International Journal of Basic & Clinical Pharmacology
Krishna AS et al. Int J Basic Clin Pharmacol. 2024 Sep;13(5):746-751
http://www.ijbcp.com
pISSN 2319-2003 | eISSN 2279-0780

DOI: https://dx.doi.org/10.18203/2319-2003.ijbcp20242441

Review Article

Emerging trends in precision medicine and its impact in pharmacy practice

Abhishek S. Krishna, Harikrishnan V. Nair, Shaiju S. Dharan, Keerthi G. S. Nair*

Department of Pharmacy Practice, Ezhuthachan College of Pharmaceutical Sciences, Marayamuttom, Neyyattinkara, Trivandrum, Kerala, India

Received: 22 July 2024
Accepted: 12 August 2024

***Correspondence:**
Dr. Keerthi G. S. Nair,
Email: keerthinair.dr@gmail.com

Copyright: © the author(s), publisher and licensee Medip Academy. This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial License, which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

ABSTRACT

Precision medicine is revolutionizing healthcare by tailoring treatments to an individual's unique genetic makeup, life style, and environment. This abstract explores the latest trends in precision medicine and discusses how it impacts pharmacy practice, including the development of targeted therapies and the role of pharmacogenomics in optimizing drug selection and dosage. Exciting advancements in this field offer the potential for improved patient outcomes and more precise medication management.

Keywords: Biomarkers, Genetics, Precision medicine, Pharmacogenomics, Pharmacy practice, Targeted therapies

INTRODUCTION

Precision medicine is a rapidly evolving approach to clinical practice that utilizes new technologies for disease prediction, prevention, diagnosis and treatment. Now a days, personalized assessment and treatments, involving detailed history, targeted examination, and specific tests are standard in medical practice.[1]

By analysing genetic, epigenomic and clinical data, we can gain insights into how an individual's unique genomic makeup influences their susceptibility to certain diseases. Pharmacogenomics is a new way of doing precision medicine, where we personalize drug choices and doses based on a person's genetic makeup.

Even though international scientific groups have released guidelines, they haven't been widely adopted in clinical practice yet.[2,3] This approach has led to significant breakthroughs in our understanding of precision medicine.[4,5] Advancements in genetics have enabled the identification of disease subtypes, complementing other methods like histology.[6] This has the potential to enhance disease prevention and treatment strategies. Indeed, the term personalized medicine was widely used before. however, it was replaced with precision medicine globally to avoid the misconception that it only caters to an individual.[7,8]

PRINCIPLES OF PRECISION MEDICINE

Genetic and genomic profiling

Central to precision medicine is the analysis of a patient's genetic and genomic information.

Advances in technologies like DNA sequencing have made it possible to identify genetic variations that underlie disease susceptibility and response to treatment. This principle recognizes that individual's genetic makeup can significantly influence their health and healthcare needs.[9,10,11]

Personalized diagnosis

The concept of personalized diagnosis emphasizes that healthcare should no longer take a one-size-fits-all approach. Instead, medical conditions are diagnosed with

precision, taking into account each patient's unique genetic and clinical characteristics. This ensures that the right diagnosis is made, which is a crucial first step toward effective treatment.[12]

Targeted therapies

Precision medicine emphasizes the development and use of targeted therapies. These treatments are designed to specifically address the genetic or molecular alterations responsible for a patient's disease. By targeting the root causes of illness, targeted therapies can be more effective and have fewer side effects than traditional treatments.[13]

Predictive medicine

Precision medicine goes beyond treating existing conditions. It strives to predict disease risk and individual responses to treatment. By analysing genetic and clinical data, healthcare providers can anticipate disease susceptibility, allowing for preventive measures, and tailor interventions based on likely treatment outcomes.[14]

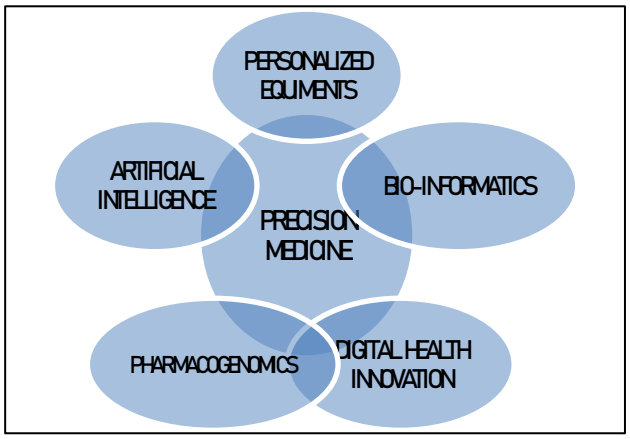

Figure 1: Various aspects of precision medicine.

PHARMACOGENOMICS: CUSTOMIZING DRUG THERAPY

Pharmacogenomics, often referred to as pharmacogenetics, is a branch of precision medicine that focuses on the study of how an individual's genetic makeup influences their response to drugs. It aims to customize drug therapy to optimize treatment outcomes while minimizing adverse effect.[15] Pharmacogenomics, an expanding research domain, explores how genetic diversity influences responses to drugs. Its aim is to create tailored and efficient drug therapies.[16] One aspect of this field involves pinpointing genetic indicators for variations in drug metabolism, while another centre on creating genetic tests to forecast individual responses to medications like statins or cancer treatments.[17]

The main features to be noted here include genetic variability, improved drug efficacy, reduced adverse effects and optimizing drug selection. Each person's genetic makeup is unique, leading to variations in the way drugs are metabolized and interact with the body.[18] Some individuals may be "rapid metabolizers" of a particular drug, while others are "poor metabolizers". By understanding a patient's genetic profile, healthcare providers can select the most appropriate medication and dosage, increasing the likelihood of treatment success. This is particularly beneficial in fields like oncology, where targeted therapies have revolutionized cancer treatment.[19]

Pharmacogenomics helps identify individuals who may be at risk of experiencing adverse drug reactions. It is a comprehensive term that covers the collective influence of various genetic mutations in the genome, which can influence an individual's response to drugs. This information allows healthcare professionals to avoid prescribing drugs that are likely to cause harm and instead choose safer alternatives.[20]

The use of pharmacogenomic information can be especially crucial in psychiatry, where the response to medications for mental health conditions can vary significantly based on genetics. It helps in finding the right antidepressants or antipsychotics for patients.[21,22] Understanding how genetic variations impact drug responses can inform drug development, leading to the creation of more targeted and effective pharmaceuticals.

BIOMARKERS AND DIAGNOSTIC TESTING IN PRECISION MEDICINE

The identification and utilization of biomarkers have become integral to the success of precision medicine. Biomarkers are measurable biological characteristics that can be used to indicate normal biological processes, pathogenic processes, or pharmacological responses to therapeutic interventions.[23] They can be found in a wide range of biological materials, including blood, tissues, and genetic data. Genetic biomarkers involve specific genetic variations or mutations that can indicate disease risk or guide treatment choices. Protein biomarkers measure the level of specific proteins that can help in diagnosing or monitoring diseases.

Metabolic biomarkers reflect the metabolic state of an individual and can be used in conditions like diabetes. Imaging techniques like MRI, CT scans, and PET scans can provide valuable biomarkers for assessing diseases such as brain tumors.[24] Epigenetic biomarkers can be used to find out changes in DNA methylation and histone modification patterns and can provide insights into disease progression and response to treatments. All these biomarkers can be used for disease diagnosis, treatment selection, and disease monitoring and drug development.[25]

Advanced diagnostic testing in precision medicine includes genomic sequencing, pharmacogenomics, liquid biopsies, metabolomics, proteomics, and microbiome

analysis and multi-omics integration. Liquid biopsies analyse components like Circulating Tumor Cells (CTCs) in the blood.[26] Proteomics involve the comprehensive analysis of proteins in a biological sample. Diagnostic tests can assess the composition and activity of the microbiome, providing insights into conditions like inflammatory bowel disease and obesity. To enhance diagnostic accuracy and precision, healthcare professionals are increasingly combining data from genomics, proteomics, metabolomics, and other omics fields.[27]

DIGITAL HEALTH TECHNOLOGIES IN PRECISION MEDICINE

Integrating digital health with artificial intelligence has instigated precision medicine, a revolutionary approach which maintains its promise to revolutionize patient care. Possible outcomes of this transformation are highly popular because they allow healthcare providers to offer therapies tailored to individual needs.[28,29] Newer innovations in digital health can provide with much precise information on patient's demographic details along with their risk assessment and grouping them into multiple categories integrating factors like medical history and responsiveness to previous medication therapies to provide with individual specific interventions.[30] The digitalization of health care data and the espousal of technology have paved way for the development and application of Artificial Intelligence which significantly contributes in the identification of phenotypes of the patients and the required individualized plan of care.[31]

Both artificial intelligence and digital health handles the medical and physiological aspects of the data in a different manner using various methodologies as required. Initially AI focuses primarily on the intelligent analysis of the available information and turning it into decisions in therapeutic management of the individual.[32] AI is also very helpful because it makes possible to process vast amounts of intricate data and provide personalized patient information with the ability to forecast outcomes, which helps to optimize and fine-tune the therapeutic course at every stage.[33]

ETHICAL AND LEGAL CONSIDERATIONS IN PRECISION MEDICINE

There are numerous ethical issues pertaining to precision medicine and these difficulties include moral dilemmas pertaining to extensive data sharing and storage.[34] Some other factors consist of potential discrimination on the part of employers and insurance providers, prejudice when gaining access to personalized medicine, unexpected results obtained from genetic testing, the inability to obtain informed consent due to lack of health literacy or genetic literacy, the dearth of empirical data supporting the safety and effectiveness of therapies, the potential for altering the doctor patient dynamic by emphasizing data as well as the growing demand on patients to provide information, time, effort and self-care.[35] Certain developments in genetics and genomics, as well as the potential for the development of useful tailored treatment in individuals possess certain ethical and legal issues.[36] The initial stages toward a treatment are identifying the genetic basis of disease, predicting risk based on genetic data, and advancing diagnostics. The creation of effective treatments ought to go hand in hand with advancements in research, prevention, and diagnosis.[37]

There are numerous, noteworthy examples of how genetic information might enhance therapy options, especially in the field of pharmacogenomics. At the same time, most of us associate personalized medicine with giving the appropriate medications to the appropriate patient at the appropriate time.[38] Gene therapy is one of the genetics-based treatments that have been developed concurrently with the advancements in pharmacogenomics. There are various definitions of gene therapy, and two of them are very pertinent from an ethical and legal standpoint because they come from regulatory agencies of the United States of America and Europe.[39] We cannot ignore the difficult ethical issues raised by the increased funding and enthusiasm surrounding precision medicine and health. By keeping in mind how these problems are interconnected through the notion of stratification which is the cornerstone of all precision health we can make more progress toward resolving them.[40]

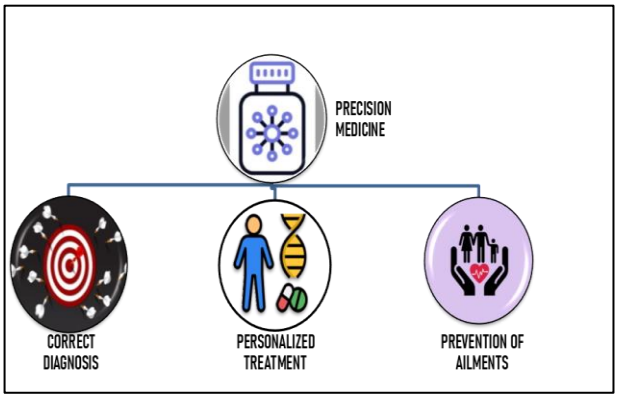

Figure 2: Representation of major objectives of precision medicine.

INTEGRATION OF PRECISION MEDICINE IN PHARMACY EDUCATION AND TRAINING

Since the practice of Pharmacy is always evolving due to scientific advancements, pharmacists must be able to adapt their skills accordingly. The profession of Pharmacy has changed over the past century from a dispensing model that concentrated on the preparation and administration of pharmaceutical products to a patient care model that prioritized providing direct patient care and customizing drug therapy for each patient.[41] It seems that in order to stay up with the changes in the health system, new approaches to medical education are required. These approaches involve all stakeholders, including patients, medical doctors, administrators, educators, engineers, nurses, data

analysts, and educators. These stakeholders need to be trained differently and with an emphasis on collaborative and multidisciplinary team work.[42] Connecting both the precision medicine and pharmacy education with appropriate dialogues can make a positive contribution in the field of management of different ailments and its prevention and will ensure its significant contributions in field of patient literacy and health care systems.[43]

Pharmacists have a multitude of opportunities in the field of personalized medicine, and their unique set of skills, knowledge, and abilities position them to further the use of personalized medicine as a clinical tool.[44] But the field of pharmacy has been sluggish to adopt the idea of clinical pharmacogenetics, and it is currently at a turning point that has the potential to completely reshape the role of the pharmacist in the workplace.[45]

FUTURE DIRECTIONS IN PRECISION MEDICINE

Precision medicine and artificial intelligence together have the potential to completely transform the medical field. According to recent research, translational research examining this convergence will aid in resolving the most challenging issues facing precision medicine, particularly those where patient symptoms, clinical histories, and lifestyle data, in conjunction with non-genomic and genomic determinants, will make individualized diagnosis and prognosis possible.[46]

Over the next ten years, precision medicine interventions are expected to become more widespread and transform the way services are provided and assessed. Healthcare systems everywhere will have to think about modifying their processes and evaluative techniques to account for these developments so they can keep doing thorough analyses of the cost benefit of novel therapies and services.[47,48]

Despite the fact that precision medicine has been pushed for more than ten years, patient care is frequently provided without a thorough understanding of the underlying social and cultural context, ignoring the effects of social determinants on health.[49] Today's healthcare system allows for the selection of a patient's medication based on their genetic composition, minimizing side effects and guaranteeing improved health. Precision medicine will benefit the healthcare system in the future by supplying every person's complete genetic profile detail at birth, which can be entered into a unique medical record.[50] Utilizing genomic data based on patient exposure to multiple diseases, clinicians and physicians will be able to adopt more dependable and effective healthcare approaches.[51] Establishing the best course of action for each patient requires determining precisely where the patient is in the course of managing their disease and what options are available to advance.[52] This is separate and apart from the actual availability of resources and treatment options. Precision medicine can be used throughout the whole healthcare by utilizing scalable technologies. All parties involved in healthcare can use precision medicine as a compass to help them navigate the future by identifying challenges, offering tailored solutions and shedding light on the path ahead.[53] Once the intricacy of illness has been understood, treatments must be customized for each patient based on their unique physiology and body type. Any individual's socioeconomic circumstances, in developed and developing countries alike, will be greatly impacted by the straightforward factor of reducing treatment duration and side effects.[54]

CHALLENGES IN PRECISION MEDICINE

Although the commercialization of precision medicine approaches holds great promise for the improvement of healthcare provision and well-being, it will also present new regulatory challenges and legitimate ethical and social concerns.[55] There is also a chance that the misuse of precision medicine will contribute to the commercialization of health rather than disease by preying on people's fears about risk factors, genetics, etc. in order to sell preventative medication, which has enormous financial ramifications and needs to be taken continuously throughout a person's life before they have even developed a disease.[56]

There will probably be disagreements regarding the choice between pharmaceutical and lifestyle-based precision treatment. The four distinct research domains are anatomy and physiology, cellular and molecular biology, genotype and phenotype, and omics systems represent a clear challenge for the life science and biomedical research communities and we must foster efforts for collaboration among these domains by unifying the professional language and conception.[57,58] Furthermore, in order to facilitate knowledge sharing and integration, a set of common elements must be extracted. We must acknowledge that integrating cutting edge technologies from various scientific domains and disciplines is essential to performing the best possible job for precision medicine.[59,60]

CONCLUSION

Precision medicine is the future of healthcare, and with its incredible array of tools, it will revolutionize the practice of medicine. It’s truly exciting to see how it will shape the future. The availability of modern biomedical technologies like DNA sequencing, proteomics, and wireless monitoring devices has opened up a whole new world of possibilities in precision medicine. These tools have allowed us to identify variations and understand the unique needs of each individual, paving the way for personalized approaches to healthcare. With advancements in genomics and data analytics, this approach has the potential to revolutionize medical practice, improving patient outcomes and reducing adverse effects. However, challenges such as ethical considerations, data privacy, and equitable access need to be addressed to fully realize the benefits of precision medicine on a global scale. It’s

crucial to develop and implement better strategies for educating and training healthcare professionals about precision medicine.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Naithani N, Sinha S, Misra P, Vasudevan B, Sahu R. Precision medicine: Concept and tools. Med J Armed Forces India. 2021;77(3):249-57.
2. Cecchin E, Stocco G. Pharmacogenomics and Personalized Medicine. Genes (Basel). 2020;11(6):679.
3. Sadee W, Wang D, Hartmann K, Toland AE. Pharmacogenomics: Driving Personalized Medicine. 2023;75(4):789-814.
4. Akhoon N. Precision medicine: A new paradigm in therapeutics. Int J Prev Med. 2021;12:4.
5. Stone A. Precision medicine: Health care tailored to you. The White House Blog. 2016;2:54.
6. Collins FS, Varmus H. A new initiative on precision medicine. N Engl J Med. 2015;372:793-5.
7. Delpierre C, Lefevre T. Precision and personalized medicine: What their current definition says and silences about the model of health they promote. Implication for the development of personalized health. Front Sociol. 2023;8:1112159.
8. Goetz LH, Schork NJ. Personalized medicine: motivation, challenges, and progress. Fertil Steril. 2018;109(6):952-63.
9. Aronson SJ, Rehm HL. Building the foundation for genomics in precision medicine. Nature. 2015;526(7573):336-42.
10. Freimuth RR, Formea CM, Hoffman JM, Matey E, Peterson JF, Boyce RD. Implementing Genomic Clinical Decision Support for Drug-Based Precision Medicine. CPT Pharmacometrics Syst Pharmacol. 2017;6(3):153-5.
11. Horton RH, Lucassen AM. Recent developments in genetic/genomic medicine. Clin Sci. 2019;133(5):697-708.
12. Johnson KB, Wei WQ, Weeraratne D, Frisse ME, Misulis K, Rhee K, et al. Precision medicine, AI, and the future of personalized health care. Clin Transl Sci. 2021;14(1):86-93.
13. Saeed RF, Awan UA, Saeed S, Mumtaz S, Akhtar N, Aslam S. Targeted Therapy and Personalized Medicine. Cancer Treat Res. 2023;185:177-205.
14. Linnea M Baudhuin, Leslie G Biesecker, Wylie Burke, Eric D Green, Robert C Green. Predictive and precision medicine with genomic data. Clinical Chemistry. 2020;66(1):33-41.
15. Kudzma EC, Carey ET. Pharmacogenomics: personalizing drug therapy. Am J Nurs. 2009;109(10):50-7.
16. Stratton TP, Olson AW. Personalizing personalized medicine: the confluence of pharmacogenomics, a person's medication experience and ethics. Pharmacy (Basel). 2023;11:3.
17. Nogueiras-Alvarez R. Pharmacogenomics in clinical trials: an overview. Front Pharmacol. 2023; 14:1247088.
18. Service RF. Pharmacogenomics. Going from genome to pill. Science. 2005;308(5730):1858-60.
19. Rodriguez-Vicente AE, Lumbreras E, Hernandez JM, Martin M, Calles A, Otin CL, et al. Pharmacogenetics and pharmacogenomics as tools in cancer therapy. Drug Metab Pers Ther. 2016;31(1):25-34.
20. Ingelman SM, Nebert DW. Emerging trends in pharmacogenomics: from common variant associations toward comprehensive genomic profiling. Hum Genomics. 2023;105:17.
21. Hiratsuka M, Sasaki T, Mizugaki M. Genetic testing for pharmacogenetics and its clinical application in drug therapy. Clin Chim Acta. 2006;363(1-2):177-86.
22. Roberts B, Cooper Z, Lu S, Stanley S, Majda BT, Collins KRL, et al. Utility of pharmacogenetic testing to optimise antidepressant pharmacotherapy in youth: a narrative literature review. Front Pharmacol. 2023;14:1267294.
23. Slikker W J. Biomarkers and their impact on precision medicine. Exp Biol Med. 2018;243(3):211-2.
24. Gyawali B. Point: the imprecise pursuit of precision medicine: are biomarkers to blame? J Natl Compr Canc Netw 2017;15:859-62.
25. Bakker E, Starokozhko V, Kraaijvanger JWM, Heerspink HJL, Mol PGM. Precision medicine in regulatory decision making: Biomarkers used for patient selection in European Public Assessment Reports from 2018 to 2020. Clin Transl Sci. 2023;16: 2394-412.
26. Dregely I, Prezzi D, Kelly-Morland C, Roccia E, Neji R, Goh V. Imaging biomarkers in oncology: Basics and application to MRI. J Magn Reson Imaging. 2018;48(1):13-26.
27. Schweitzer M. Biomarkers, bioindicators, molecular imaging, functional imaging, precision medicine, and the search for intelligent life in the universe. J Magn Reson Imaging. 2016;44(1):11.
28. Giansanti D. Precision medicine 2.0: How digital health and ai are changing the game. J Pers Med. 2023;13(7):1057.
29. Ginsburg G S, Phillips K A. Precision Medicine: From Science to Value. Health Aff. 2018;37:694-701.
30. Fernandez-Luque L, Al Herbish A, AI Shammari R, Argente J, Bin-Abbas B, Deeb A, et al. Digital health for supporting precision medicine in pediatric endocrine disorders: opportunities for improved patient care. Front Pediatr. 2021;9:715705.
31. Johnson KB, Wei WQ, Weeraratne D, Frisse ME, Misulis K, Rhee K, et al. Precision medicine, ai, and the future of personalized health care. Clin Transl Sci. 2021;14(1):86-93.
32. Wang F, Preininger A. AI in Health: State of the art, challenges, and future directions. Year Med Inform. 2019;28(1):16-26.

33. Topol EJ. High performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019;25(1):44-56.
34. Korngiebel DM, Thummel KE, Burke W. Implementing Precision Medicine: The Ethical Challenges. Trends Pharmacol Sci. 2017;38(1):8-14.
35. Erdmann A, Rehmann-Sutter C, Bozzaro C. Patients' and professionals' views related to ethical issues in precision medicine: a mixed research synthesis. BMC. Med Ethics. 2021;22(1):116.
36. Evans WE. Pharmacogenomics: marshalling the human genome to individualize drug therapy. GUT. 2003;52:10-8.
37. Ashley EA. The precision medicine initiative: a new national effort. JAMA. 2015;313:2119-20.
38. Olson S, Beachy SH, Giammaria CF, Berger AC. Integrating large-scale genomic information into clinical practice. The National Academies Press; Washington, DC, USA. 2012. Available at: www.ncbi.nlm.nih.gov/books.
39. Joaeo VC. Ethical and legal challenges of personalized medicine: Paradigmatic examples of research, prevention, diagnosis, and treatment. Revista Portuguesa de SaA de Pablic. 2014;32(2):164-80.
40. Eric T. Why does the shift from personalized medicine to precision health and wellness genomics matter? Am J of Ethics. 2018;20(9):881-90.
41. Carter BL. Evolution of clinical pharmacy in the USA and future directions for patient care. Drugs aging. 2016;33(3):169-77.
42. Papadopoulou P, Lytras M. Advancing precision medicine in medical education: Integrated, precise, and data-driven smart solutions. Appl Res. 2023;2:202200131.
43. Singh AK, Malviya R, Verma S. Personalized Medicine: Advanced Treatment Strategies to Revolutionize healthcare. Curr Drug Res Rev. 2023;15(2):101-4.
44. Kennedy MJ. Personalized medicines-are pharmacists ready for the challenge? Integrated Pharmacy Research and Practice. 2018;7:113-23.
45. Kennedy MJ, Phan H, Benavides S, Potts A, Sorensen S. The role of the pediatric pharmacist in personalized medicine and clinical pharmacogenomics for children: Pediatric pharmacogenomics working group. J Pediatr Pharmacol Ther. 2011;16(2):118-22.
46. Naithani N, Atal AT, Tilak TVSVGK, Vasudevan B, Misra P, Sinha S. Precision medicine: Uses and challenges. Med J Armed Forces India. 2021;77(3):258-65.
47. Love-koh J, Peel A, Rejon-Parrilla JC, Ennis K, Lovett R, Manca A, et al. The future of precision medicine: potential impacts for health technology assessment. Pharmacoeconomics. 2018;36(12):1439-51.
48. Ory MG, Adepoju OE, Ramos KS, Silva PS, Vollmer DD. Health equity innovation in precision medicine: current challenges and future directions. Front Public Health. 2023;11:1119736.
49. Callier SL. The use of racial categories in precision medicine research. Ethn Dis. 2019:651-8.
50. Badhe Pravin. Personalized medicine: the future of modern medicine. Authorea. 2021:1-9.
51. Mathur S, Sutton J. Personalized medicine could transform healthcare. Biomed Rep. 2017;7(1):3-5.
52. Amelio I, Bertolo R, Bove P. Liquid biopsies and cancer omics. Cell Death Discover. 2020;6(1):1-8.
53. Wilson JF, Weale ME, Smith AC, Gratrix F, Fletcher B, Thomas MG. Population genetic structure of variable drug response. Nat Genet. 2001;29:265-9.
54. Liu X, Luo X, Jiang C, Zhao H. Difficulties, and challenges in the development of precision medicine. Clin Genet. 2019;95(5):569-74.
55. Mc Gonigle V. The collective nature of personalized medicine. Genet Res. 2016;98:3.
56. Duffy DJ. Problems, challenges and promises: perspectives on precision medicine. Brief Bioinform. 2016;17(3):494-504.
57. Hood L, Friend SH. Predictive, personalized, preventive, participatory cancer medicine. Nat Rev Clin Oncol. 2011;8:184-7.
58. Xue Y, Lameijer EW, Ye K, Zhang K, Chang S. Precision medicine: What challenges are we facing? Genomics Proteomics Bioinformatics. 2016;14(5):253-61.
59. Beckmann JS, Lew D. Reconciling evidence-based medicine and precision medicine in the era of big data: challenges and opportunities. Genome Med. 2016;8(1):134.

Cite this article as: Krishna AS, Nair HV, Dharan SS, Nair KGS. Emerging trends in precision medicine and its impact in pharmacy practice. Int J Basic Clin Pharmacol 2024;13:746-51.