

A Narrative Review

Bridging the Gap: Reclaiming the Clinical Role of Pharmacologists in Modern Healthcare.

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ABSTRACT

Background: Pharmacologists play a fundamental role in drug discovery, rational therapeutics, pharmacovigilance, and medical education. Despite their extensive expertise, their contribution to direct patient care remains limited in many healthcare systems, particularly in low- and middle-income countries. This underutilization restricts the effective translation of pharmacological knowledge into clinical practice and may adversely affect medication safety, rational prescribing, and healthcare quality.

Objective: To examine the current barriers limiting the clinical integration of pharmacologists and to propose evidence-based strategies for strengthening their role in modern healthcare through clinical pharmacology services, interdisciplinary collaboration, and healthcare policy reforms.

Methods: This expert opinion article was developed through a narrative review of published literature, international guidelines, and policy documents related to clinical pharmacology, rational drug use, pharmacovigilance, antimicrobial stewardship, and precision medicine. Relevant evidence was critically synthesized to identify existing challenges, emerging opportunities, and practical recommendations for integrating pharmacologists into multidisciplinary healthcare systems.

Conclusion: Reintegrating pharmacologists into hospital-based clinical practice is essential for improving medication safety, optimizing rational drug use, strengthening pharmacovigilance and antimicrobial stewardship, and advancing precision medicine. Establishing Clinical Pharmacology Units, modernizing pharmacology training, promoting interdisciplinary collaboration, and implementing supportive institutional and national policies will enable pharmacologists to become integral members of multidisciplinary healthcare teams and improve patient outcomes.

INTRODUCTION

Clinical pharmacology is the branch of medical science that bridges experimental pharmacology with patient-centered clinical practice. It encompasses the study of drug actions in humans, including pharmacokinetics, pharmacodynamics, pharmacogenomics, therapeutic drug monitoring (TDM), adverse drug reaction (ADR) surveillance, and evidence-based prescribing. As healthcare systems become increasingly complex because of aging populations, multimorbidity, polypharmacy, antimicrobial resistance, and the rapid introduction of novel therapeutics, the importance of clinical pharmacology has grown substantially. Clinical pharmacologists possess the expertise to optimize drug therapy, improve medication safety, and promote rational use of medicines, thereby contributing significantly to patient-centered healthcare and improved clinical outcomes [1,2]. Despite these competencies, pharmacologists remain underutilized in direct patient care in many healthcare systems, particularly in low- and middle-income countries. In most teaching hospitals and medical institutions, responsibilities are largely confined to undergraduate and postgraduate education, laboratory research, and regulatory activities, with limited participation in bedside clinical decision-making. This disconnect between pharmacological science and clinical medicine weakens the translation of scientific evidence into routine clinical practice. It contributes to medication errors, irrational prescribing, avoidable adverse drug reactions, and increased healthcare costs [1,3,4]. The World Health Organization (WHO) recognizes rational use of medicines as a cornerstone of quality healthcare. Rational prescribing requires clinicians to consider efficacy, safety, patient characteristics, cost-effectiveness, and treatment adherence before selecting appropriate therapy. Clinical pharmacologists possess specialized knowledge to support these decisions through therapeutic drug monitoring, pharmacokinetic consultations, drug interaction assessments, pharmacovigilance, and individualized dose optimization. Their involvement is particularly valuable for patients receiving medications with narrow therapeutic indices, complex drug regimens, or therapies requiring pharmacogenomic guidance [2,5]. One of the most effective approaches to strengthening clinical pharmacology services is establishing Clinical Pharmacology Units (CPUs) within tertiary-care hospitals. These units provide integrated services including therapeutic drug monitoring, pharmacovigilance, antimicrobial stewardship, drug information services, formulary management, and evidence-based prescribing support. Studies have demonstrated that hospitals with dedicated clinical pharmacology services report improved medication safety, reduced adverse drug reactions, enhanced antimicrobial stewardship, and better compliance with evidence-based treatment guidelines. Nevertheless, such facilities remain limited in many developing countries due to inadequate infrastructure, insufficient institutional support, and a lack of trained clinical pharmacologists [1,6]. The rapid evolution of precision medicine has further expanded the scope of clinical pharmacology. Pharmacogenomics now enables individualized drug therapy based on genetic variation, reducing treatment failure and minimizing drug toxicity. Simultaneously, advances in artificial intelligence (AI), machine learning, digital therapeutics, electronic health records, and clinical decision-support systems are transforming medication management by facilitating personalized prescribing and early identification of adverse drug events. These innovations create new opportunities for pharmacologists to become active contributors to multidisciplinary patient care rather than remaining exclusively

within academic settings [6,7]. Several barriers continue to hinder this transition. In many medical schools, postgraduate pharmacology curricula continue to emphasize theoretical knowledge and laboratory-based experimentation with limited exposure to clinical practice. Furthermore, inadequate collaboration between pharmacologists and clinicians, absence of dedicated hospital positions, limited awareness among healthcare administrators, and insufficient policy support restrict the effective utilization of pharmacologists within multidisciplinary healthcare teams. Addressing these challenges requires comprehensive educational reforms, institutional commitment, and national policies that recognize pharmacologists as integral members of patient-care services [3,7,8]. Globally, multidisciplinary healthcare has become the standard approach for delivering safe, effective, and evidence-based patient care. Clinical pharmacologists working alongside physicians, pharmacists, nurses, microbiologists, and other healthcare professionals can improve therapeutic decision-making through medication optimization, adverse drug reaction monitoring, antimicrobial stewardship, and formulary development. Their participation in Drug and Therapeutics Committees, pharmacovigilance centers, quality improvement initiatives, and clinical governance programs has been associated with improved prescribing practices, enhanced medication safety, and more cost-effective healthcare delivery [5,8,9]. Considering these evolving healthcare needs, redefining the professional role of pharmacologists has become increasingly important. Their contribution should extend beyond teaching and research to include direct clinical consultation, translational research, precision medicine, leadership in pharmacovigilance, therapeutic drug monitoring, and healthcare policy development. Strengthening clinical pharmacology services through Clinical Pharmacology Units, interdisciplinary collaboration, curriculum modernization, and supportive institutional policies will help bridge the longstanding gap between pharmacological science and clinical practice while improving patient safety and healthcare quality [1,6,9]. This narrative review aims to critically evaluate the current barriers to the clinical integration of pharmacologists, summarize emerging evidence supporting their expanding role in modern healthcare, and propose practical strategies to strengthen clinical pharmacology services through educational reform, institutional support, policy initiatives, and technological innovation. Ultimately, the review advocates for repositioning pharmacologists as essential members of multidisciplinary healthcare teams capable of improving rational prescribing, medication safety, pharmacovigilance, antimicrobial stewardship, and precision medicine in contemporary clinical practice [2,6,10].

Materials and Methods

Study Design

This narrative review was conducted in the Department of Pharmacology at Prafulla Chandra Sen Government Medical College, Arambagh, Hooghly, West Bengal, India, from January 2025 to January 2026. It drew on a comprehensive review of published literature, international guidelines, and policy documents. The review was designed to synthesize current literature, international recommendations, and expert perspectives on the clinical responsibilities of pharmacologists in contemporary healthcare systems.

Literature Search Strategy

A comprehensive literature search was performed using electronic databases, including PubMed/MEDLINE, Scopus, Google Scholar, Web of Science, and publications from the World Health Organization (WHO). Relevant clinical practice guidelines, consensus statements, policy documents, and peer-reviewed review articles were also examined to ensure comprehensive coverage of the topic.

Selection Criteria

Articles published in English between 2015 and 2025 were preferentially included to capture contemporary evidence, while landmark publications of historical significance were incorporated where appropriate. Original research articles, systematic reviews, meta-analyses, clinical guidelines, expert consensus statements, and policy reports addressing the clinical role of pharmacologists and related healthcare services were considered eligible. Publications that were not relevant to clinical pharmacology practice or that contained insufficient scientific evidence were excluded.

Data Synthesis

The retrieved literature was critically reviewed and synthesized using a thematic approach. Evidence was organized into major domains, including barriers to clinical integration, expanding hospital-based roles, translational research, participation in multidisciplinary care, educational reforms, institutional and policy support, and future directions in clinical pharmacology. The findings were interpreted to develop evidence-informed recommendations aimed at enhancing the contribution of clinical pharmacologists to rational prescribing, medication safety, pharmacovigilance, antimicrobial stewardship, and precision medicine.

RESULTS

Current Challenges Limiting the Clinical Role of Pharmacologists

The reviewed literature consistently demonstrates that clinical pharmacologists remain underutilized in direct patient care despite their extensive expertise in therapeutics, pharmacokinetics, pharmacovigilance, and rational prescribing. In many healthcare institutions, pharmacologists are predominantly engaged in teaching and laboratory-based research rather than participating in multidisciplinary clinical decision-making. The principal barriers identified include inadequate institutional infrastructure, limited availability of Clinical Pharmacology Units (CPUs), insufficient collaboration between pharmacologists and clinicians,

outdated postgraduate training curricula, and limited recognition of pharmacologists' clinical capabilities by healthcare administrators. These challenges collectively reduce opportunities for therapeutic optimization, medication safety initiatives, and evidence-based prescribing.

Expanding Role of Clinical Pharmacology in Hospitals

Evidence indicates that clinical pharmacologists can substantially improve healthcare quality through active participation in hospital-based clinical services. Their roles extend beyond academic teaching to include therapeutic drug monitoring, pharmacovigilance, antimicrobial stewardship, drug information services, formulary management, and membership in Drug and Therapeutics Committees. Hospitals that incorporate clinical pharmacology services report improvements in medication safety, reduced adverse drug reactions, optimized antimicrobial use, and greater adherence to evidence-based treatment protocols. The establishment of Clinical Pharmacology Units represents a practical strategy for integrating pharmacologists into multidisciplinary healthcare systems.

Research and Translational Relevance

The literature highlights the increasing importance of clinical pharmacologists in translational research and evidence-based medicine. Pharmacologists contribute to drug utilization evaluations, pharmacoepidemiological studies, investigator-initiated clinical trials, pharmacogenomic research, and real-world evidence generation. Their expertise facilitates the translation of laboratory discoveries into clinical practice while supporting precision medicine initiatives. Collaboration between pharmacologists and clinical specialties enhances research quality and promotes individualized therapeutic approaches.

Active Participation in Patient Care Teams

Clinical pharmacologists provide valuable support to multidisciplinary healthcare teams by optimizing medication therapy, identifying adverse drug reactions, interpreting pharmacokinetic data, and recommending individualized dosing strategies. Their participation in antimicrobial stewardship programs, medication safety rounds, and clinical consultations contributes to improved prescribing practices and better patient outcomes. Integration into ward-based clinical services also strengthens communication among physicians, pharmacists, nurses, and other healthcare professionals.

Upskilling and Professional Development

The review identified the need for continuous professional development to expand pharmacologists' clinical competencies. Recommended areas include advanced clinical pharmacology, pharmacogenomics, biostatistics, clinical research methodology, regulatory science, artificial intelligence, digital health technologies, and communication skills. Structured hospital rotations and interdisciplinary training programs can further improve bedside decision-making and prepare pharmacologists for evolving healthcare roles.

Institutional and Policy Support

Successful integration of pharmacologists into healthcare systems requires strong institutional commitment and supportive national policies. The reviewed evidence emphasizes establishing dedicated Clinical Pharmacology Units, creating sanctioned clinical pharmacist positions in hospitals, incorporating pharmacologists into Drug and Therapeutics Committees, and strengthening pharmacovigilance and antimicrobial stewardship programs. National regulatory bodies and healthcare organizations should develop standardized guidelines that recognize clinical pharmacologists as essential members of multidisciplinary healthcare teams.

Academic Reform and Cultural Realignment

Current postgraduate pharmacology education requires modernization to better align with contemporary clinical practice. The literature recommends increasing patient-oriented teaching, introducing mandatory clinical rotations, encouraging collaborative research with clinical departments, and incorporating pharmacogenomics, precision medicine, and digital therapeutics into the curriculum. Greater collaboration between basic and clinical sciences would improve the clinical relevance of pharmacology education and facilitate the transition from laboratory-based learning to patient-centered practice.

Future Directions in Clinical Pharmacology

Emerging technologies are expected to reshape the future role of clinical pharmacologists. Artificial intelligence, machine learning, pharmacogenomics, digital therapeutics, wearable monitoring systems, and real-world evidence platforms offer new opportunities to improve individualized therapy and medication safety. Future healthcare systems should promote interdisciplinary collaboration while expanding the responsibilities of pharmacologists in clinical decision support, precision medicine, healthcare policy development, and sustainable pharmaceutical practices.

Table 1. Major Challenges Limiting the Clinical Integration of Pharmacologists

Challenge	Impact on Healthcare	Proposed Solution
Limited clinical involvement	Reduced therapeutic optimization	Clinical Pharmacology Units
Lack of institutional support	Underutilization of expertise	Dedicated hospital positions
Poor interdisciplinary collaboration	Fragmented patient care	Multidisciplinary healthcare teams
Outdated postgraduate training	Limited clinical competency	Curriculum modernization
Limited policy recognition	Restricted professional roles	National clinical pharmacology policies

Table 1. Major barriers restricting the integration of pharmacologists into contemporary healthcare systems and potential strategies to address them.

Table 2. Expanding Clinical Responsibilities of Pharmacologists

Clinical Service	Pharmacist's Role	Expected Benefit
Therapeutic Drug Monitoring	Dose optimization	Improved efficacy and reduced toxicity
Pharmacovigilance	ADR monitoring	Enhanced medication safety
Antimicrobial Stewardship	Rational antibiotic use	Reduced antimicrobial resistance
Drug Information Services	Evidence-based consultation	Better prescribing decisions
Drug & Therapeutics Committee	Formulary management	Rational medicine use
Precision Medicine	Pharmacogenomic guidance	Personalized therapy

Table 2. Key hospital-based services where clinical pharmacologists contribute to improving patient safety and healthcare quality.

Table 3. Strategic Priorities for Strengthening Clinical Pharmacology

Strategic Area	Recommended Action	Expected Outcome
Education	Clinical rotations and competency-based training	Enhanced clinical expertise
Research	Promote translational and pharmacogenomic research	Evidence-based therapeutics
Policy	Establish dedicated clinical pharmacologist positions	Better healthcare integration
Infrastructure	Develop Clinical Pharmacology Units	Improved patient care services
Digital Health	AI and precision medicine training	Future-ready clinical practice

Table 3. Strategic recommendations for expanding the role of clinical pharmacologists in modern healthcare.

Figure 1. Conceptual Framework for Integrating Clinical Pharmacologists into Modern Healthcare

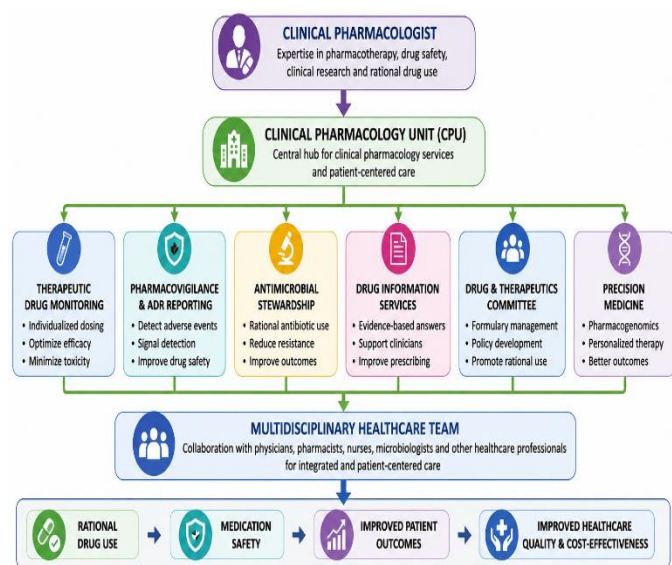


Figure 1. Proposed framework illustrating how the integration of clinical pharmacologists into multidisciplinary healthcare teams through Clinical Pharmacology Units supports medication safety, rational prescribing, pharmacovigilance, antimicrobial stewardship, precision medicine, and improved patient outcomes.

DISCUSSION

The present narrative review highlights the evolving role of

clinical pharmacologists in addressing contemporary healthcare challenges through rational prescribing, medication safety, pharmacovigilance, antimicrobial stewardship, and precision medicine. Although pharmacologists possess extensive expertise in drug therapy and clinical pharmacology, their participation in direct patient care remains limited in many healthcare systems, particularly in low- and middle-income countries. The evidence reviewed suggests that expanding their clinical responsibilities would improve therapeutic decision-making, reduce medication-related harm, and strengthen multidisciplinary healthcare delivery [11,12]. Previous studies have consistently reported that inadequate institutional support and the absence of dedicated Clinical Pharmacology Units limit opportunities for pharmacologists to participate directly in patient care [11,13]. In contrast, healthcare systems in several developed countries have successfully integrated clinical pharmacologists into multidisciplinary teams, demonstrating improvements in medication safety, therapeutic optimization, and evidence-based prescribing [14]. The establishment of Clinical Pharmacology Units represents one of the most practical strategies for bridging the gap between pharmacological science and clinical medicine. These specialized units provide therapeutic drug monitoring, pharmacovigilance services, antimicrobial stewardship, formulary management, and drug information support. Previous studies have demonstrated that hospitals with well-established clinical pharmacology services experience lower rates of adverse drug reactions, improved antimicrobial utilization, and more rational prescribing practices [15–17]. Previous studies have demonstrated that therapeutic drug monitoring improves treatment efficacy while minimizing drug toxicity, particularly for drugs with narrow therapeutic indices [18]. Pharmacologists are being integrated into routine clinical practice. Another major area where pharmacologists contribute substantially is pharmacovigilance. The increasing complexity of modern pharmacotherapy has resulted in a growing burden of adverse drug reactions worldwide. Active pharmacovigilance systems led by trained pharmacologists facilitate early identification, assessment, documentation, and prevention of medication-related adverse events. The Pharmacovigilance Program of India (PvPI) has demonstrated the value of structured ADR monitoring in improving medication safety and supporting national drug regulatory decisions [19]. Similar pharmacovigilance models have been successfully implemented internationally, emphasizing the indispensable role of clinical pharmacologists in drug safety surveillance. Antimicrobial resistance continues to threaten global public health and has increased the importance of antimicrobial stewardship programs. Clinical pharmacologists contribute significantly through antibiotic selection, dose optimization, treatment monitoring, and prescribing audits. Previous multidisciplinary stewardship initiatives have demonstrated reductions in inappropriate antimicrobial prescribing, healthcare-associated infections, antimicrobial resistance, and hospital costs following the

inclusion of pharmacologists within stewardship teams [20]. These findings underscore the importance of incorporating pharmacologists into institutional antimicrobial stewardship programs. The emergence of precision medicine and pharmacogenomics has created new opportunities for expanding the clinical responsibilities of pharmacologists. Advances in genetic testing now enable individualized drug selection and dose optimization based on pharmacogenetic profiles, thereby improving therapeutic efficacy while reducing adverse drug reactions. Simultaneously, artificial intelligence, machine learning, digital therapeutics, and clinical decision-support systems are transforming medication management through predictive analytics and personalized treatment recommendations. Recent evidence indicates that clinical pharmacologists are uniquely positioned to integrate these technologies into routine healthcare while ensuring their safe and evidence-based application [21–23]. Despite these promising developments, several barriers continue to impede the integration of pharmacologists into clinical practice. Many postgraduate pharmacology curricula remain focused on theoretical knowledge and laboratory-based experimentation, providing limited exposure to patient-centered clinical activities. Previous educational studies have recommended competency-based curricula, structured clinical rotations, interdisciplinary learning, and greater emphasis on translational pharmacology to prepare future pharmacologists for evolving healthcare demands [24]. Curriculum modernization should therefore be considered a priority for medical education policymakers. Institutional and policy reforms are equally important for strengthening clinical pharmacology services. Dedicated hospital positions for clinical pharmacologists, mandatory representation on Drug and Therapeutics Committees, development of Clinical Pharmacology Units, and integration into quality improvement programs would substantially enhance the specialty's visibility and effectiveness. National regulatory agencies and accreditation bodies should recognize clinical pharmacologists as essential contributors to medication safety, pharmacovigilance, antimicrobial stewardship, and rational prescribing [25,26]. This review has several strengths. It synthesizes current evidence from diverse areas of clinical pharmacology and provides a comprehensive overview of the expanding responsibilities of pharmacologists in modern healthcare. By integrating evidence from clinical pharmacology, pharmacovigilance, precision medicine, antimicrobial stewardship, and healthcare policy, the review presents a practical framework for improving patient-centered medication management. However, several limitations should also be acknowledged. As a narrative review, the findings depend on published literature rather than systematic evidence synthesis or quantitative meta-analysis. Additionally, healthcare systems differ considerably across countries; therefore, some recommendations may require adaptation according to local institutional resources, regulatory frameworks, and workforce availability [27]. Future research

should evaluate the clinical and economic impact of Clinical Pharmacology Units through prospective multicenter studies. Additional evidence is needed regarding the effectiveness of pharmacist-led therapeutic drug monitoring services, artificial intelligence-assisted prescribing, pharmacogenomic implementation, and multidisciplinary stewardship programs in improving patient outcomes. Such research will further strengthen the evidence base supporting expanded clinical roles for pharmacologists and facilitate policy implementation worldwide [28,29]. Overall, the available evidence consistently supports a transition from the traditional academic role of pharmacologists toward active participation in multidisciplinary healthcare teams. Integrating pharmacologists into routine clinical practice has the potential to improve medication safety, optimize therapeutic outcomes, strengthen pharmacovigilance, promote rational prescribing, and advance precision medicine. As healthcare becomes increasingly complex, the contributions of clinical pharmacologists will be indispensable to delivering safe, effective, and evidence-based patient care.

Limitations

This article is a narrative review and expert opinion based on published literature, clinical guidelines, and policy documents rather than a systematic review or meta-analysis. Consequently, the findings may be subject to publication bias and variations in study quality. Additionally, the applicability of the proposed recommendations may vary across healthcare systems due to differences in institutional infrastructure, workforce availability, regulatory policies, and available resources. Future multicenter studies and implementation research are needed to evaluate the clinical and economic impact of integrating clinical pharmacologists into routine patient care.

Conclusion

The role of clinical pharmacologists has evolved beyond traditional teaching and laboratory-based research to encompass medication safety, therapeutic optimization, pharmacovigilance, antimicrobial stewardship, precision medicine, and evidence-based clinical decision-making. Integrating clinical pharmacologists into multidisciplinary healthcare teams through dedicated Clinical Pharmacology Units has the potential to improve rational prescribing, reduce medication-related harm, enhance patient safety, and optimize healthcare quality. Achieving this transformation will require curriculum modernization, institutional commitment, supportive healthcare policies, and stronger collaboration between pharmacologists and clinicians. As healthcare continues to advance toward personalized and technology-driven medicine, clinical pharmacologists should be recognized as essential contributors to safe, effective, and patient-centered healthcare delivery.

Ethical Approval

This article is a narrative review and expert opinion based exclusively on previously published literature and publicly available data. It did not involve human participants, animals, patient records, or identifiable personal information. Therefore, ethical approval and informed consent were not required.

Consent for Publication

The author declares that there are no competing interests related to this manuscript.

Availability of Data and Materials

No new datasets were generated or analyzed during the preparation of this review. All information discussed in this article was obtained from published literature cited in the reference list.

Conflict of Interest

The authors declare that they have no competing interests related to the preparation or publication of this manuscript.

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Author Contributions (ICMJE)

Dr. Sk Sabir Rahaman: Conceptualization; literature search; evidence synthesis; interpretation of the literature; manuscript drafting; critical revision of the manuscript; preparation of tables and figures; final approval of the manuscript; and accountability for all aspects of the work in accordance with the ICMJE authorship criteria.

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Data Availability

No primary data were collected for this study. All supporting information is available through the cited references.

References

1. Adeyeye E, New BJM, Chen F, Kulkarni S, Fisk M, Coleman JJ. Sustainable medicines use in clinical practice: A clinical pharmacological view on eco-pharmaco-stewardship. *Br J Clin Pharmacol*. 2022;88(7):3023-3029. doi:10.1111/bcp.15140.
2. Barrachina J, Margarit C, Andreu B, Zandonai T, Ballester P, Muriel J, et al. Therapeutic alliance impact on analgesic outcomes in a real-world clinical setting: An observational study. *Acta Pharm*. 2022;72(4):529-545. doi:10.2478/acph-2022-0035.
3. Belančić A, Sans-Pola C, Jouanjus E, Alcubilla P, Arellano AL, Žunić M, et al. European Association for Clinical Pharmacology and Therapeutics Young Clinical Pharmacologists Working Group: A cornerstone for the brighter future of clinical pharmacology. *Eur J Clin Pharmacol*. 2022;78(4):691-694. doi:10.1007/s00228-022-03277-3.
4. Durydivka O, Palivec P, Gazdarica M, Mackie K, Blahos J, Kuchar M. Hexahydrocannabinol (HHC) and Δ^9 -tetrahydrocannabinol (Δ^9 -THC)-driven activation of cannabinoid receptor 1 results in biased intracellular signaling. *Sci Rep*. 2024;14:9181. doi:10.1038/s41598-024-58845-7.
5. Fedotova MM, Chigrina VP, Shirinskaya AV, Fedosenko SV, Fedorova OS. Antibiotic prescribing practices and perceptions on antimicrobial resistance among healthcare practitioners in Russia. *Public Health*. 2023;225:45-52. doi:10.1016/j.puhe.2023.09.008.
6. Greener M. Lower extremity lymphoedema: Some recent literature highlights. *Br J Community Nurs*. 2022;27(Suppl 4):S13-S14. doi:10.12968/bjcn.2022.27.Sup4.S13.
7. Jia N, Zhao Y, Sun X, Wang M, Guo D. The effect of early initiation of a self-management program based on multidisciplinary education in heart failure patients. *BMC Cardiovasc Disord*. 2024;24:503. doi:10.1186/s12872-024-04185-3.
8. Johnson-Williams B, Reynolds K, Gobburu J, Rundio A. A modified Delphi study to establish essential clinical pharmacology competencies. *Ther Innov Regul Sci*. 2024;58(3):473-482. doi:10.1007/s43441-023-00609-y.
9. Jouanjus E, Sans-Pola C, Mainoli B, Javid FA, Ekheden I. Establishing and evaluating a study questionnaire on knowledge and attitudes of healthcare professionals towards recreational and medical cannabis across Europe. *Clin Drug Investig*. 2021;41(8):701-710. doi:10.1007/s40261-021-01058-x.
10. Juhi A, Pipil N, Santra S, Mondal S, Behera JK, Mondal H. The capability of ChatGPT in predicting and explaining common drug-drug interactions. *Cureus*. 2023;15(4):e36272. doi:10.7759/cureus.36272.
11. Kadro ZO, Chilcoat A, Hill J, Kenney S, Nguyen C, Post E, et al. Healthcare professionals' perspectives on improving dietary supplement documentation in the electronic medical record: Current challenges and opportunities to enhance quality of care and patient safety. *Glob Adv Integr Med Health*. 2023;12:27536130231215029. doi:10.1177/27536130231215029.
12. Lapatto-Reiniluoto O, Siven M, Backman JT, Törrönen A. Medicines, environment and clinical pharmacology. *Basic Clin Pharmacol Toxicol*. 2022;131(3):149-152. doi:10.1111/bcpt.13757.
13. Liu BM, Thillainadesan J, Langford A, Fujita K, Gnjdic D, Hilmer SN. Patient, carer and healthcare professional perspectives on deprescribing in surgical wards: A mixed methods study. *Br J Clin Pharmacol*. 2025;91(8):2684-2695. doi:10.1002/bcp.70088.
14. Mandelli G, Dore F, Langer M, Garbero E, Alagna L, Bianchin A, et al. Effectiveness of a multifaceted antibiotic stewardship program: A pre-post study in seven Italian ICUs. *J Clin Med*. 2022;11(15):4409. doi:10.3390/jcm11154409.
15. Martin-Loeches I, Cornely OA, Denning DW, Guinea J, Bassetti M, Maertens J, et al. Invasive candidiasis in intensive care medicine: Shaping the future of diagnosis and therapy. *Intensive Care Med*. 2025;51:2065-2078. doi:10.1007/s00134-025-08151-1.
16. Montastruc F, Storck W, de Canecaude C, Victor L, Li J, Cesbron C, et al. Will artificial intelligence chatbots replace clinical pharmacologists? An exploratory study in clinical practice. *Eur J Clin Pharmacol*. 2023;79(10):1375-1384. doi:10.1007/s00228-023-03547-8.
17. Nunnari P, Ceccarelli G, Ladiana N, Notaro P. Prescribing cascades and medications most frequently involved in pain therapy: A review. *Eur Rev Med Pharmacol Sci*. 2021;25(2):1034-1041. doi:10.26355/eurrev.202101.24673.
18. Rhaman MM, Islam MR, Akash S, Mim M, Noor Alam M, Nepovimova E, et al. Exploring the role of nanomedicines for the therapeutic approach of central nervous system dysfunction: At a glance. *Front Cell Dev Biol*. 2022;10:989471. doi:10.3389/fcell.2022.989471.
19. Saleem MM, Elahi N, Athar R, Gul A, Adil M, Ellahi A, et al. The Petri dish under the ice: Permafrost pathogens and their impact on global healthcare and antibiotic resistance. *Ann Med Surg (Lond)*. 2024;86:7193-7201. doi:10.1097/MS9.0000000000002650.

20. Samajdar SS, Venkatraman S. Transforming medical education to meet India's healthcare demands. *J Assoc Physicians India*. 2025;73:91-93. doi:10.59556/japi.73.1196.
21. Schröder S, Schulze Westhoff M, Pfister T, Bleich S, Wedegärtner F, Krüger TH, et al. Characteristics of clinical-pharmacological recommendations in psychiatry in Germany. *Int J Psychiatry Med*. 2024;59(4):393-405. doi:10.1177/00912174231177230.
22. Sel EK, Gkrinia EMM, Roncato R, Vitezić D, Janković S, Belančić A. Pharmacokinetics of therapies approved for spinal muscular atrophy: A narrative review of current evidence. *J Int Med Res*. 2025;53:3000605251397777. doi:10.1177/03000605251397777.
23. Shawahna R, Amer R, Salameh H, Shawahna AR, Aljondy M, Zain-Aldain M. Adherence to evidence-based recommendations in managing bone health, pain, and mobility of patients with multiple myeloma: A mixed-method study in the Palestinian healthcare system. *BMC Cancer*. 2024;24:301. doi:10.1186/s12885-024-12024-z.
24. Shubow S, Gunsior M, Rosenberg A, Wang YM, Altepeter T, Guinn D, et al. Therapeutic drug monitoring of biologics: Current practice, challenges, and opportunities—A workshop report. *AAPS J*. 2025;27:62. doi:10.1208/s12248-025-01050-9.
25. Singh H, Nim DK, Randhawa AS, Ahluwalia S. Integrating clinical pharmacology and artificial intelligence: Potential benefits, challenges, and role of clinical pharmacologists. *Expert Rev Clin Pharmacol*. 2024;17(4):381-391. doi:10.1080/17512433.2024.2317963.
26. Snyman JR, Gumedze F, Jones ESW, Alaba OA, Tsabedze N, Vira A, et al. Comparing cardiovascular outcomes and costs of perindopril-, enalapril-, or losartan-based antihypertensive regimens in South Africa: Real-world medical claims database analysis. *Adv Ther*. 2023;40(11):5076-5089. doi:10.1007/s12325-023-02641-8.
27. Song Z, Hu Y, Liu S, Wang G, Zhai S, Zhang X, et al. Medication therapy of high-dose methotrexate: An evidence-based practice guideline of the Division of Therapeutic Drug Monitoring, Chinese Pharmacological Society. *Br J Clin Pharmacol*. 2022;88(5):2456-2472. doi:10.1111/bcp.15134.
28. Viswanathan VK, Ghoshal AG, Mohan A, Patil K, Bhargave C, Choudhari S, et al. Patient profile-based management with nintedanib in patients with idiopathic pulmonary fibrosis. *Pulm Ther*. 2024;10(2):377-409. doi:10.1007/s41030-024-00271-1.
29. Walsh J, Schaufelberger D, Iurian S, Klein S, Batchelor H, Turner R, et al. Path towards efficient pediatric formulation development based on partnering with clinical pharmacologists and clinicians: A conect4children expert group white paper. *Br J Clin Pharmacol*. 2022;88(11):5034-5051. doi:10.1111/bcp.14989.