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Review Article

Precision Medicine in Pharmacy Practice: Advancements and Implications

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ABSTRACT

Precision medicine, which is often referred to as personalised medicine, is a cutting-edge approach to healthcare that aims to customise medical treatments for individual patients according to their lifestyle, genetic composition, and environmental circumstances. Precision medicine, which emphasises pharmacogenomics, individualised medication regimens, and the use of biomarkers to improve patient care, has completely changed the way pharmacists approach drug therapy in pharmacy practice. The function of precision medicine in pharmacy practice is covered in this review article, which also highlights significant developments, difficulties, and potential paths forward.

Keywords: Precision medicine, Pharmacy practice, Pharmacogenomics, Personalised drug therapies, Biomarkers, Patient care, Genetic testing, Treatment optimization.

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INTRODUCTION

Individuals respond differently to various drugs. Patients who receive prescriptions for inadequate medications may not only incur financial costs, but also have physiological adverse effects that, in certain cases, could be fatal. This necessitates customising therapy for every patient. It may be possible to lower financial costs and improve quality of life by tailoring healthcare services for a specific person or group of individuals (Sun *et al*., 2019).

In recent years, the term "precision medicine" has gained a lot of traction thanks to both political and scientific viewpoints (König *et al*., 2017). Precision medicine is a new paradigm in healthcare that aims to treat patients more individually and specifically by doing away with the conventional one-size-fits-all approach to treatment (Hodson, 2016). Precision medicine in pharmacy practice includes individualised pharmacological regimens, pharmacogenomics, and the use of biomarkers to inform treatment choices, among other things (Ramaswami *et al*., 2018). With precision medicine, drug discovery and genomics can now work together to provide novel insights into the causes of a patient's illness as well as possible treatment approaches (Dugger *et al*., 2018).

A new area of study in public health called Precision Public Health (PPH) aims to better target public health initiatives within populations by building on the progress of precision medicine and leveraging new technological advancements and insights gained from big data (Bilkey *et al*., 2019). By tailoring the healthcare process to each patient's particular and constantly changing health status, precision medicine aims to optimise the quality of medical care. In order to enable evidence-based, or data-driven, decision making, this project encompasses a wide range of scientific fields, including medication development, genetics and genomics, health communication, and causal inference. Formally, precision medicine is a treatment plan that links the most recent patient data to a recommended course of action through a set of decision rules, one for each decision point. Precision medicine has the potential to transform patient care and treatment decisions (Kosorok and Laber, 2019; Duffy, 2016).

It will be necessary to modify genomics techniques, such as DNA sequencing technology and analytic algorithms, that were created for genetic discoveries in order to meet clinical requirements in order to fully realise this promise. To do this, it will be important to optimize alignment algorithms, adopt consensus standards for variant calling and interpretation, provide tailored solutions for paralogous or low-complexity sections of the genome, and pay attention to quality-coverage measures (Ashley, 2016).

With the goal of understanding and treating disease by integrating multimodal or multi-omics data from an individual to create patient-tailored decisions, precision medicine is an emerging approach to clinical research and patient treatment. Novel tools were required to interpret and comprehend the enormous and complicated datasets produced by precision medicine diagnostic approaches (MacEachern and Forkert, 2021). With minimal

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negative effects and maximal effectiveness, precision medicine should guarantee that patients receive the appropriate treatment at the appropriate dose at the appropriate time. However, it will alter the way health care is provided and paid for as well as how medicine is taught and practised. It will alter the financing and regulations around research and development. It will have a significant impact on patient-clinician relationships and public trust, and it will call for previously unheard-of levels of cooperation amongst stakeholders in the health care system (Mirnezami *et al*., 2012). Precision medicine can advance and become more widely used if patients take an active role in their care and take greater personal responsibility for their health and well-being (Bahcall, 2015).

In actuality, the phrase "precision medicine" can refer to more than just choosing a course of therapy; it can also refer to developing customised medical devices for specific patients (Zhang, 2015). Precision medicine has been included into the broader field of complement-mediated disorders by the resurgence of complement diagnostics and treatments. Specifically, paroxysmal nocturnal hemoglobinuria, cold agglutinin disease, hemolytic uremic syndrome, nephropathies, HELLP syndrome, transplant-associated thrombotic microangiopathy, antiphospholipid antibody syndrome, myasthenia gravis, and neuromyelitis optica are complement-mediated diseases (or complementopathies) with ongoing or published clinical trials of complement inhibitors (Gavriilaki and Brodsky, 2020).

Population sciences including epidemiology, behavioral, social, and communication sciences, health economics, implementation science, and outcomes research are needed to illustrate the advantages of precision medicine. Strategies that strike a balance between population- and individual-level treatments can optimise health outcomes, reduce harm, and prevent avoidable medical expenses (Khoury *et al*., 2012; Sandhu, Qureshi, and Emili, 2018). This article provides an overview of these key components and their implications for pharmacy practice.

Difference between precision medicine and personalised medicine

While precision medicine refers to a health care delivery model that heavily relies on data, analytics, and information, personalised medicine refers to an approach to patients that takes into account their genetic make-up while also paying attention to their preferences, beliefs, attitudes, knowledge, and social context. This concept extends beyond genomics and has far-reaching consequences for the direction of research in our country as well as for its application and uptake in the medical field. For precision medicine and its supporting ecosystem to succeed, patient participation and centeredness, digital health, genomics and other molecular technologies, data sharing, and data science must all be embraced (Ginsburg and Phillips, 2018).

Precision medicine: Concept and tools

The term "precision medicine," which describes modern medicine, refers to adjusting a patient's course of care to a subgroup of people who share a predisposition to a specific illness or drug reaction. The Precision Medicine Initiative, introduced by Barack Obama in 2015, gave the idea a boost even though it was there when Sir William Osler was alive. Big data, artificial intelligence, diverse omics, pharmaco-omics, environmental and social elements, and their integration with population and preventive medicine are the primary instruments of precision medicine. Big data can be obtained from patient electronic health records and comprises a variety of biomarkers (clinical and omics based), laboratory and radiological investigations, and other information. It can be analysed via machine learning using a variety of intricate flowcharts that establish an algorithm for the management of particular subpopulations. Thus, precision-based medicine is replacing the conventional "one size fits all" approach to therapy. The field of "omics" research has advanced significantly, with notable breakthroughs being made in transcriptomics, metabolomics, proteomics, genomes, epigenomics, and microbiomics. With the creation of novel medications and the matching of a given treatment to a certain subpopulation, pharmaco-omics has also taken the lead in reducing unintended side effects, prescribing medications to non-responders, and proving cost-effective over the long term. For the majority of complicated diseases, environmental, social, and behavioural factors are just as important-if not more so-than genetic determinants. One of the most important aspects of precision medicine is managing these variables (Naithani *et al*., 2021, Hulsen *et al*., 2019).

AI in precision medicine

Precision medicine and Artificial Intelligence (AI) together have the potential to completely transform the medical field. Over the next ten years, as precision medicine develops in several critical areas such as large cohorts, artificial intelligence, routine clinical genomics, phenomics and environment, and returning value across varied populations-it will continue to revolutionise healthcare. With this method, medical professionals and researchers may more precisely forecast which preventive and treatment measures for a certain illness will be effective for specific populations. It necessitates a large amount of processing capacity (supercomputers); deep learning algorithms that can learn on their own at a never-before-seen rate; and, all things considered, a method that makes novel use of doctors' cognitive abilities (Johnson *et al*., 2021).

Supercomputer computational capacity has turned into a battlefield where nations vie for dominance. In the fields of cardiology, dermatology, and oncology, deep learning algorithms have been demonstrated to diagnose patients at least as well as doctors. But we must stress how crucial it is to combine these

algorithms with medical professionals' expertise. As part of the International Symposium on Biomedical Imaging grand challenge, participants developed computer programs that could identify metastatic breast cancer in entire slide pictures obtained from sentinel lymph node biopsies. The success rate of the winning algorithm was 92.5%. A pathologist's independent evaluation of the same photos yielded a 96.6% success rate. The pathologist's success rate was raised to 99.5% by combining the deep learning system's predictions with the human pathologist's diagnosis, which resulted in an almost 85% decrease in the rate of human mistake. Artificial Narrow Intelligence (ANI), Artificial General Intelligence (AGEI), and Artificial Super Intelligence (ASEI) are the three broad stages of AI. The most likely to emerge in the upcoming ten years is ANI. ANI could uncover new correlations, make inferences, evaluate data sets, and assist doctors in their work. Some businesses have shown how ANI, deep learning, and supercomputers could help with precision medicine (Mesko, 2017; Denny and Collins, 2021)

Biomarkers in Patient Care

Measurable indications of biological processes or disease states, known as biomarkers, can inform therapy choices and track how well a treatment is working. Biomarkers are essential in pharmacy practice because they help identify patients who will benefit from particular medications, forecast treatment results, and track the effectiveness of treatments. Pharmacists use biomarker testing to customise medication regimens, maximise dosage efficiency, and modify treatment schedules in response to patient response. Pharmacists can improve medication management and patient outcomes by integrating biomarkers into patient care.

Precision medicine in oncology

The best option for maximising the immediate benefits of precision medicine is unquestionably oncology. Cancer is a widespread disease that ranks among the top causes of mortality both domestically and globally, and its frequency rises with ageing populations. Their lethality, symptoms, and the frequently poisonous or disfiguring medicines used to cure them make them particularly feared (Collins and Varmus, 2015). The link between cancer genotype and phenotype is not well understood biologically, which limits the potential of genome-based cancer therapy matching. Functional assessment of live patient tumour cells subjected to possible treatments can overcome this constraint. Many 'next-generation' functional diagnostic technologies have been reported recently; these overcome the shortcomings of the previous generation of chemosensitivity tests. Examples include novel techniques for manipulating tumours, assays of tumour responses that are molecularly precise, and device-based *in situ* approaches. With the potential to precisely match combination medicines to specific cancer patients, the promise of these new technologies points to a future diagnostic approach that combines functional testing with next-generation sequencing and immunoprofiling (Friedman *et al*., 2015).

Targeted IDH1/IDH2, FLT3, and BCL-2 inhibitors have shown the successful development of precision therapy for patients with AML. These inhibitors have a mild antileukaemic effect when administered alone. On the other hand, increased clinical activity has been seen when they are used in conjunction with traditional cytotoxic treatments or medications with more expansive modes of action that target epigenetic and/or other oncogenic signalling pathways. The development of immunotherapies has been hampered by the expression of antigens produced by leukemic and non-malignant hematopoietic progenitor cells; nevertheless, a number of immunotherapies are currently advancing into clinical development (Döhner *et al*., 2021).

Precision medicine in the epilepsies

With gene discovery advancing fresh insights of disease biology, precision medicine in the treatment of epilepsies has garnered significant attention. There are now a number of tailored therapies available, some of which are highly sophisticated and customised on an individual basis (Sisodiya, 2021). Precision medicine is becoming more and more apparent as a result of technological advancements that have expedited genome discovery. Because of the rapidly growing genetic knowledge base in epilepsy, the availability of high-quality *in vitro* and *in vivo* model systems to effectively study the biological effects of genetic mutations, the capacity to transform these models into efficient drug-screening platforms, and the formation of collaborative research groups, epilepsy research in particular is well-suited to serve as a model for the development and deployment of targeted therapeutics in precision medicine. These partnerships must be strengthened going forward, especially through integrated research platforms, in order to produce reliable results for precise personal genome analysis as well as gene and medicine development. Comparably, the establishment of clinical trial networks will enable the enlargement of patient sample populations with epilepsy that is genetically characterised, hence facilitating the translation of medication discovery into clinical practice (EpiPM Consortium, 2015).

Precision medicine in cardiology

Through the development and use of precision medicine, the cardiovascular research and clinical communities are uniquely positioned to address the epidemic of noncommunicable causes of death and further our understanding of human health and illness. The description of the cardiovascular health state of individuals and populations will require the use of new technologies, such as patient-generated data, 'omic' data, exposome and social determinants of health, the microbiome, behaviours and motivations, and the wealth of information found in electronic medical records. Cardiovascular specialists have the opportunity to leverage their expertise in precision medicine

to advance clinical research efficiency and enhance discovery science, ultimately leading to more accurate information that will benefit both individual and population health. Resolving a number of technological and societal challenges will be necessary to remove the obstacles in the way of precision medicine implementation. Precision medicine will transform health care into a more dynamic, interconnected system where patients are important stakeholders who actively provide data and engage in shared decision-making, rather than being a passive subject on which measurements are performed. A universal precision medicine environment will eventually be possible when siloed approaches to health are eliminated because many traditionally characterised diseases share underlying processes (Antman and Loscalzo, 2016).

Precision medicine in challenges in IBD research

The Challenges in IBD research document lists five priority areas: environmental triggers, novel technologies, pragmatic clinical research, and preclinical human IBD mechanisms. Precision medicine is one of these topics. The publication "Challenges in IBD Research" offers a thorough summary of the present gaps in the field's understanding of Inflammatory Bowel Disorders (IBD) and suggests practical solutions. It is the outcome of multidisciplinary input from researchers, physicians, patients, and funders, and it is an important tool for patient-centred research priority. The precision medicine portion, in particular, focuses on identifying the primary areas of unmet need that need to be filled in order to move toward the goal of precision medicine, which is to develop treatments that are specific to the biological and clinical characteristics of individual patients. The three key areas of unmet need were: 1) forecasting and comprehending the natural history of Inflammatory Bowel Disease (IBD) including susceptibility, activity, and behaviour; 2) predicting the course of the disease and response to treatment; and 3) refining existing and creating new molecular technologies. Prospective longitudinal cohort studies to find and confirm precision biomarkers for prognosticating the course of a disease and for predicting and tracking therapy response are some suggested strategies to close these gaps. Harmonisation among research and the creation of common infrastructure and procedures are essential for achieving this. It will also be crucial to apply cutting-edge systems biology, machine learning, and molecular technologies for multi-omics and clinical data integration and analysis. In order to assess the clinical efficacy of validated signatures and biomarkers in enhancing patient outcomes and providing cost-effective care, randomised biomarker-stratified trials will be essential (Denson *et al*., 2019). Table 1 summarizes the application of precision medicine in different specialities.

Challenges and Future Directions

Precision medicine has great potential to improve patient care, but there are a number of obstacles to overcome before it can be fully implemented in pharmacy practice. These include the requirement for uniform rules for interpreting the results of genetic tests, the need to remove financial and accessibility obstacles to genetic testing, and the need to guarantee that pharmacists have the proper instruction and training. To further optimise precision medicine's deployment in practice, its integration into pharmacy workflow systems and electronic health records is still a top objective (Seymour *et al*., 2017).

Table 1: Application of precision medicine in different specialities.

Specialty	Application in Precision Medicine	Examples
Oncology	Genomic profiling and functional tumour testing	FLT3, IDH1/2 inhibitors; AML immunotherapies (Friedman *et al*., 2015; Döhner *et al*., 2021).
Neurology (Epilepsy)	Genetic therapies, gene-guided drug development	Collaborative genomic networks, targeted therapies (Sisodiya, 2021; EpiPM Consortium, 2015).
Cardiology	Omics data and exposome integration	Patient-generated data, electronic health records, tailored risk prevention (Antman and Loscalzo, 2016).
Gastroenterology (IBD)	Biomarker discovery, predictive algorithms	Disease course prediction, biomarker-stratified clinical trials (Denson *et al*., 2019).

CONCLUSION

Precision medicine holds tremendous potential for transforming pharmacy practice and improving patient outcomes. By embracing pharmacogenomics, personalised drug therapies, and biomarker-guided care, pharmacists can deliver more tailored and effective treatments to their patients. However, addressing challenges such as standardisation, accessibility, and education will be essential for realising the full benefits of precision medicine in pharmacy practice. Moving forward, continued research, collaboration, and innovation will be critical in advancing the role of precision medicine in optimising medication therapy and enhancing patient care.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ABBREVIATIONS

PPH: Precision Public Health; **DNA:** Deoxyribonucleic Acid; **ANI:** Artificial Narrow Intelligence; **AGEI:** Artificial General Intelligence; **ASEI:** Artificial Super Intelligence; **IDH1/IDH2:** Isocitrate Dehydrogenase 1/2; **FLT3:** FMS-like tyrosine kinase 3; **BCL-2:** B-cell CLL/lymphoma 2; **AML:** Acute Myeloid Leukemia; **IBD:** Inflammatory Bowel Disorders.

SUMMARY

Precision medicine is transforming pharmacy practice by allowing the customization of drug therapies based on individual genetic, environmental, and lifestyle factors, with pharmacists using pharmacogenomics, biomarker-guided care, and AI-powered tools to tailor treatments for improved efficacy and safety. Recent advancements include integrating genetic testing into clinical workflows, adopting targeted therapies in oncology and neurology, and expanding pharmacist's roles in medication management. Although significant progress is made, challenges remain around standardization, costs, workforce training, and equitable access, making ongoing research, interdisciplinary collaboration, and digital innovation critical for fully realizing precision medicine's potential to optimize patient outcomes and redefine pharmacy practice.

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