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### The Rise of Precision Medicine and Genomic Health Care

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**Abstract:** Precision medicine is a modern healthcare approach in which medical treatment and prevention methods designed according to an individual person's genes. Precision medicine is the providing right treatment to the right patient at the right time.

Precision medicine focuses on understanding individual differences to improve diagnosis, prevention, and treatment outcomes. Genomic healthcare also helps in the early detection of diseases, reducing side effects from medications and improving the overall quality of patient care. Precision medicine studies how each person is different and then providing the personalized healthcare. Precision medicine is widely used in areas like: cancer treatment, genetic disorders, and heart diseases also for drug therapies.

Challenges in precision medicine and healthcare include high treatment and testing costs, limited accessibility in developing regions, it concerns about genetic data privacy and security. These challenges must be addressed to ensure safe and affordable and equal access to personalized healthcare for all patients.

**Keywords:** Precision medicine, Genomic Healthcare, Pharmacogenomics, Personalized Medicine, Artificial Intelligence, Multi-Omics, Genome Sequencing, Targeted Therapy.

#### INTRODUCTION:

Traditionally, medical practice has relied on standardized treatment protocols designed to benefit the majority of patients. While effective in many cases, this approach often overlooks individual variability in disease risk and treatment response.

But it helps a lot of the people, but with the advent of precision medicine, this principle has brought a whole new meaning. Instead of a same standard procedure checklist, doctors look at your unique biology to figure out prevention, diagnosis, and treatment that fits you and it provides individualized treatments based on a patient's genetic makeup, lifestyle and environment.

Genomic information, often described as the body's blueprint, provides critical insights that guide individualized prevention, diagnosis, and therapy (National Human Genome Research Institute, 2020)

To answer why some people, get certain diseases or react differently to the same drugs. A big reason for this shift is DNA sequencing getting much faster and cheaper. What once has taken up years and many billions of dollars now takes days and a fraction of the cost. So, personalized medicine is no longer something for only a few research labs or costliest treatment. It's starting to show up in ordinary clinics

Precision medicine has already shown unexpected results in oncology, where clinicians can identify the genetic changes responsible for tumor growth and select targeted treatments accordingly. This improves treatment effectiveness while reducing damage to healthy tissues. Beyond cancer, pharmacogenomics is

helping clinicians predict how patients will respond to medications, reducing adverse drug reactions and improving treatment outcomes.

## **HISTORY OF PRECISION MEDICINE**

Precision medicine is a relatively new field, but its roots can be traced back to the mid-20th century. In 1953, Watson and Crick discovered the structure of DNA, the molecule that carries the genetic instructions for all living organisms.

In the 1970s, researchers began to explore the relationship between genetic changes and disease. One of the early successes in this field was the discovery of the genetic basis for sickle cell anemia, a genetic blood disorder. This success led to development of the genetic tests for the diseases. In the 1980s, the field of genomics began to emerge, driven by the development of new DNA sequencing technologies. This showed the way for the development of techniques for sequencing the human genome, which was completed in 2003.

The term “precision medicine” was first used in 2011, in a report from the National Research Council that described a vision for a new approach to healthcare that would be tailored to individual patients based on their unique genetic makeup, environment, and lifestyle.

## **WHAT IS PRECISION MEDICINE**

Precision medicine does one thing differently from traditional care it treats you as an individual, not an average. This allows for more accurate diagnoses, targeted therapies, and better outcomes. For example, in the case of cancer, precision medicine can identify the specific genetic changes driving the tumor’s growth and develop therapies that target those mutations. The Precision Medicine Initiative was launched by the US Government with the aim of advancing the field of precision medicine in 2015.

It mainly depends on patient data. your medical records, lab work, and scan results, to what medicines you’ve taken, your family disease history, and notes from your doctor. All this makes a clearer picture of your current health. But the main thing here is genetic data obtained from simple things like blood, saliva, or cheek swabs. From these samples, labs can read your DNA and search for variations linked to certain diseases or drug responses.

Another advantage of precision medicine is its potential to reduce health-care costs. By identifying the patients who are at higher risk of developing certain diseases, health-care providers can take proactive measures to prevent or manage those conditions, thereby reducing the need for costly treatments down the line.

## **SOME EXAMPLES OF PRECISION MEDICINE PRODUCTS:**

**TruSight oncology 500:** A comprehensive genomic profiling assay for solid tumors that can identify clinically relevant genomic alterations and potentially actionable targets

**GeoMx digital spatial profiler:** A platform that can analyze the spatial distribution of gene expression in tissue samples, enabling deeper insights into the molecular mechanisms of disease.

**OncoPrint Dx target test:** A NGS assay that can detect multiple genetic variants in solid tumours, which can help guide targeted therapy decisions.

## **THE REAL-LIFE EXAMPLES OF PRECISION MEDICINE IN HEALTHCARE**

### **CANCER TREATMENT**

Precision medicine has significantly altered the treatment of cancer. Doctors can now use genomic testing to identify specific genetic alterations driving a tumour’s growth and use targeted therapies to attack these mutations. In many patients targeted therapies have also reduced unnecessary side effects compared with conventional chemotherapy.

### **CARDIOVASCULAR DISEASES**

Precision medicine is also being used to prevent and treat cardiovascular disease. Genetic testing can identify patients who are at higher risk of developing heart disease, allowing health-care providers to implement lifestyle interventions and medications to prevent the onset of the disease. Early identification of genetic risk factors can help doctors recommend lifestyle changes before severe complications develop.

## **RARE DISEASES**

Precision medicine is helping to diagnose and treat rare diseases. By analyzing a patient's genome, doctors can identify the pathogenic variations responsible for the disease and develop targeted therapies.

## **INFECTIOUS DISEASES**

Precision medicine is being used to develop more effective treatments for infectious diseases. By analysing the genome of the pathogen, doctors can identify the specific genetic mutations that make it resistant to antibiotics and develop more targeted treatments.

## **MENTAL HEALTH**

Precision medicine is also being used to treat mental health disorders. Genetic testing can identify patients who are at higher risk of developing certain disorders and help doctors develop personalized treatment plans.

## **THE ROLE OF GENOMICS IN PRECISION MEDICINE**

Genomics play the main key role in Precision medicine and public health research. Modification or changes in genetic material helps to detect the changes occurred in the body which clearly shows the genetic material that needs the modification which cures the disease and useful in prevention of disease.

Drug responses vary between individuals because of genetic differences and severe cases many common chronic diseases have known environmental, social, and behavioral risk factors (e.g., smoking, physical activity, diet, racial, ethnic and economic factors, and access to health care), it is important to evaluate the benefits, harms and costs of the use of human genomic information in the prevention and control of these diseases

Other emerging applications include genetic predisposition to adverse drug effects (pharmacogenomics), carrier testing of prospective parents and use of polygenic risk scores (PRS) in disease detection and prevention.

## **PHARMACOGENOMIC TESTING:**

Precision medicine has become a new standard in contemporary healthcare, enabling treatment plans that incorporate each patient's individualized genetic and clinical history. In this metamorphosis, pharmacogenomics has become the basis for next generation therapeutics, as it has the role of subtle genetic variation in determining an individual's response to a drug.

Further introducing the pharmacogenomics into precision medicine is opening new horizons for tailored care. The Geno type guided therapy is becoming more accessible and clinically meaningful through the emergence of new tools, such as rapid point-of-care genomic testing, cloud-based pharmacogenomics decision-support systems, and AI-powered prediction of drug-gene interactions and so on. This change is already evident in clinical practice across psychiatry, cardiology, oncology and infectious diseases.

Pharmacogenomics in psychiatry is redefining antidepressant therapy by creating the capacity to predict treatment resistance in advance, thereby avoiding months of therapeutic frustration on both the part of the patients and the clinician. Geno type directed warfarin and clopidogrel dosing are averting lethal incidents in cardiology. In oncology, new pharmacogenomics biomarkers are enabling ultra-targeted therapies that strike tumour-specific mutations with remarkable precision.

Finally, the incorporation of pharmacogenomics into precision medicine is not just a scientific breakthrough but a new era of treatment. By bringing together genomic understanding, technological advancement, and predictive analytics, this new model has ensured that future healthcare will be safer, more personal and more effective.

## **TOOLS USED IN PRECISION MEDICINE AND GENOMIC HEALTHCARE**

The various tools by which precision medicine seeks to achieve its goals are omics, pharmaco-omics, big data, artificial intelligence, machine learning (ML), environmental, social and behavioural factors and integration with preventive and public health.

## **OMICS**

Since the completion of human genome project at the beginning of the millennium, high-throughput technologies have revolutionized medical research. These technologies help in providing a great chance of any biological system of interest at a resolution that has never been possible before. This high resolution and high-throughput outcomes constitute "Omics" which is a nomenclature broadly applied to a collective study

of molecular characterization and quantification of biological molecules from various subdomains of molecular biology using high-throughput technology.

### **TYPES OF OMICS**

- Genetics alone are not enough. now researchers look at “Multi-omics” they are
- Transcriptomics (like which genes are turned on)
- Proteomics (Behaviour of Proteins)
- Metabolomics (Chemicals running the metabolism)
- Epigenomics (How the environment changes gene activity without changing the DNA itself)

### **MULTI-OMICS TECHNIQUES AND APPROACHES**

Sequencing as a technology has revamped the world of omics. Though sequencing has evolved from first generation Sanger's sequencing to the current third generation next-generation sequencing (NGS), the basic concept of sequencing remains same that is determining the order of bases adenine, guanine, cytosine and thymine. NGS has been very essential in deciphering genomics, epigenomics and transcriptomics with the help of various approaches.

### **GENOME SEQUENCING TECHNOLOGIES**

To really see what's happening inside your DNA, doctors and researchers turn to genome sequencing.

**WHOLE GENOME SEQUENCING (WGS)** covers your entire genome, both the pages that code for proteins and those that don't. This helps find even rare changes but generates a mountain of data and comes with higher costs.

**WHOLE EXOME SEQUENCING (WES)** on the other hand, focuses on just the parts of DNA that tell your body how to make proteins where most disease-causing defects pop up. It's faster, cheaper, and easier to interpret. There's also targeted gene panel testing, which focuses on the specific genes tied to known conditions. For example, testing the BRCA1 and BRCA2 genes can show whether someone's at higher risk for breast and ovarian cancer.

**NEXT-GENERATION SEQUENCING (NGS)** Next-generation sequencing (NGS) is a rapid and high-throughput technologies that enable great parallel DNA sequencing of entire human genomes, exomes or coding exons of selected genes. Targeted exome NGS capture panels are gaining popularity for pharmacogenetic testing due to their time- and cost-effectiveness, and ability to simultaneously detect common and rare genetic variation. Despite anticipated technical challenges for the application of short-read based NGS to genes with high sequence homology and nearby pseudogenes.

Next-generation sequencing platforms are starting to impact upon many clinical fields, especially cancer studies. Bringing these technologies to clinical pharmacogenetics represents a timely and logical convergence, especially given the history of applied genetic concepts and molecular methods within the discipline.

Through the validation of performance and accuracy, results from our study and others demonstrate the utility of targeted exome sequencing panels as sensitive and reliable sequencing platforms for pharmacogenes. But despite the relative ease of the sequencing process, the time and effort required for post-sequencing computational and bioinformatics data analyses are significant due to the technical and interpretive complexity of NGS and the biology of some pharmacogenetic gene targets. Moreover, as new variants are discovered reducing these high-throughput detection methods, the need for standards in contributing pathogenicity together with development of tools for high-throughput functional assessment and clinical validation are required before implementing findings to aid therapeutic decision-making

### **ARTIFICIAL INTELLIGENCE (AI) AND MACHINE LEARNING (ML)**

Because genomic data is extremely large and complex, AI and machine learning tools help researchers analyze the information more quickly and identify useful clinical patterns in a less time with the help of the bioinformatics system. AI and ML can and convert Big Data into useful diagnostic and therapeutic treatments. Data storing, handling and analysis are best carried out using these methods. They can also handle all statistical challenges more efficiently than traditional methods.

Internal and external validation of study models are another area where they will shine. Data mining and removing the noise in data are special techniques offered by AI and ML. By developing various clinical, diagnostic and therapeutic algorithms through flowcharts, these methods allow the clinician to make various quick decisions. Predictive and prognostic models can also be designed effectively with these tools. AI speeds up the analysis but the final call still belongs to the clinician.

## **BARRIERS AND CHALLENGES IN PRECISION MEDICINE**

### **COST**

It is often stated that Precision medicine will inevitably lead to better clinical outcomes for patients and more efficient use of healthcare funds. Unfortunately, Low-income countries have not had the same funding to dedicate to developing this field. This has significantly impacted, where resources are limited, and continuous clinical monitoring of the disease is often not possible.

### **LACK OF BIOTECHNOLOGY RESOURCES**

The difficulties that researchers in LMICs encounter daily regarding biotechnology resources, are probably unknown to the international scientific community. Next-generation sequencing (NGS) methods and sophisticated imaging modalities are essential tools in precision medicine. Such technologies can be expensive

### **LACK OF EDUCATED HEALTHCARE PROFESSIONALS AND SCIENTIFIC RESEARCH**

Future leaders with a strong background in advanced genomic medicine, including molecular diagnostic methods like whole genome sequencing interpretation and NGS, are needed in the emerging field of Precision Medicine. To use instruments such as medical big data, e-medicine, AI, telemedicine, and electronic health records (EHRs). Health professionals will need to acquire new skills as well unfortunately there are insufficient residency and fellowship specialties or technological training available especially in developing countries that could currently meet all these demands.

### **ETHICAL ISSUES CONFEDENTIALITY AND DATA SECURITY**

There are some challenges that might need to be discussed to ensure protection and fair treatment of individuals in Precision medicine demands extensive patient participation leading to a sheer volume of information exposed to privacy issues indigenous people also deserve special considerations to ensure ethical and quality research in these communities. Globally, indigenous communities are underrepresented in multi-omics research studies for several reasons,

### **DATA PRIVACY**

While the potential scientific and social benefits of sharing genomic data are strong, these data are particularly sensitive. There is a growing need to keep personal data private without impeding the technological, scientific and societal advances that will come from analysing large datasets. This obviously applies to genomic data, even more so because of several specific features of these data.

### **FUTURE PERSPECTIVE**

The future of personalized medicine is for significant advancements, driven by continuous progress in genomics, biotechnology, and data analytics. These developments promise to enhance the precision of healthcare, enabling more individualized and effective treatment strategies.

### **ADVANCEMENTS IN GENOMIC TECHNOLOGIES**

As genomic sequencing becomes increasingly affordable and efficient, the integration of comprehensive genetic profiles into clinical practice will become routine. Whole-genome sequencing and other advanced techniques will deepen our understanding of the genetic underpinnings of diseases, facilitating the development of highly targeted therapies. This will not only enhance treatment efficacy but also enable the identification of genetic predispositions to various conditions, allowing for earlier interventions and personalized preventive strategies

## INTEGRATION OF BIG DATA AND AI

The convergence of big data analytics and AI with personalized medicine holds immense promise. Largescale genomic, clinical, and lifestyle data can be analysed by AI algorithms to find trends and forecast patient reactions to treatments with previously unheard-of accuracy. Machine learning models will assist in identifying novel biomarkers and therapeutic targets, leading to the development of new precision medicines. Furthermore, AI-powered decision support systems will help doctors make better, faster treatment decisions, improving patient outcomes

## COLLABORATIVE RESEARCH AND GLOBAL INITIATIVES

The future of personalized medicine will be shaped by collaborative research efforts and global initiatives. International and partnerships will enable the sharing of genomic data and clinical insights, accelerating the discovery of new biomarkers and therapeutic targets. Collaborative projects will also promote the development of standardized protocols and best practices, ensuring consistency and quality in personalized medicine applications worldwide.

## CONCLUSION:

Precision medicine is a fundamental shift in how we think about health and disease. For too long, medicine treated patients as if they were all the same drugs, same doses and same expectations. But people are not the same, and precision medicine finally acknowledges that reality. Through genomics, pharmacogenomics, and artificial intelligence, doctors can now detect diseases earlier, choose more targeted therapies, and avoid treatments likely to cause harm. The impact is already visible in cancer care, rare disorders and drug response prediction. The gaps are real though. High costs and limited access mean these advances still do not reach most of the world. Data privacy concerns remain unresolved. These are not small problems but the outcome is promising. As technology improves and global collaboration grows, precision medicine has a genuine chance to move from a privilege of the few to a standard of care for everyone and that is accessible for future generations.

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