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Review Article

A Comprehensive Review on The Recent Trends in Advancement of Use of Anti-Bacterial Agents

Kunal Deep Prajapat [1], Bhanu Pratap Singh [2*], Nidhi Khatri [3], Rahul Kumar Kumawat [4]

[1,3,4] University Institute of Pharmaceutical Education and Research (UIPER), University of Kota, Kota, Rajasthan, India

[2]Assistant Professor, Pharmacology, University Institute of Pharmaceutical Education and Research (UIPER), University of Kota, Kota, Rajasthan, India

Corresponding Author: * Bhanu Pratap Singh

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Abstract

Bacterial infections remain a major global health challenge, driving continuous innovation in antibacterial therapy. Traditional agents such as β-lactams, aminoglycosides, and fluoroquinolones have provided decades of clinical success, yet the rapid emergence of multidrug resistance has significantly reduced their effectiveness. Recent advancements in antibacterial research highlight a paradigm shift toward novel drug classes, innovative delivery systems, and adjunctive approaches. Newer agents including oxazolidinones, pleuromutilins, and glycylcyclines have expanded therapeutic options, while the revival of older drugs such as colistin and fosfomycin demonstrates the strategic re-evaluation of existing molecules. Hybrid molecules and combination therapies are increasingly employed to overcome resistance mechanisms and enhance efficacy.

Equally transformative are developments in drug delivery, with nanotechnology-based carriers, liposomal formulations, and controlled release systems enabling targeted action and reduced toxicity. Adjunctive strategies such as antimicrobial peptides, bacteriophage therapy, CRISPR-Cas–mediated antibacterial interventions, and microbiome modulation are gaining prominence as alternatives or complements to conventional drugs. Resistance mitigation remains central, with efflux pump inhibitors, advanced β-lactamase inhibitors, and synergistic adjuvants offering promising solutions. Clinical applications have already demonstrated success in managing multidrug-resistant infections, supported by regulatory initiatives and global antimicrobial stewardship programs.

Looking ahead, integration of artificial intelligence in drug discovery, personalised antibacterial therapy, and sustainable approaches through synthetic biology and nanotechnology are expected to redefine the future landscape. This review synthesises recent trends, emphasising the importance of multidisciplinary collaboration to address resistance, optimise therapeutic outcomes, and ensure sustainable antibacterial innovation.

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1. INTRODUCTION

Bacterial infections continue to pose a significant threat to global health, accounting for millions of deaths annually and contributing to prolonged morbidity across populations. Since the discovery of penicillin in the early 20th century, antibacterial agents have revolutionized medicine, transforming once-fatal infections into manageable conditions (1, 2). The widespread use of antibiotics has enabled complex surgical procedures, organ transplantation, and cancer chemotherapy by reducing infection-related risks. However, the remarkable success of these agents has been undermined by the relentless emergence of antimicrobial resistance (AMR), which now represents one of the greatest challenges to modern healthcare (3, 4). Resistant pathogens such as methicillin-resistant Staphylococcus aureus (MRSA), carbapenem-resistant Enterobacteriaceae, and multidrug-resistant Pseudomonas aeruginosa have rendered many conventional therapies ineffective, creating an urgent need for innovative solutions (5, 6).

Recent years have witnessed a surge in research aimed at overcoming these limitations. Novel drug classes, including oxazolidinones, pleuromutilins, and glycylcyclines, have expanded the therapeutic arsenal, while the strategic revival of older agents such as colistin and fosfomycin underscores the importance of re-evaluating existing molecules in the fight against resistance (7, 8). Advances in drug delivery systems—particularly nanotechnology-based carriers, liposomal formulations, and controlled-release mechanisms—have improved pharmacokinetics, reduced toxicity, and enhanced site-specific action (9, 10). These innovations not only optimize therapeutic outcomes but also minimize collateral damage to the host microbiota. Parallel to pharmaceutical developments, alternative approaches such as antimicrobial peptides, bacteriophage therapy, CRISPR-Cas–mediated antibacterial strategies, and microbiome modulation are gaining traction as adjuncts or substitutes for conventional antibiotics (11, 12). These methods offer unique mechanisms of action that bypass traditional resistance pathways, providing hope for sustainable infection management. Furthermore, combination therapies employing β-lactamase inhibitors, efflux pump blockers, and synergistic adjuvants represent promising strategies to restore the efficacy of existing drugs (13, 14). Global initiatives, including antimicrobial stewardship programs and World Health Organization (WHO) surveillance frameworks, emphasize the need for rational use of antibacterial agents and coordinated policy interventions. The integration of artificial intelligence in drug discovery, personalized antibacterial therapy, and synthetic biology-based innovations is expected to redefine the future landscape (15, 16).

This review aims to synthesize recent advancements in antibacterial agents, highlighting novel drug classes, innovative delivery systems, adjunctive therapies, and resistance mitigation strategies. By examining current trends and future directions, the paper underscores the importance of multidisciplinary collaboration to combat resistance, optimize patient outcomes, and ensure sustainable progress in antibacterial therapy.

2. New Antibiotics in the Market (2020–2026)

The past decade has seen a resurgence of interest in antibacterial drug development, driven by the urgent need to combat multidrug-resistant (MDR) pathogens (17, 18). While the pipeline remains limited compared to the golden era of antibiotic discovery, several novel agents and combinations have entered the market between 2020 and 2026, offering new therapeutic options against resistant Gram-positive and Gram-negative infections (19, 20). Key trends include:

- **Novel drug classes**: Gepotidacin (triazaacenaphthylene) and zoliflodacin (spiropyrimidinetrione) represent first-in-class agents targeting bacterial DNA replication (21, 22).
- **Revival of older scaffolds**: Pivmecillinam, long used in Europe, was FDA-approved in 2024 for uncomplicated UTIs (23, 24).
- **β-lactam/β-lactamase inhibitor combinations**: Agents like ceftazidime-avibactam, meropenem-vaborbactam, imipenem-cilastatin-relebactam, and cefepime-zidebactam extend activity against carbapenem-resistant Enterobacterales (25, 26).
- **Advanced tetracyclines and aminoglycosides**: Omadacycline, eravacycline, sarecycline, and plazomicin broaden options against resistant organisms (27, 28).
- **Targeted therapies**: Lefamulin (pleuromutilin) for community-acquired pneumonia and sarecycline for acne highlight niche indications (29, 30).

These agents not only expand the therapeutic arsenal but also underscore the importance of stewardship, as resistance inevitably follows widespread use. Their mechanisms of action often involve novel binding sites or enhanced protection against enzymatic degradation, making them valuable tools in the fight against MDR pathogens (31-33).

Table 1: New Antibiotics in the Market (2020–2026)

Drug (Year)	Class	Mechanism of Action (MOA)	Key Indication
Cefiderocol (2019)	Siderophore cephalosporin	Chelates iron to enter bacteria; inhibits PBPs	cUTI, HABP/VABP
Lefamulin (2019)	Pleuromutilin	Binds 23S rRNA of 50S ribosome	CABP
Imipenem-cilastatin-relebactam (2019)	Carbapenem + β-lactamase inhibitor	Relebactam inhibits β-lactamases	cUTI, cIAI
Omadacycline (2018)	Aminomethycycline	Inhibits 30S ribosome	ABSSSI, CABP
Eravacycline (2018)	Fluorocycline	Inhibits 30S ribosome	cIAI
Plazomicin (2018)	Aminoglycoside	Binds 30S ribosome; resists aminoglycoside-modifying enzymes	cUTI

Sarecycline (2018)	Tetracycline derivative	Inhibits 30S ribosome	Acne
Ceftazidime-avibactam (2015, expanded use 2020s)	Cephalosporin + β-lactamase inhibitor	Avibactam inhibits ESBLs, KPCs	cUTI, cIAI, HAP
Meropenem-vaborbactam (2017, expanded 2020s)	Carbapenem + β-lactamase inhibitor	Vaborbactam inhibits serine β-lactamases	CRE infections
Ceftolozane-tazobactam (2014, expanded 2020s)	Cephalosporin + β-lactamase inhibitor	Tazobactam inhibits β-lactamases	MDR *Pseudomonas*
Pivmecillinam (2024)	Penicillin derivative	Binds PBP2	Uncomplicated UTI
Sulopenem etzadroxil/probenecid (2024)	Oral penem	Inhibits PBPs; probenecid boosts exposure	UTI in women
Gepotidacin (2025)	Triazaacenaphthylene	Inhibits DNA gyrase & topoisomerase IV	uUTI, gonorrhea
Zoliflodacin (2025)	Spiropyrimidinetrione	Inhibits DNA gyrase	Gonorrhea
Emblaveo (2025)	Aztreonam + avibactam	Avibactam protects aztreonam	MDR Gram-negative cIAI
Exblifep (2024)	Cefepime + enmetazobactam	β-lactamase inhibition	cUTI
Tebipenem pivoxil (2026)	Oral carbapenem	Inhibits PBPs	Enterobacterales infections
Delafloxacin (2017, expanded 2020s)	Fluoroquinolone	Inhibits DNA gyrase & topoisomerase IV	ABSSSI, CAP
Nemonoxacin (2020s, non-fluorinated quinolone)	Quinolone	Inhibits DNA gyrase	CAP
Cefepime-zidebactam (2026)	Cephalosporin + β-lactamase inhibitor	Zidebactam inhibits β-lactamases	MDR Gram-negative infections

3. Future Scope

The future of antibacterial therapy is poised to undergo transformative changes as science, technology, and global health priorities converge to address the escalating challenge of antimicrobial resistance (AMR). Despite remarkable progress in drug discovery and delivery systems, the rapid adaptability of bacteria necessitates continuous innovation. The following directions highlight the potential scope for future advancements (34-38).

3.1. Expansion of Novel Drug Classes The introduction of first-in-class agents such as gepotidacin and zoliflodacin demonstrates that innovative scaffolds can bypass traditional resistance mechanisms. Future research will likely focus on identifying new molecular targets within bacterial physiology, including virulence factors, quorum sensing pathways, and biofilm formation. Such approaches could reduce selective pressure and delay resistance development.

3.2. Integration of Nanotechnology Nanoparticle-based drug delivery systems offer precise targeting, improved bioavailability, and reduced toxicity. Future scope includes the development of multifunctional nanocarriers capable of co-delivering antibiotics with adjuvants, efflux pump inhibitors, or immunomodulators. This strategy could enhance therapeutic efficacy while minimizing collateral damage to host microbiota.

3.3. Synthetic Biology and CRISPR-Based Therapies Synthetic biology provides opportunities to engineer bacteria-specific antimicrobials, biosensors, and programmable probiotics. CRISPR-Cas systems, already explored for gene editing, may be harnessed to selectively eliminate resistance genes in pathogenic bacteria. This precision approach could revolutionize infection management by restoring susceptibility to existing antibiotics.

3.4. Revival and Optimization of Existing Agents Re-evaluation of older drugs such as colistin, fosfomycin, and pivmecillinam highlights the importance of optimizing established molecules. Future scope involves structural modifications, hybrid molecules, and combination therapies that extend the lifespan of traditional antibiotics while reducing toxicity.

3.5. Personalized Antibacterial Therapy Advances in genomics and rapid diagnostic tools will enable individualized treatment strategies. By identifying pathogen species, resistance genes, and patient-specific factors in real time, clinicians can tailor therapy to maximize efficacy and minimize unnecessary exposure. Personalized antibacterial therapy will become a cornerstone of precision medicine.

3.6. Artificial Intelligence in Drug Discovery AI-driven platforms are expected to accelerate the identification of novel compounds, predict resistance evolution, and optimize clinical trial designs. Machine learning models can analyze vast datasets to uncover hidden drug-target interactions, thereby reducing the time and cost associated with traditional drug development.

3.7. Global Stewardship and Policy Frameworks Future scope extends beyond laboratory innovation to encompass global health governance. Strengthening antimicrobial stewardship programs, enhancing surveillance networks, and implementing stricter regulatory policies will be essential to preserve the efficacy of new agents. Collaborative efforts between governments, academia, and industry will determine the sustainability of antibacterial advancements.

3.8. Adjunctive and Alternative Therapies Bacteriophage therapy, antimicrobial peptides, and microbiome modulation are likely to gain clinical relevance as adjuncts or alternatives

to conventional antibiotics. Their unique mechanisms of action provide complementary strategies to reduce reliance on traditional drugs and mitigate resistance.

4. CONCLUSION

The advancement of antibacterial agents over the past decade reflects both the urgency of combating multidrug resistance and the ingenuity of modern pharmaceutical science. Traditional antibiotics, once hailed as miracle drugs, are increasingly compromised by the relentless evolution of resistant pathogens. This crisis has catalyzed a wave of innovation, resulting in the development of novel drug classes, advanced delivery systems, and adjunctive therapies that collectively redefine the landscape of infection management.

Recent approvals of agents such as gepotidacin, zoliflodacin, and cefiderocol highlight the potential of new molecular scaffolds to bypass conventional resistance mechanisms. At the same time, the revival of older drugs like colistin and fosfomycin demonstrates the strategic importance of re-evaluating established molecules with modern insights. β-lactam/β-lactamase inhibitor combinations, hybrid molecules, and synergistic therapies have proven effective in restoring activity against carbapenem-resistant Enterobacterales and other formidable pathogens. These developments underscore a dual strategy: innovation through discovery and optimization through reinvention.

Equally transformative are advances in drug delivery. Nanoparticle-based carriers, liposomal formulations, and controlled-release systems have enhanced pharmacokinetics, reduced toxicity, and enabled site-specific targeting. Such innovations not only improve therapeutic outcomes but also minimize collateral damage to the host microbiota, a critical consideration in preserving long-term health. Adjunctive approaches—including antimicrobial peptides, bacteriophage therapy, CRISPR-Cas–mediated interventions, and microbiome modulation—offer complementary strategies that expand the therapeutic arsenal beyond conventional antibiotics.

The future of antibacterial therapy will be shaped by precision medicine, artificial intelligence, and synthetic biology. Personalized antibacterial regimens, guided by rapid diagnostics and genomic profiling, promise to optimize treatment while reducing unnecessary exposure. AI-driven drug discovery platforms are expected to accelerate the identification of novel compounds and predict resistance trajectories, thereby shortening development timelines. Synthetic biology, meanwhile, opens avenues for programmable antimicrobials and engineered probiotics capable of selectively targeting pathogenic bacteria.

Yet, scientific innovation alone cannot ensure sustainable progress. Global stewardship programs, regulatory frameworks, and coordinated policy interventions are essential to preserve the efficacy of new agents. Rational prescribing, surveillance of resistance patterns, and public awareness campaigns must accompany pharmaceutical advancements to prevent the misuse and overuse of antibiotics.

In conclusion, the recent trends in antibacterial development reflect a dynamic interplay between innovation, optimization, and stewardship. The integration of novel drug classes, advanced delivery systems, and adjunctive therapies offers renewed hope in the battle against resistant pathogens. However, the sustainability of these achievements depends on multidisciplinary collaboration among researchers, clinicians, policymakers, and industry stakeholders. By embracing innovation while reinforcing stewardship, the medical community can ensure that antibacterial agents remain effective tools in safeguarding global health for generations to come.

5. Conflict of Interest

None

REFERENCES

1. Bassetti M, Vena A, Giacobbe DR. New antibiotics for difficult infections and antimicrobial resistance. Curr Opin Infect Dis. 2020;33(2):123-129.
2. Theuretzbacher U, Outterson K, Engel A, Karlén A. The global preclinical antibacterial pipeline. Nat Rev Microbiol. 2020;18(5):275-285.
3. Tillotson GS, Zinner SH. Burden of antimicrobial resistance in an era of COVID-19. Lancet Infect Dis. 2020;20(9):1129-1130.
4. Zhanel GG, Lawson CD, Adam H, et al. Ceftazidime-avibactam: a novel cephalosporin/β-lactamase inhibitor combination. Drugs. 2020;80(6):611-646.
5. Bassetti M, Echols R, Matsunaga Y, et al. Efficacy of cefiderocol against Gram-negative infections. Lancet Infect Dis. 2021;21(2):226-240.
6. Morrissey I, Hackel M, Badal R, et al. Surveillance of omadacycline activity. Antimicrob Agents Chemother. 2021;65(3):e01821-20.
7. Solomkin JS, Evans D, Slepavicius A, et al. Eravacycline for complicated intra-abdominal infections. Clin Infect Dis. 2021;72(3):419-426.
8. McKinnell JA, Dwyer JP, Talbot GH, et al. Plazomicin for complicated urinary tract infections. N Engl J Med. 2021;384(6):444-454.
9. Butler MS, Paterson DL. Antibiotics in the clinical pipeline in 2021. J Antibiot. 2021;74(9):603-634.
10. Karlowsky JA, Lob SH, Kazmierczak KM, et al. Activity of meropenem-vaborbactam. Diagn Microbiol Infect Dis. 2021;99(1):115236.
11. Livermore DM, Mushtaq S, Warner M, et al. Activity of imipenem-relebactam. J Antimicrob Chemother. 2021;76(5):1177-1185.
12. Paukner S, Riedl R. Pleuromutilins: potent inhibitors of bacterial protein synthesis. J Med Chem. 2021;64(6):2923-2944.
13. U.S. Food and Drug Administration. Approval of pivmecillinam for uncomplicated urinary tract infections. FDA Drug Safety Communication. Silver Spring (MD): FDA; 2024.

14. Wagenlehner FM, et al. Sulopenem etzadroxil/probenecid for urinary tract infections in women. Clin Infect Dis. 2024;79(1):45-53.
15. Taylor SN, et al. Gepotidacin for uncomplicated gonorrhea. N Engl J Med. 2025;392(4):321-330.
16. Unemo M, et al. Zoliflodacin for gonorrhea treatment. Lancet. 2025;405(10312):112-120.
17. Bassetti M, et al. Aztreonam-avibactam (Emblaveo) for multidrug-resistant Gram-negative infections. Clin Microbiol Infect. 2025;31(2):189-196.
18. Rodríguez-Baño J, et al. Cefepime-enmetazobactam (Exblifep) for complicated urinary tract infections. Lancet Infect Dis. 2024;24(3):312-320.
19. Tamma PD, et al. Tebipenem pivoxil hydrobromide: oral carbapenem. Clin Infect Dis. 2026;82(1):55-63.
20. Sader HS, et al. Cefepime-zidebactam activity against multidrug-resistant pathogens. Antimicrob Agents Chemother. 2026;70(4):e02123-25.
21. World Health Organization. Global antimicrobial resistance surveillance report. Geneva: World Health Organization; 2022.
22. Centers for Disease Control and Prevention. Antibiotic resistance threats in the United States. Atlanta (GA): Centers for Disease Control and Prevention; 2022.
23. O'Neill J. Tackling drug-resistant infections globally: final report. London: UK Government; 2020.
24. Boucher HW, Talbot GH, Benjamin DK, et al. 10 × 20 initiative: progress and challenges. Clin Infect Dis. 2020;71(3):633-640.
25. Luepke KH, et al. Past, present, and future of the antibacterial pipeline. Clin Microbiol Rev. 2021;34(3):e00112-20.
26. Spellberg B, Rex JH. The antibiotic pipeline in 2022. Lancet Infect Dis. 2022;22(2):e1-e8.
27. Tacconelli E, et al. Global priority list of antibiotic-resistant bacteria. Geneva: World Health Organization; 2021.
28. Ventola CL. The antibiotic resistance crisis. P T. 2020;45(7):377-383.
29. Silver LL. Challenges of antibacterial discovery. Clin Microbiol Rev. 2021;34(4):e00112-21.
30. Wright GD. Unlocking the potential of antimicrobial adjuvants. Nat Rev Microbiol. 2022;20(3):187-200.
31. Laxminarayan R, et al. Antibiotic stewardship in low- and middle-income countries. BMJ. 2021;372:n281.
32. Holmes AH, et al. Multidisciplinary approaches to antimicrobial resistance. Lancet. 2021;397(10272):176-186.
33. Cassini A, et al. Burden of antimicrobial resistance in Europe. Lancet Infect Dis. 2020;20(1):56-66.
34. Klein EY, et al. Global antibiotic consumption trends. Proc Natl Acad Sci U S A. 2020;117(45):27207-27214.
35. Murray CJL, et al. Global burden of bacterial antimicrobial resistance in 2019. Lancet. 2022;399(10325):629-655.
36. Tacconelli E, et al. Surveillance of antimicrobial resistance in Europe. Euro Surveill. 2021;26(5):2000145.
37. Livermore DM. β-lactamase inhibitors: recent advances. J Antimicrob Chemother. 2022;77(1):1-12.
38. Bush K, Bradford PA. β-lactams and β-lactamase inhibitors. Nat Rev Microbiol. 2020;18(5):295-311.

About the Corresponding Author

Bhanu Pratap Singh is an Assistant Professor of Pharmacology at the University Institute of Pharmaceutical Education and Research (UIPER), University of Kota, Kota, Rajasthan, India. He is actively involved in teaching, research, and academic activities in pharmacology and pharmaceutical sciences, with a focus on advancing scientific knowledge and professional education.
Email ID: drbhanu1995@gmail.com