The role of precision medicine in healthcare

Hettiarachchi NM¹, Manilgama SR², Liyanage ADMD³

Definition and overview

Precision medicine is an emerging approach that takes into account an individual's variability in genes, environment, and lifestyle in disease treatment and prevention. (1,2)

Instead of the traditional one-size-fits-all approach, precision medicine aims to tailor medical treatment and prevention strategies to the specific characteristics of each individual. By taking into account unique variations in genes, environments, and lifestyles of an individual, this approach allows healthcare providers to better predict which treatment and prevention strategies will be most appropriate and effective for a particular patient, leading to improved outcomes and reduced side effects.

The terms “precision medicine” and “personalised medicine” show considerable overlap and are used interchangeably. “Precision medicine” appears to better capture the focus on treating and preventing diseases based on genetic, lifestyle-related, and environmental factors(3) as opposed to “personalised medicine” which incorporates dimensions beyond therapeutics, addressing the patient's social environment, cultural values etc. The term “personalised medicine” is also given a different interpretation which aligns with “holistic care” in traditional medicine. Therefore depending on context it may be considered an older term and a precursor to “precision medicine”.

The ultimate goal of precision medicine is to provide the right treatment to the right patient at the right time, leading to better patient outcomes and a more efficient healthcare system(4,5,6)

History

From the discovery of the structure of DNA by Watson and Crick in 1953 to DNA sequencing by Sanger in 1977, culminating in the Human Genome Project launched in the 1990s, the concept of precision medicine has gradually established itself.

Research on Mendelian genetics and patterns of inheritance set the stage for the current knowledge in complex interactions between multiple genes in the development of disease. It also brought to light the diversity in the manifestation of the same genetic mutation due to variation in gene expression.(5) It is apparent therefore that the predictive ability of genetics alone in determining disease causation is relatively modest. Consequently, there arose a need for new technologies and approaches in the field of medicine.

Pharmacogenomics emerged as a response to such need and is a field that explores how an individual's genetic inheritance affects the body's response to drugs.(7)

The term "precision medicine" gained prominence in 2015 with the launch of the precision medicine initiative in the United State of America which aims to advance the treatment of diseases such as cancer and diabetes.(8) Since then the field of precision medicine has received much attention and has shown rapid development up to date.
Precision medicine over Traditional Medicine/Evidence-based medicine

Traditional medicine follows a uniform treatment approach where the same drug is prescribed to all patients for a particular illness. These interventions are based on evidence from research that are generalised to the population at large. However, this approach poses challenges as not all patients respond equally to the drug. Some may not respond at all while others may experience adverse effects. These differences in individual responses could be attributed to genetic variations, age, gender, lifestyle choices, race, ethnicity, concurrent medications, underlying health conditions, environmental factors, and more. This not only leads to drug wastage but also increases costs and reduces satisfaction among patients and healthcare providers.

Precision medicine addresses these challenges by considering the diverse genetic, socio-environmental, and lifestyle factors within subpopulations to tailor specific therapies. It focuses on accurately measuring molecular, environmental, and behavioural contributors to health and disease, leading to more precise diagnostics, targeted disease prevention strategies, individualised treatment selection, and the development of innovative therapies.(5)

The role of AI in precision medicine

Precision medicine requires the analysis of large volumes of diverse data in order to deliver the desired outcome. The advancements in artificial intelligence (AI) with technologies of machine learning, neural networks, etc. demonstrates great promise in this context by making it a tool to handle such data efficiently, effectively and accurately.

The integration of AI and precision medicine thus shows significant potential to revolutionise healthcare as evidenced by AI application in the field of radiogenomics. Here associations between cancer imaging characteristics and genetic factors are studied to predict a patient's risk of developing complications from radiotherapy. This interdisciplinary approach has shown promise in various types of cancer, including glioma, breast cancer, liver cancer, and colorectal cancer.(6)

Application of precision medicine in different disciplines

The successful application of precision medicine is apparent in almost all disciplines in medicine. Some prominent discoveries and applications are discussed below under each discipline.

Oncology

Molecular testing has allowed for precise subtyping of cancers based on genetic abnormalities, leading to the development of targeted therapies tailored to individual patients.

For example, specific mutations like EGFR in lung cancer have led to the emergence of targeted therapies such as osimertinib (an EGFR inhibitor) that shows improved outcomes compared to traditional treatments.

Molecular profiling has also proven beneficial in breast cancer. Targeted therapies for HER-2 positive breast cancer, hormone receptor positive breast cancer, BRCA gene mutations are now available and applied with success and reduced side effects.

Mutations in many genes such as VEGF, EGFR, BRAF, HER-2, NTRK, etc. are implicated in colorectal cancer and targeted therapies to inhibit the activity of these genes are used successfully.

In addition to targeted therapies, genetic sequencing also provides prognostic information to guide treatment strategies. Tools that analyse and sequence individual tumour biology has led to the development of several prognostic kits, such as Oncotype DX, Mammastrat, and EndoPredict analyses, which stratify a patient's risk of future cancer recurrence (9, 10).

Radiology

Developments in imaging, which is part and parcel of the armamentarium of precision medicine, have considerably contributed to improved diagnostics. For example imaging modalities such as positron emission tomography indicate the metabolic activity of disease and is capable of guiding the management plan and detecting recurrence of cancer prior to the emergence of symptoms in cases of Hodgkin's Lymphoma (11,12).

Cardiology

Revolutionary advancements have taken place in the context of precision medicine in cardiology. Pharmacogenomics have enabled to demonstrate how polymorphisms in key genes, such as CYP2C9, CYP2C19, VKORC1 and SLCO1B1, significantly impact...
the outcomes of treatment with clopidogrel, warfarin and simvastatin. PCSK9 inhibitors in the management of hyperlipidaemia are another example of targeted cardiovascular therapeutics.

The more common cardiovascular diseases such as hypertension, atrial fibrillation and coronary artery disease occur in part due to an accumulation of thousands of small effect size genetic variants known as single nucleotide polymorphisms. Precision medicine helps in identifying the nuances in gene expression of these polygenic diseases, and applying both curative and preventive strategies tailored to the patient. (14)

Wearable health technology has significantly advanced precision medicine and has transformed insights into cardiovascular health redefining how risk stratification, diagnosis, therapy and monitoring takes place. (15)

**Respiratory Medicine**

Increased understanding of the immuno-pathophysiology of asthma has enabled the identification of multiple disease endotypes through clinical biomarkers such as sputum and blood eosinophils, serum IgE and fractional exhaled nitric oxide (FeNO). It is now possible to consider the individual pheno-endotype of the patient when planning treatment strategies. For example omalizumab (anti-IgE) is approved for allergic asthma patients with high IgE serum values while mepolizumab, reslizumab and benralizumab (anti-IL-5/Rα) are used for patients with severe eosinophilic asthma. Dupilumab (anti-IL-4Rα) is used for patients with high eosinophil and/or FeNO values. It is evidenced by clinical trials that these drugs reduce the number of exacerbations and are also instrumental in limiting the exposure to long-term oral corticosteroids and stabilising respiratory function, improving the overall asthma control. (16)

Application of similar successful targeted therapies are observed in many other respiratory disorders like chronic obstructive pulmonary disease, interstitial lung disease, bronchiectasis, etc.

**Gastroenterology**

Patients with monogenic inflammatory bowel disease (mIBD) have the opportunity of receiving genotype-guided therapy with the advent of precision medicine in addressing molecular aetiologies related to gastrointestinal disease. (17)

**Neurology**

Treating neurological diseases such as epilepsy, neurodegenerative disorders, movement disorders, etc. has proved challenging due to the diverse presentations, diverse response to treatment and adverse effects experienced when prescribing from the limited choice of drugs available.

Precision medicine therefore presents a great opportunity in the field of neurology in optimising diagnostics and treatment to achieve better patient outcomes. With advancements in gene sequencing it has been possible to identify the pathophysiological mechanisms of various epilepsy syndromes at a molecular level. The use of retigabine (ezogabine), a positive allosteric modulator of KCNQ2–5 (Kv7.2–7.5) ion channels, in KCNQ2-associated encephalopathy is a great example of the level of accuracy in therapy that can be achieved with precision medicine approaches. (18)

The use of neuromodulation in place of surgical resection in treating refractory epilepsy syndromes also demonstrates the revolutionary care possible with advances in precision medicine. (19)

**Precision medicine and population health**

Precision medicine can also be adapted for population-based strategies, emphasising a significant preventive aspect. It promotes patient engagement in both research and healthcare, giving rise to the concept of "preventive, personalised, precise, population-based, and participatory medicine." (5)

Precision medicine has some important implications in communicable diseases such as influenza, HIV and Ebola where identification of resistant strains aids in formulating effective treatment strategies. Genetic sequencing extends beyond therapeutics and is capable of facilitating disease surveillance as demonstrated in a study on drug-resistant tuberculosis where genetic analysis combined with epidemiological methods enhanced disease mapping and informed public health policies. (20)

Overall, by leveraging genetic insights and molecular data, precision medicine has the potential to revolutionise healthcare by improving patient outcomes and advancing personalised medicine practices. (20)
Considerations, challenges and limitations in the practice of precision medicine

While precision medicine aims to improve disease classification and treatment precision, several considerations need addressing.

Firstly, the value of enhancing disease classification lies in the availability of effective therapies. Without viable treatment options, improved disease understanding may offer limited benefits to patients. The challenge remains evident in conditions like Huntington’s disease, where genetic testing is available, but treatment options are limited to symptomatic and supportive care. Additionally, the cost and time associated with developing targeted therapies based on precise diagnoses pose significant challenges.

Secondly, the financial implications of precise disease stratification and personalised treatments raise concerns about efficiency and clinical benefits. While targeting specific genetic or molecular aberrations may offer tailored therapies, the cost and resource-intensive nature of development and implementation need careful consideration.

Lastly, the complex nature of molecular classifications within diseases may strain existing healthcare systems, potentially fragmenting disease management based on molecular subtypes rather than organ systems. This can introduce inefficiencies and challenges in delivering holistic healthcare services, emphasising the need for careful integration of precision medicine approaches within existing healthcare frameworks.(2)

Summary

Precision medicine has taken root and is growing deep and wide with the aid of new technologies related to AI and advancements in molecular typing. Its effects are apparent in almost all disciplines of medicine showing great promise in achieving highly personalised and precise diagnoses and therapies. However, it is important to be mindful of the gap between the outcomes and investments in precision medicine so as to avoid unnecessary strain on the healthcare system and providers.

Precision medicine overall, has aided us in climbing out of the one-size-fits-all way of practice, opening an avenue of optimal healthcare for all.

References


