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# Beneficial antimicrobial treatment options for pan-drug-resistant bacterial species

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**Abstract**

The World Health Organization (WHO) has issued a warning that antibiotic resistance is a problem that must be effectively addressed and controlled that it poses serious challenges to the existing healthcare system. Pan-drug-resistant (PDR) infections are caused by microbes that have evolved methods to withstand all forms of antimicrobial treatment, such as those that impede drug absorption, alter drug targets, inactivate drugs, or utilize efflux pumps. The importance of treating this sort of medication resistance is underscored by the fact that the development of new therapies to treat it pushes clinicians to take action. Only a few numbers of antibiotics, particularly when used in combination, are successful against PDR Gram-negative bacteria such *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, *Klebsiella pneumoniae*, and *Escherichia coli*. Treatment of PDR *A. baumannii* is best accomplished using tigecycline in collaboration with colestimethate, imipenem, or amikacin. The use of β-lactamase antagonists, including ceftolozane-tazobactam or imipenem-cilastatin-relebactam, is the greatest effective method of treating PDR *P. aeruginosa*. Nitrofurantoin, fosfomycin, and pivmecillinam appear to be the best successful medication for the treatment of PDR *E. coli*, whereas tigecycline and colistin have been used to treat PDR *K. pneumoniae* throughout the last several decades. Despite the fact that these medications fight PDR infections quite well, there is a pressing need for the development of new substances and techniques of countering resistance since antibiotic resistance is increasing every day in microbial species throughout the globe.

**Keywords**: Antibiotic resistance, antimicrobial drugs.

## Introduction

Bacterial resistance (figure 1) to existing antimicrobials is a global health threat. This problem has arisen since there are no effective antimicrobials to combat the bacterium. All Gram-positive and Gram-negative microorganisms may develop resistance to antibiotics, and this issue has prompted a number of new scientific nomenclature to describe the phenomenon (1). The concept of multidrug-resistant organisms (MDR) is a microorganism that is resistant to more than one antimicrobial drugs, rendering therapy unsuccessful towards the illness or delaying therapy and putting the patient's health at risk (2). Pathogens that fall into the "extensively drug-resistant" (XDR) category are not only resistant to many antibacterial agents but also have the ominous capability of becoming resistant to practically all permitted antimicrobials, producing them to be epidemiologically significant. Mycobacterium tuberculosis (MTB) strains that are resistant to all four first-line substances (rifampicin and amikacin, or capreomycin) and one of the second-line substances (amikacin or capreomycin) were originally referred to as an XDR (3,4).

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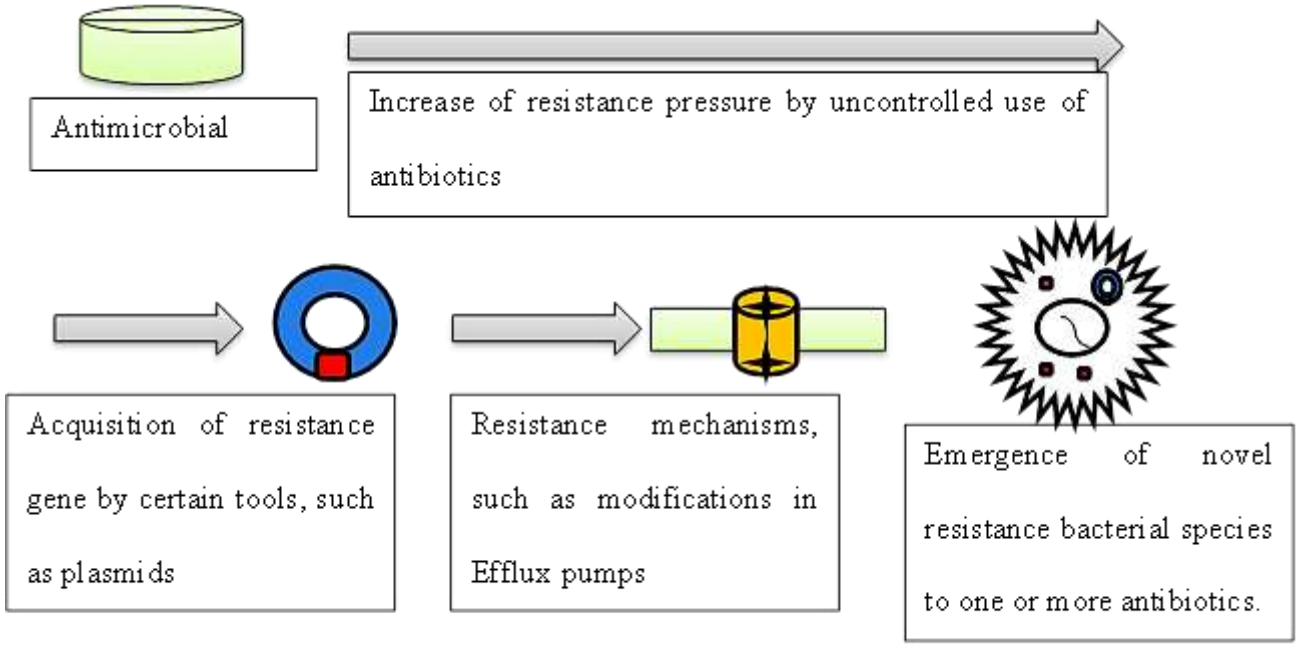


**Figure 1**: Bacterial resistance

Resistance to all antimicrobial substances is known as PDR. Overuse of broad-spectrum antibiotics in medicine has led to bacteria becoming resistant to several antibiotics, creating a major public health risk known as PDR infections. Since these microorganisms are becoming more resistant to all currently employed antibacterial drugs or are only responsive to older, possibly more toxic medicines like polymyxins and tigecycline, treatment options for infections are becoming increasingly constrained and suboptimal. Some of the most important bacteria are Gram-negative PDR strains include *P. aeruginosa, A. baumannii*, *K. pneumoniae*, and *E. coli*, and they are only susceptible to a small subset of antibiotics (5,6). Due to their high stability, high infection occurrence, and resistance to antimicrobial agents, PDR bacteria are extensively spread in the health care facilities (7,8).

There is also controversy around the effectiveness and sensitivity of resistant pathogens while using antibiotics in clinical settings, since PDR microorganisms rapidly develop resistance strategies. Consequently, describing a universal treatment protocol for treating PDR illnesses in sick patients is challenging (9,10). In this scoping review, we'll discuss the most current developments in antibiotic therapy for PDR diseases and the strategies that have been most successful in managing them.

**Antimicrobial resistance**

The incidence of antibiotic resistance is a complex problem with several aspects. The World Health Organization (WHO) has issued a warning that antibiotic resistance is a problem that must be effectively addressed and controlled that it poses serious challenges to the existing healthcare system. Even before penicillin was widely produced, in 1943, bacteria belonging to the genus Staphylococcus were found to be resistant to it; this suggests that the bacteria likely have a genetic predisposition for resistance, which has been increasing over time (11). Therefore, bacteria may develop resistance to drugs by processes that need no input from humans. Even so, since penicillin was introduced as an intervention for pathogenic bacteria, the accomplishment of bacterial species to obtain such opposition has been speeded up. This, merged with the widely misuse of antibiotics across human, animal, and agricultural settings, has quickly amplified this concept (12).

The issue of what is driving the alarming rise in antibiotic resistance is an important one. A major contributor to the worldwide spread of antibiotic-resistant infections is the careless use of existing medicines. This is compounded by the slow pace at which new, effective antibiotics are being developed. The present stagnation in antibiotic development and study is a multifaceted issue with several potential causes. Antibiotic pipeline departments of many major pharmaceutical companies have been cut down or

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eliminated recently because to low profitability. A negative risk-reward ratio is the result of the pharmaceuticals' limited use and short shelf life, rising regulatory costs, rising generic competition, and eventual resistance leading to larger decreases in drug usage (13).

**Treatment of pan-drug-resistant bacterial species**

**Anti-*Pseudomonas aeruginosa* compounds**

P. aeruginosa is a very adaptable bacteria, able to thrive in a wide range of conditions. In addition to wreaking havoc on plants and animals, it may have devastating effects on people with impaired immune systems, such as cancer patients, burn victims, and those with cystic fibrosis (CF). This bacterium is a major factor for biofilms and pneumonia in intensive care units (ICUs), and it is also a major source of drug-resistant nosocomial infectious diseases. Individuals with cystic fibrosis were the first to report MDR-*P. aeruginosa*, and this strain has subsequently been reported to be circulating across hospitalized individuals (14–18).

Nosocomial infections (NCIs) and the incidence of P. aeruginosa strains insensitive to carbapenems or all antimicrobial drugs available for medical use are linked to individuals in ICUs and burn units. Carbapenems, ceftazidime, fourth-generation cephalosporins, ciprofloxacin, and aztreonam are all traditional anti-pseudomonal compounds that P. aeruginosa rapidly develops opposition to after being used for an elongated period of time in hospital admissions, particularly in ICU patients (19,20).

Cefepime, ceftazidime, carbapenems, and piperacillin-tazobactam are often used for the treatment of PDR P. aeruginosa illness, often in conjunction with an additional antibiotic from a different family, like from aminoglycosides, fluoroquinolones, or polymyxins (21). The use of a single recently identified or developed β-lactamase antagonist, including ceftolozane-tazobactam, imipenem-cilastatin-relebactam, or ceftazidime-avibactam is advisable to combine treatment with traditional drugs when the use of traditional β-lactams for the fighting of *P. aeruginosa* PDR-illnesses (22,23). Cefiderocol, over the utilization of combination of standard antibiotic agents, is the preferred treatment for acute PDR caused by P. aeruginosa if β-lactamase antagonists are unavailable (22,24,25).

**Anti-*Klebsiella pneumoniae* compounds**

Among the most primary triggers of NCIs in inpatients is K. pneumoniae, a major bacterial infection. Over the last years, K. pneumoniae has seen an increase in the frequency with which it is recovered in the treatment center, and in many regions, it has surpassed E. coli as the highest often identified Gram-negative bacillus. Occurrence of carbapenem-resistant K. pneumoniae poses a serious threat to community health since there are now no good treatment alternatives for this kind of illness. One of the most important carbapenemases identified in K. pneumoniae is called kpc, and its possession has resulted in resistance to all beta-lactams in this microbe, making treatment of diseases generated by it difficult to achieve (26,27).

Infections caused by carbapenem-resistant K. pneumoniae are difficult to treat because the bacteria are resistant to antibiotics including tigecycline and colistin, a class of bacteria called as PDR bacteria or super bacteria (28). In several hospitals across many countries, PDR K. pneumoniae has been detected. Resistance to Beta -Lactams, aminoglycosides, fosfomycins, and quinolones is all common features among KPC-possessing K. pneumoniae isolates. Infections caused by KPC-causing PDR K. pneumoniae may be effectively treated with tigecycline or colistin (29). At the time of its first clinical use, tigecycline proved effective against the vast majority of KPC-possessing K. pneumoniae; now, colistin is recognized as the final option for the treatment of illnesses caused by carbapenem-resistant K. pneumoniae strains (30–32).

**Anti-*Escherichia coli* compounds**

The species Escherichia coli (E. coli) is the classic member of the family Enterobacteriaceae and the most common facultative anaerobe bacterium in the human intestines. Some strains may now affect the digestive tract, the urinary tract (UT), and even the brain and spinal cord. Since effective treatments are not currently available, UT infections (UTIs) associated with antimicrobial agent resistance of E. coli, particularly PDR UTIs, are becoming more alarming. It is crucial to understand the regional vulnerability profiles of the most frequent uropathogens in order to choose the best antimicrobial treatment for UTIs (33,34).

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For healthful, nonpregnant women with acute, uncomplicated cystitis, a term of nitrofurantoin, pivmecillinam, or fosfomycin tromethamine is advised. Patients who have lately used these substances or who are dealing with an infection caused by extended-spectrum -lactamases (ESBLs)-generating E. coli are at increased risk of developing resistance to these and other antibiotics, limiting their utility as treatments for UTIs in various nations. Oral cephalosporins like cephalexin and cefixime generations, fluoroquinolone substances, and beta-lactams like amoxicillin-clavulanate are all options for secondary treatment (35,36).

Fosfomycin, pivmecillinam, nitrofurantoin, fluoroquinolones, piperacillin-tazobactam, cefepime, and carbapenems are all viable options for treating UTIs caused by E. coli that may develop AmpC—lactamase. Treatment options for ESBLs-E. coli-related UTIs involve the use of nitrofurantoin, fosfomycin, pivmecillinam, finafloxacin, amoxicillin-clavulanate, and sitafloxacin, whereas pivmecillinam, finafloxacin, ffosfomycin, and sitafloxacin are also viable oral treatment options. In order to combat the spread of drug-resistant strains and the loss of effective treatments, it is crucial to use novel antimicrobials in the treatment of illnesses brought on by such germs (37,38).

**Anti- *Acinetobacter baumannii* compounds**

the aerobic Gram-negative coccobacillus *A. baumannii* is a significant NCI pathogen due to its several drug-resistance pathways, and it may be a challenging germ for specialists to treat. Infections in certain conditions and body locations like pneumonia, wounds, UTI, and intra-abdomen are only few of the diseases it might lead to. There has been an upsurge in the incidence of *A. baumannii* with carbapenem-resistant phenotypes during the last two years. High death rates and challenging eradication have resulted from the development and spread of the PDR *A. baumannii* isolates in healthcare facilities (39,40).

Antibiotics like carbapenems formerly had a great deal of success in treating patients, but now a growing number of pathogens are becoming resistant to them. Individuals with PDR *A. baumannii* are often treated with unconventional compounds such polymyxin E and polymyxin B, regardless the toxicity of these drugs. Some isolates have also developed resistance to certain antimicrobial agents while being treated with them (39,40).

The use of pharmacological strategies, such as the introduction of novel antibacterial medications or the strategic deployment of antimicrobial synergistically combined treatments, has become more important in the fight against these illnesses (41). Tigecycline has also been approved for the treatment of digestive tract and dermatological infections induced by vulnerable bacteria. Infections caused by PDR bacteria respond well to tigecycline therapy, either when used alone or in combination with additional antibacterial drugs such imipenem, amikacin, colestimethate, and ampicillin-sulbactam (42). Mixtures of imipenem-colestimethate and tigecycline-imipenem were also very efficient (43). These findings highlight the value of synergistic intake to enhance the efficacy of certain antibacterial drug combinations towards PDR *Acinetobacter baumannii* based infections.

**References**

1. Catalano A, Iacopetta D, Ceramella J, Scumaci D, Giuzio F, Saturnino C, et al. Multidrug Resistance (MDR): A Widespread Phenomenon in Pharmacological Therapies. Molecules [Internet]. 2022 Feb 1 [cited 2022 Dec 25];27(3):616. Available from: /pmc/articles/PMC8839222/
2. Ozma MA, Khodadadi E, Rezaee MA, Asgharzadeh M, Aghazadeh M, Zeinalzadeh E, et al. Bacterial Proteomics and its Application in Pathogenesis Studies. Curr Pharm Biotechnol [Internet]. 2022 Sep 10 [cited 2022 Dec 25];23(10):1245–56. Available from: https://pubmed.ncbi.nlm.nih.gov/34503411/
3. Pillay S, Steingart KR, Davies GR, Chaplin M, De Vos M, Schumacher SG, et al. Xpert MTB/XDR for detection of pulmonary tuberculosis and resistance to isoniazid, fluoroquinolones, ethionamide, and amikacin. Cochrane Database Syst Rev [Internet]. 2022 May 18 [cited 2022 Dec 25];2022(5):CD014841. Available from: /pmc/articles/PMC9115865/
4. Ozma MA, Rashedi J, Poor BM, Vegari A, Asgharzadeh V, Kafil HS, et al. Tuberculosis and Diabetes Mellitus in Northwest of Iran. Infect Disord Drug Targets [Internet]. 2020 Jul 19 [cited 2022 Dec 25];20(5):667–71. Available from: https://pubmed.ncbi.nlm.nih.gov/31322073/
5. Karakonstantis S, Kritsotakis EI, Gikas A. Pandrug-resistant Gram-negative bacteria: a systematic review of current epidemiology, prognosis and treatment options. J Antimicrob Chemother [Internet].

ISSN NO: 2771-8840
Date of Publication: 07-03-2023

2020 Feb 1 [cited 2022 Dec 25];75(2):271–82. Available from: https://pubmed.ncbi.nlm.nih.gov/31586417/

6. Ferry T, Kolenda C, Laurent F, Leboucher G, Merabischvilli M, Djebara S, et al. Personalized bacteriophage therapy to treat pandrug-resistant spinal Pseudomonas aeruginosa infection. Nat Commun [Internet]. 2022 Dec 1 [cited 2022 Dec 25];13(1):4239. Available from: /pmc/articles/PMC9306240/
7. Karakonstantis S, Ioannou P, Kofteridis DD. In search for a synergistic combination against pandrug-resistant A. baumannii; methodological considerations. Infection [Internet]. 2022 Jun 1 [cited 2022 Dec 25];50(3):569–81. Available from: https://pubmed.ncbi.nlm.nih.gov/34982411/
8. Karakonstantis S, Ioannou P, Samonis G, Kofteridis DP. Systematic review of antimicrobial combination options for pandrug-resistant acinetobacter baumannii. Antibiotics [Internet]. 2021 Nov 1 [cited 2022 Dec 25];10(11):1344. Available from: /pmc/articles/PMC8615225/
9. Bassetti M, Righi E, Vena A, Graziano E, Russo A, Peghin M. Risk stratification and treatment of ICU-acquired pneumonia caused by multidrug- resistant/extensively drug-resistant/pandrug-resistant bacteria. Curr Opin Crit Care [Internet]. 2018 [cited 2022 Dec 25];24(5):385–93. Available from: https://pubmed.ncbi.nlm.nih.gov/30156569/
10. Addis T, Araya S, Desta K. Occurrence of Multiple, Extensive and Pan Drug-Resistant Pseudomonas aeruginosa and Carbapenemase Production from Presumptive Isolates Stored in a Biobank at Ethiopian Public Health Institute. Infect Drug Resist [Internet]. 2021 [cited 2022 Dec 25];14(9):3609–18. Available from: /pmc/articles/PMC8427834/
11. Morehead MS, Scarbrough C. Emergence of Global Antibiotic Resistance. Prim Care [Internet]. 2018 Sep 1 [cited 2022 Dec 25];45(3):467–84. Available from: https://pubmed.ncbi.nlm.nih.gov/30115335/
12. Hwang AY, Gums JG. The emergence and evolution of antimicrobial resistance: Impact on a global scale. Bioorg Med Chem [Internet]. 2016 [cited 2022 Dec 25];24(24):6440–5. Available from: https://pubmed.ncbi.nlm.nih.gov/27117692/
13. Francine P. Systems Biology: New Insight into Antibiotic Resistance. Microorg 2022, Vol 10, Page 2362 [Internet]. 2022 Nov 29 [cited 2022 Dec 25];10(12):2362. Available from: https://www.mdpi.com/2076-2607/10/12/2362/htm
14. Ozma MA, Khodadadi E, Pakdel F, Kamounah FS, Yousefi M, Yousefi B, et al. Baicalin, a natural antimicrobial and anti-biofilm agent. J Herb Med. 2021 Jun 1;27(2):100432.
15. Vaez H, Salehi-Abargouei A, Ghalehnoo ZR, Khademi F. Multidrug Resistant Pseudomonas aeruginosa in Iran: A Systematic Review and Metaanalysis. J Glob Infect Dis [Internet]. 2018 Oct 1 [cited 2022 Dec 25];10(4):212–7. Available from: /pmc/articles/PMC6276320/
16. Raman G, Avendano EE, Chan J, Merchant S, Puzniak L. Risk factors for hospitalized patients with resistant or multidrug-resistant Pseudomonas aeruginosa infections: a systematic review and meta-analysis. Antimicrob Resist Infect Control [Internet]. 2018 Jul 4 [cited 2022 Dec 25];7(1):79. Available from: /pmc/articles/PMC6032536/
17. Rasamiravaka T, El Jaziri M. Quorum-Sensing Mechanisms and Bacterial Response to Antibiotics in P. aeruginosa. Curr Microbiol [Internet]. 2016 Nov 1 [cited 2022 Dec 25];73(5):747–53. Available from: https://pubmed.ncbi.nlm.nih.gov/27449213/
18. Ciofu O, Tolker-Nielsen T. Tolerance and Resistance of Pseudomonas aeruginosa Biofilms to Antimicrobial Agents—How P. aeruginosa Can Escape Antibiotics. Front Microbiol [Internet]. 2019 [cited 2022 Dec 25];10(5):913. Available from: /pmc/articles/PMC6509751/
19. Bassetti M, Castaldo N, Cattelan A, Mussini C, Righi E, Tascini C, et al. Ceftolozane/tazobactam for the treatment of serious Pseudomonas aeruginosa infections: a multicentre nationwide clinical experience. Int J Antimicrob Agents [Internet]. 2019 Apr 1 [cited 2022 Dec 25];53(4):408–15. Available from: https://pubmed.ncbi.nlm.nih.gov/30415002/
20. Gorityala BK, Guchhait G, Goswami S, Fernando DM, Kumar A, Zhanel GG, et al. Hybrid Antibiotic Overcomes Resistance in P. aeruginosa by Enhancing Outer Membrane Penetration and Reducing Efflux. J Med Chem [Internet]. 2016 Sep 22 [cited 2022 Dec 25];59(18):8441–55. Available from: https://pubmed.ncbi.nlm.nih.gov/27524179/
21. Zheng X, Cao Q, Cao Q, Mao F, Li X, Zhu J, et al. Discovery of synergistic activity of

ISSN NO: 2771-8840
Date of Publication: 07-03-2023

fluoroquinolones in combination with antimicrobial peptides against clinical polymyxin-resistant Pseudomonas aeruginosa DK2. Chinese Chem Lett. 2020 Feb 1;31(2):413–7.

22. Ulloa ER, Sakoulas G. Azithromycin: An Underappreciated Quinolone-Sparing Oral Treatment for Pseudomonas aeruginosa Infections. Antibiotics [Internet]. 2022 Apr 1 [cited 2022 Dec 25];11(4):515. Available from: /pmc/articles/PMC9024921/
23. Tamma PD, Aitken SL, Bonomo RA, Mathers AJ, van Duin D, Clancy CJ. Infectious Diseases Society of America Guidance on the Treatment of Extended-Spectrum β-lactamase Producing Enterobacterales (ESBL-E), Carbapenem-Resistant Enterobacterales (CRE), and Pseudomonas aeruginosa with Difficult-to-Treat Resistance (DTR-P. aerug. Clin Infect Dis [Internet]. 2021 Apr 8 [cited 2022 Dec 25];72(7):e169–83. Available from: https://pubmed.ncbi.nlm.nih.gov/33106864/
24. Samad T, Co JY, Witten J, Ribbeck K. Mucus and Mucin Environments Reduce the Efficacy of Polymyxin and Fluoroquinolone Antibiotics against Pseudomonas aeruginosa. ACS Biomater Sci Eng [Internet]. 2019 Mar 11 [cited 2022 Dec 25];5(3):1189–94. Available from: /pmc/articles/PMC9267971/
25. von Silva-Tarouca MSE, Wolf G, Mueller RS. Determination of minimum inhibitory concentrations for silver sulfadiazine and other topical antimicrobial agents against strains of Pseudomonas aeruginosa isolated from canine otitis externa. Vet Dermatol [Internet]. 2019 Apr 1 [cited 2022 Dec 25];30(2):145-e42. Available from: https://pubmed.ncbi.nlm.nih.gov/30663140/
26. Campos AC, Albiero J, Ecker AB, Kuroda CM, Meirelles LEF, Polato A, et al. Outbreak of Klebsiella pneumoniae carbapenemase-producing K pneumoniae: A systematic review. Am J Infect Control [Internet]. 2016 Nov 1 [cited 2022 Dec 25];44(11):1374–80. Available from: https://pubmed.ncbi.nlm.nih.gov/27156198/
27. Russo TA, Olson R, Fang CT, Stoesser N, Miller M, MacDonald U, et al. Identification of Biomarkers for Differentiation of Hypervirulent Klebsiella pneumoniae from Classical K. pneumoniae. J Clin Microbiol [Internet]. 2018 Sep 1 [cited 2022 Dec 25];56(9):776–94. Available from: /pmc/articles/PMC6113484/
28. Ozma MA, Abbasi A, Asgharzadeh M, Pagliano P, Guarino A, Köse S, et al. Antibiotic therapy for pan-drug-resistant infections. Le Infez Med [Internet]. 2022 [cited 2022 Dec 25];30(4):525–31. Available from: /pmc/articles/PMC9715010/
29. Alghoribi MF, Alqurashi M, Okdah L, Alalwan B, AlHebaishi YS, Almalki A, et al. Successful treatment of infective endocarditis due to pandrug-resistant Klebsiella pneumoniae with ceftazidime-avibactam and aztreonam. Sci Rep [Internet]. 2021 Dec 1 [cited 2022 Dec 25];11(1):9684. Available from: /pmc/articles/PMC8102575/
30. Zhang Y, Guo LY, Song WQ, Wang Y, Dong F, Liu G. Risk factors for carbapenem-resistant K. pneumoniae bloodstream infection and predictors of mortality in Chinese paediatric patients. BMC Infect Dis [Internet]. 2018 May 31 [cited 2022 Dec 25];18(1):248. Available from: /pmc/articles/PMC5984460/
31. Xu J, Zhao Z, Ge Y, He F. Rapid Emergence of a Pandrug-Resistant Klebsiella pneumoniae ST11 Isolate in an Inpatient in a Teaching Hospital in China After Treatment with Multiple Broad-Spectrum Antibiotics. Infect Drug Resist [Internet]. 2020 [cited 2022 Dec 25];13(3):799–804. Available from: /pmc/articles/PMC7071855/
32. El-Badawy MF, El-Far SW, Althobaiti SS, Abou-Elazm FI, Shohayeb MM. The First Egyptian Report Showing the Co-Existence of blaNDM-25, blaOXA-23, blaOXA-181, and blaGES-1 Among Carbapenem-Resistant K. pneumoniae Clinical Isolates Genotyped by BOX-PCR. Infect Drug Resist [Internet]. 2020 [cited 2022 Dec 25];13(4):1237–50. Available from: /pmc/articles/PMC7196799/
33. Nkansa-Gyamfi NA, Kazibwe J, Traore DAK, Nji E. Prevalence of multidrug-, extensive drug-, and pandrug-resistant commensal Escherichia coli isolated from healthy humans in community settings in low- and middle-income countries: a systematic review and meta-analysis. Glob Health Action [Internet]. 2019 Dec 13 [cited 2022 Dec 25];12(Suppl):1815272. Available from: /pmc/articles/PMC7782630/
34. Kim J, Hwang BK, Choi H, Wang Y, Choi SH, Ryu S, et al. Characterization of mcr-1-Harboring Plasmids from Pan Drug-Resistant Escherichia coli Strains Isolated from Retail Raw Chicken in

ISSN NO: 2771-8840
Date of Publication: 07-03-2023

South Korea. Microorganisms [Internet]. 2019 Sep 1 [cited 2022 Dec 25];7(9):344. Available from: /pmc/articles/PMC6780365/

35. Feuerstein A, Scuda N, Klose C, Hoffmann A, Melchner A, Boll K, et al. Antimicrobial resistance, serologic and molecular characterization of E. coli isolated from calves with severe or fatal enteritis in Bavaria, Germany. Antibiotics [Internet]. 2022 Jan 1 [cited 2022 Dec 25];11(1):23. Available from: /pmc/articles/PMC8772957/
36. Benklaouz MB, Aggad H, Benameur Q. Resistance to multiple first-line antibiotics among Escherichia coli from poultry in Western Algeria. Vet World [Internet]. 2020 [cited 2022 Dec 25];13(2):290–5. Available from: /pmc/articles/PMC7096288/
37. Page MG, Bush K. Discovery and development of new antibacterial agents targeting Gram-negative bacteria in the era of pandrug resistance: is the future promising? Curr Opin Pharmacol [Internet]. 2014 [cited 2022 Dec 25];18(10):91–7. Available from: https://pubmed.ncbi.nlm.nih.gov/25277839/
38. Falagas ME, Mavroudis AD, Vardakas KZ. The antibiotic pipeline for multi-drug resistant gram negative bacteria: what can we expect? Expert Rev Anti Infect Ther [Internet]. 2016 Aug 2 [cited 2022 Dec 25];14(8):747–63. Available from: https://pubmed.ncbi.nlm.nih.gov/27400643/
39. Cherubini S, Perilli M, Segatore B, Fazii P, Parruti G, Frattari A, et al. Whole-Genome Sequencing of ST2 A. baumannii Causing Bloodstream Infections in COVID-19 Patients. Antibiotics [Internet]. 2022 Jul 1 [cited 2022 Dec 25];11(7):955. Available from: /pmc/articles/PMC9311945/
40. Ghaffoori Kanaan MH, Khashan HT. Molecular typing, virulence traits and risk factors of pandrug-resistant Acinetobacter baumannii spread in intensive care unit centers of Baghdad city, Iraq. Rev Res Med Microbiol. 2022 Jan 1;33(1):51–5.
41. Fragkou PC, Poulakou G, Blizou A, Blizou M, Rapti V, Karageorgopoulos DE, et al. The Role of Minocycline in the Treatment of Nosocomial Infections Caused by Multidrug, Extensively Drug and Pandrug Resistant Acinetobacter baumannii: A Systematic Review of Clinical Evidence. Microorganisms [Internet]. 2019 Jun 1 [cited 2022 Dec 25];7(6):159. Available from: /pmc/articles/PMC6617316/
42. Karakonstantis S. A systematic review of implications, mechanisms, and stability of in vivo emergent resistance to colistin and tigecycline in Acinetobacter baumannii. J Chemother [Internet]. 2021 [cited 2022 Dec 25];33(1):1–11. Available from: https://pubmed.ncbi.nlm.nih.gov/32677578/
43. Deng ZW, Wang J, Qiu CF, Yang Y, Shi ZH, Zhou JL. A case report of intraventricular and intrathecal tigecycline infusions for an extensively drug-resistant intracranial Acinetobacter baumannii infection. Medicine (Baltimore) [Internet]. 2019 Apr 1 [cited 2022 Dec 25];98(15):e15139. Available from: /pmc/articles/PMC6485835/