faculty of Biology, Dept. of Botanics and, Bucharest, Romania
E-mail: iryna_84@yahoo.com
Introduction

Urinary tract infections (UTIs) are one of the most common pathological conditions, with a variety of clinical symptoms, caused by the colonization and invasion of the urinary tract by different microbial species (AL-BADR A. & al [1]). UTIs are the most common infectious diseases in either community or in health-care institutions. UTIs can be uncomplicated or complicated. Uncomplicated UTIs are usually found in sexually active healthy female patients with no history suggesting abnormalities of the urinary tract (GUPTA K. & al [15]). Complicated UTIs are usually found in both women and men of different ages and are often associated with structural or functional urinary tract abnormalities (PALLETT A. & al [27]) (LICHTENBERGER P. & al [21]). If not diagnosed or diagnosed too late UTIs will lead to renal failure. The most common uropathogenic Gram-negative bacteria are E. coli and K. pneumoniae (OBIODGBOLU C.H. & al [25]). Depending on how the infection is acquired, there are two types of UTI, i.e. hospital-acquired (HA) and community-acquired UTIs (CA) (SHALINI MAYA A. & al [31]). In case of HA-UTI the onset of urinary tract infection in patients occurs after 48 hours after admission, whereas CA-UTIs refer to the development of infections before admission to hospital and not within 10 days after the patient exit (SHALINI MAYA A. & al [31], WAGENLEHNER FME & al [32]). E. coli is the most common cause of both hospitals acquired and community UTIs (DIAS NETO J.A. & al [10], NERURKAR A & al [24]). Other common uropathogens encountered in CA-UTIs include Staphylococcus saprophyticus, K. pneumoniae, and Citrobacter sp. (GYANSA-LUTTERODT M. & al [16], BAHADIN J. & al [3]). The etiology of HA-UTI is more diverse and includes a wide range of organisms such as P. aeruginosa and Proteus spp., which are barely encountered in CA-UTIs (MITTAL R. & al [22]; RONALD A. [30]). CA-UTI is commonly uncomplicated, and risk factors typically include sexual activity and the use of contraception methods (FOX Y.S. & al [1]). Other common uropathogens encountered in hospital-acquired UTIs (MITTAL R. & al [1], K. pneumoniae, and others) responsible for resistance against penicillins, cephalosporins and aztreonam (CANTON R. & al [6]). The spread of ESBL-producing bacteria worldwide has become a serious public health being a frequent cause of infection in healthcare centres and in the community: it is estimated that around 50% of non-hospitalised patients are infected with a resistant strain, although it may be difficult to establish boundaries between community and nosocomial cases (YANG Y.S. & al [33]). Although a global problem, antibiotic resistance of uropathogens raises more significance in the developing world, where treatment options are limited.

The aim of this study was to characterize the phenotypic and genotypic resistance profiles of uropathogenic E. coli and K. pneumoniae strains isolated from HA- and CA- UTIs.

Material and Methods

1. Bacterial Strains

In this study, a total number of 35 strains (n=23 of K. pneumoniae and n=12 of E. coli) were isolated in May 2017 from patients with UTIs, hospitalized in the National Institute for Cardiovascular Diseases Prof. C.C. Iliescu and from community infections (CA) in Central Reference Synevo-Medicover Laboratory from Bucharest. The HA strains were identified by BD Phoenix and the CA ones by mass spectrometry using MALDI Biotyper. All selected strains exhibited multidrug resistance (MDR) and extended spectrum β-lactamases (ESBL).

2. Antimicrobial Susceptibility Testing

The antimicrobial susceptibility profiles for the K. pneumoniae and E. coli strains were determined by agar disk diffusion (CLSI, 2017) and automated methods (BD Phoenix and Vitrek II system).

3. Molecular investigation

The resistance genes (carbapenemases, ESBLs, aminoglycosides, quinolones and tetracyclines) were investigated by simplex and multiplex PCR, using a reaction mix of 20 µl (PCR Master Mix 2x, Thermo Scientific) containing 1 µl of bacterial DNA extracted using the alkaline extraction method. For this purpose, 1-5 colonies of bacterial cultures were suspended in 1.5 ml tubes containing 20 µl solution of NaOH 0.05M (sodium hydroxide) and SDS 0.25% (sodium dodecyl sulphate) and heated on a thermo block at 95°C for 15 min. for the permeabilization of bacterial cell wall. The following step was the addition of 180 µl of TE buffer (TRIS+EDTA) 1X and centrifugation at 13000 rpm for 3 min., and the supernatant was used as the DNA template for the polymerase chain reaction (PCR) on a Corbet Thermal Cycler. The primers used for the detection of carbapenemase resistance genes blaOXA-48, blaTEM and tetracycline resistance genes tet(A), tet(B), tet(C), tet(D) and PCR conditions are presented in the Tables no. 1, 2, 3, 4.

The resulting PCR products were subjected to electrophoretic migration on a 1.5% agarose gel, followed by the visualization of ampiclons after staining with ethidium bromide (7 µg/ml) under UV trans illuminator. DNA bands of each amplicon were compared with specific molecular weight 1000-bp DNA marker (Table 1).
Results and Discussion

Antimicrobial Susceptibility Profiles of the UTI isolates

In this study, the resistance profiles of 35 strains (23 K. pneumoniae and 12 E. coli) isolated from patients with CA- and HA-UTIs were investigated by phenotypic and genotypic approaches. The β-lactam drugs are one of the most effective drugs for the UTI treatment. The ESBL-producing bacteria, with inactivation of a wide range of β-lactam drugs especially cephalosporins and monobactams, cause treatment failure and increase healthcare costs. Therefore, the study of β-lactams resistance mechanisms is important. It seems that the emergence and spread of these bacteria are due to prolonged hospitalization, increased consumption of β-lactam antibiotics (especially ceftazidime), use of catheters, and experimental treatments against antibiotic resistant strains (EJAZ H & al [12]). The PCR screening revealed the presence of the β-lactamase encoding genes (blaOXA-48 was present in 40% of the K. pneumoniae isolates) and of blaTEM (25% of E. coli and 10% of K. pneumoniae strains) and of tetracycline resistance genes: tet(A) (67% of E. coli and 45% of K. pneumoniae strains) and tet(D) (8% of E. coli and 5% of K. pneumoniae investigated strains. The OXA-48carbapenemase was first described in K. pneumoniae epidemic isolates from Turkey and then in several European countries, such as France and Belgium. Recently, it has also been identified in enterobacterial isolates recovered from non-European countries, such as Lebanon, Tunisia, Senegal, Morocco, Israel, and India (GOREN MG & al [14]; KTARI S & al [19]; LASCOLS C & al [20]; MOQUET O & al [23]; POIREL & al [29]). In E. coli strains, the most prevalent gene responsible for β-lactams resistance was blaTEM.

Table 1. Reaction components used in the PCR experiments

| Primer F&R | MgCl₂ | DNTP | DNA Taq-pol | Reaction buffer | DNA template | Concentration | Final volume |
|------------|-------|------|-------------|----------------|--------------|---------------|--------------|
| 0.5 µM     | 1.2 mM| 2 µM | 0.2 U       | 1x             | 10x          | 20 µl         |

Table 2. The amplification program for carbapenems resistance genes

| Gene      | Initial denaturation | Numbers of cycle | Denaturation in each cycle | Annealing | Extension primer |
|-----------|----------------------|------------------|---------------------------|-----------|------------------|
| blaOXA-48 | 95°C for 5 min       | 30               | 95°C, 30 sec              | 55°C, 40 sec | 72°C, 5 min     |
| blaTEM    | 95°C for 5 min       | 35               | 95°C, 30 sec              | 59°C, 40 sec | 72°C, 10 min    |

Table 3. The amplification program for tetracycline resistance genes

| Genes   | Initial denaturation | Number of cycle | Denaturation in each cycle | Annealing | Extension primer |
|---------|----------------------|-----------------|---------------------------|-----------|------------------|
| tet(A)  | 94°C for 5 min       | 25              | 94°C, 30 sec              | 61°C, 30 sec | 61°C, 7 min     |
| tet(B)  | 94°C for 5 min       | 25              | 94°C, 30 sec              | 60°C, 30 sec | 68°C, 7 min     |
| tet(C)  | 94°C for 5 min       | 25              | 94°C, 30 sec              | 60°C, 30 sec | 68°C, 7 min     |
| tet(D)  | 94°C for 5 min       | 25              | 94°C, 30 sec              | 60°C, 30 sec | 68°C, 7 min     |

Table 4. Primer sequences and amplicons for selected genes

| The gene | Primer | Nucleotide sequence | Amplification size(bp) | References |
|----------|--------|---------------------|------------------------|------------|
| blaOXA-48| N/A    | 5' GCGTAGAGGATCCACAGGACG-3' | 438 | (OKEKE I.N. & al [26]) |
| blaTEM   | N/A    | 5'CATCAAGTTCAACCCAACCG-3' | 861 | (FOXMAN B. [13]) |
| tet(A)   | N/A    | 5'GCCGGATCTGGTTACCCACCTCG-3' | 164 | (AMINO R. & al [2]) |
| tet(B)   | N/A    | 5'ATACGACATCCAAAGGCCAC-3' | 206 | (AMINO R. & al [2]) |
| tet(C)   | N/A    | 5'GCCGGATATCGGGATCCACCTCG-3' | 207 | (AMINO R. & al [2]) |
| tet(D)   | N/A    | 5'GCCGTAGAGGATCCACAGGACG-3' | 187 | (OKEKE I.N. & al [26]) |
Antibiotic resistance features in Klebsiella pneumoniae and Escherichia coli strains isolated from hospital

(13%). Extended-spectrum TEM β-lactamases are derived from TEM-1 and TEM-2 enzymes. TEM-1 is the most important β-lactamase in Gram-negative bacteria. Both TEM-1 and TEM-2 are capable of hydrolyzing penicillins and first generation cephalosporins, but are not able to degrade oxyimino – cephalosporins (Bonomo RA & al [5]; Pitout JD & al [28]). A study from Iran reported a prevalence of 59.2% for ESBLs production in K. pneumoniae and E. coli strains, while in Japan and USA the prevalence rate was reported to be of 40 and 44% respectively (Pitout JD & al [28]; Coque TM & al [9]). Recently, a study performed by Baidu et al reported that the carbapenem resistance genes of K. pneumoniae most frequently detected in Romanian patients were OXA 48 (73,77% of cases), while 13,11%, of isolates presented the combinations blaOXA-48 and blanDM (Baidu et al [34]). The analyzed strains showed increase of resistance to antibiotics from other classes indicating the presence of MDR phenotypes. From the non β-lactam antibiotics, tetracyclines registered the highest resistance rates, the K. pneumoniae strains carrying the tet(A) (62%) and followed by the tet(D) (7%) gene while, the E. coli strains harboured less frequently, both tet(A) (28%) and tet(D) (3%). Tetracyclines and other antibiotics have been frequently used to treat diseases, but unfortunately repeated use of these compounds has resulted in the development of resistant strains (Chopra I & al [8]). A study performed in Iran on UTIs K. pneumoniae isolates has also demonstrated a high resistance rate to tetracyclines (50%) (Bokaeian M & al [4]). As the investments for development of new antibiotics remain insufficient in the scope of drug development while resistance trends are increasing alarmingly, clinicians need to apply new therapeutic strategies to fight infections (i.e. synergistic drug combinations) (UNLU [35]).

Conclusion

Urinary tract infections are among the most common bacterial infections, with high costs for the medical care. K. pneumoniae and E. coli uropathogens have been shown to be the most prevalent bacterial strain isolated from patients hospitalized or diagnosed in ambulatory from Bucharest, Romania. The high rates of resistance threaten the efficiency of the antibiotic treatment. Therefore, the discovery of new appropriate treatments as well as the improvement of the prevention methods are required. This study shows the high prevalence of resistance genes, in particularly of bla-OXA-48, blaTEM and tet(A). Therefore, continuous surveillance is essential to monitor the occurrence and dissemination of these resistant microorganisms in both hospitals and community.

Acknowledgements

The financial support of the Research Projects PN-III-P1.1-PD-2016-1798 (PD 148/2018) and PN-III-P4-ID-PCCF-2016-0114 awarded by UEFISCDI is gratefully acknowledged, and appreciation to Iraqi government for financial grant of the PhD study (PhD student AL SHAIKHLI NAWFAL HAITHAM).

References

1. Al-Badr A. & al-Shaikh G. (2013). Recurrent urinary tract infections management in women: a review. Sultan Qaboos University Medical Journal, 13(3), 359.
2. Aminov R., Chee-Sanford J., Garrigues N., Teferedegne B., Krapac I., White B.A. & Mackie R.I. (2002). Development, validation, and application of PCR primers for detection of tetracycline efflux genes of gram-negative bacteria. Appl. Environ. Microbiol., 68(4), 1786-1793.
3. Bahadin J., Teo S. & Mathew S. (2011). Aetiology of community-acquired urinary tract infection and antimicrobial susceptibility patterns of uropathogens isolated. Singapore medical journal, 52(6), 415-420.
4. Bokaeian M., Saedi S., Shahi Z. & Kadaei V. (2014). TetA and tetB Genes in Klebsiella pneumoniae isolated from clinical samples. Gene, Cell and Tissue, 1(2).
5. Bonomo R.A. & Szabo D. (2006). Mechanisms of multidrug resistance in Acinetobacter species and Pseudomonas aeruginosa. Clinical infectious diseases, 43(Supplement_2), S49-S56.
6. Cantón R., Valverde A., Novais A., Baquero F. & Coque T. (2007). Evolución y panorama actual de las BLEE. Enferm Infecc Microbiol Clin, 25(Supl 2), 2-10.
7. Chin T.L., Mcnulty C., Beck C. & Macgowan A. (2016). Antimicrobial resistance surveillance in urinary tract infections in primary care. Journal of antimicrobial chemotherapy, 71(10), 2723-2728.
8. Chopra I. & Roberts M. (2001). Tetracycline antibiotics: mode of action, applications, molecular biology, and epidemiology of bacterial resistance. Microbiol. Mol. Biol. Rev., 65(2), 232-260.
9. Coque T., Baquero F. & Canto R. (2008). Increasing prevalence of ESBL-producing Enterobacteriaceae in Europe. Eurosurveillance, 13(47), 1904.
10. Dias Neto J.A., Martins A.C.P., Silva L.D., M.D., Tiraboschi R.B., Domingos A.L.A., Cologna A.J., Tucci Jr S. (2003). Community acquired urinary tract infection: etiology and bacterial susceptibility. Acta Cirurgica Brasileira, 18, 33-36.
11. Donkor E.S., Tetteh P.B., Nartey P. & Agyeman I.O. (2012). Self-medication practices with antibiotics among tertiary level students in Accra, Ghana: a cross-sectional study. International journal of environmental research and public health, 9(10), 3519-3529.
12. Eiaz H., Zaza A., Mahmod S. & Javed M.M. (2011). Urinary tract infections caused by extended spectrum β-lactamase (ESBL) producing Escherichia coli and Klebsiella pneumoniae. African Journal of Biotechnology, 10(73), 16661-16666.
13. Foxman B. (2013). Urinary tract infection syndromes: occurrence, recurrence, bacteriology, risk factors, and
disease burden. *Infectious disease clinics of North America*, 28(1), 1-13.

14. GOREN M.G., CHMELNITSKY I., CARMELI Y. & NAVON-VENEZIA S. (2010). Plasmid-encoded OXA-48. *Antimicrob Agents Chemother*, 54, 4914-4916.

15. GUPTA K., GRIGORYAN L. & TRAUTNER B. (2017). Urinary tract infection. *Annals of internal medicine*, 167(7), ITC49-ITC64.

16. GYANSA-LUTTERODT M., AFRIYIE D., ASARE G., AMPONSAH S., ABUTIATE H. & DARKO D. (2014). Antimicrobial use and susceptibility pattern of uropathogens associated with urinary tract infections at the Ghana Police Hospital. *Glob J Pharmacol*, 8, 306-315.

17. HOOTON T.M. (2012). Uncomplicated urinary tract infection. *New England Journal of Medicine*, 366(11), 1028-1037.

18. IACOVELLI V., GAZIEV G., TOPAZIO L., BOVE P., VESPASIANI G. & AGRO E.F. (2014). Nosocomial urinary tract infections: A review. *Urologia Journal*, 81(4), 222-227.

19. KTARI S., MNIF B., LOUATI F., REKIK S., MEZGHANI S., MAHJOUBI F. & HAMMAMI A. (2011). Spread of Klebsiella pneumoniae isolates producing OXA-48 β-lactamase in a Tunisian university hospital. *Journal of antimicrobial chemotherapy*, 66(7), 1644-1646.

20. LASCOLS C., HACKEL M., MARSHALL S.H., HUJER A.M., BOUCHILLON S., BADAL R., BONOMO R.A. (2011). Increasing prevalence and dissemination of NDM-1 metallo-β-lactamase in India: data from the SMART study (2009). *Journal of antimicrobial chemotherapy*, 66(9), 1992-1997.

21. LICHTENBERGER P. & HOOTON T.M. (2008). Complicated urinary tract infections. *Current infectious disease reports*, 10(6), 499-504.

22. MITTAL R., AGGARWAL S., SHARMA S., CHHIBBER S. & HARJAI K. (2009). Urinary tract infections caused by Pseudomonas aeruginosa: a mini-review. *Journal of infection and public health*, 2(3), 101-111.

23. MOQUET O., BOUCHIAT C., KINANA A., SECK A., AROUNA O., BERCION R., GARIN B. (2011). Class D OXA-48 carbapenemase in multidrug-resistant enterobacteria, Senegal. *Emerging infectious diseases*, 17(1), 143.

24. NEURURKAR A., SOLANKY P. & NAIK S S. (2012). Bacterial pathogens in urinary tract infection and antibiotic susceptibility pattern. *Journal of Pharmaceutical and Biomedical Sciences*, 21(21).

25. OBIOGBOLU C., OKONKO I., ANYAMERE C., ADEDEJI A., AKANBI A., OGUN A., FALEYE T. (2009). Incidence of urinary tract infections (UTIs) among pregnant women in Akwa metropolis, South-eastern Nigeria. *Sci Res Essays*, 4(8), 820-824.

26. OKEKE I.N., LAMIKANRA A. & EDELMAN R. (1999). Socioeconomic and behavioral factors leading to acquired bacterial resistance to antibiotics in developing countries. Emerging infectious diseases, 5(1), 18.

27. PALLET T.A. & HAND K. (2010). Complicated urinary tract infections: practical solutions for the treatment of multiresistant Gram-negative bacteria. *Journal of antimicrobial chemotherapy*, 65(suppl_3), iii25-iii33.

28. PITOUT J.D., NORDMANN P., LAUPLAND K.B. & POIREL L. (2005). Emergence of Enterobacteriaceae producing extended-spectrum β-lactamases (ESBLs) in the community. *Journal of antimicrobial chemotherapy*, 56(1), 52-59.

29. POIREL L., ROS A., CARRÉR A., FORTINEAU N., CARRICAJO A., BERTHELOT P. & NORDMANN P. (2011). Cross-border transmission of OXA-48-producing Enterobacter cloacae from Morocco to France. *Journal of antimicrobial chemotherapy*, 66(5), 1181-1182.

30. RONALD A. (2002). The etiology of urinary tract infection: traditional and emerging pathogens. *The American journal of medicine*, 113(1), 14-19.

31. SHALINI MAYA A., PRABHAKAR K. & LAKSHMI SARAYU Y. (2010). A Study on prevalence and evaluation of clinical isolates from community acquired infections using different media in semiurban areas. *World J Med Sci*, 5(2), 49-53.

32. WAGENLEHNER F.M. & NABER K.G. (2006). Treatment of bacterial urinary tract infections: presence and future. *European urology*, 49(2), 235-244.

33. YANG Y.-S., KU C.-H., LIN J.-C., SHANG S.-T., CHIU C.-H., YEH K.-M., CHANG F.-Y. (2010). Impact of extended-spectrum β-lactamase-producing Escherichia coli and Klebsiella pneumoniae on the outcome of community-onset bacteremic urinary tract infections. *Journal of Microbiology, Immunology and Infection*, 43(3), 194-199.

34. BAICUS A., LIXANDRU B., STROIA M., CIRSTOIU M., CONSTANTIN A., USEIN C.R., CIRSTOIU C.F. (2018). Antimicrobial susceptibility and molecular epidemiology of carbapenem-resistant Klebsiella pneumoniae strains isolated in an emergency university hospital. *Rom Biotechnol Lett*, 23(3): 13525-29.

35. UNLU O., YILANCI OGLU K. Exploration of Synergistic Antibiotic Interactions in Klebsiella pneumoniae. *Rom Biotechnol Lett*. 2020; 25(1): 1246-1252. DOI: 10.25083/rbl/25.1/1246.1252