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PERSONALIZED MEDICINE: REVOLUTION IN HEALTHCARE

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ABSTRACT

Personalized medicine adapts clinical decisions to the individual rather than to the population average, drawing on the molecular, genetic, environmental, and lifestyle features of each patient when tests and treatments are chosen. Where conventional protocols apply a single regimen across heterogeneous groups, individualised approaches identify the subset of patients most likely to benefit from a given intervention and at what dose. The supporting toolkit includes high-throughput sequencing, proteomic profiling, pharmacogenomic assays, biomarker measurement, and computational methods drawn from machine learning and deep learning that integrate clinical and molecular records. Such methods are used to stratify risk, predict therapeutic response, and shorten time to diagnosis, with established applications in oncology, rare inherited disease, and pharmacogenomically guided prescribing. Reported gains include closer alignment of drug to patient, fewer avoidable adverse reactions, and more efficient use of clinical resources along the care pathway. Active patient participation is encouraged, since care plans can be tuned to the individual's situation and treatment goals. Several barriers continue to slow broad uptake, among them the unit cost of sequencing and targeted agents, the protection of identifiable genetic information, regulatory variation across jurisdictions, and shortages of clinical infrastructure and trained personnel. As sequencing prices fall and clinical informatics matures, personalized medicine is projected to extend beyond current strongholds into more areas of routine practice, supporting more accurate, patient-centred, and economically sustainable care.

Keywords: Personalized; Medicine; Revolution; Healthcare; Effectiveness.

1.INTRODUCTION TO PERSONALIZED MEDICINE

Personalized medicine (PM) is an active area of research within clinical practice and biomedical investigation. The approach aims to tailor diagnosis and therapy to the individual patient through the integration of genomic, epigenomic, and proteomic information, with attention to the patient's specific clinical circumstances. Beyond treatment, PM is also relevant to disease prevention.[1]

Conventional prescribing applies protocols derived from the average response of a group, which can yield variable efficacy and tolerability across individuals. PM seeks to address these limitations by using individual genetic information to select therapies; for example, mutations identified in cancer cells can be used to choose agents directed against the relevant molecular target, so that the intervention acts on the underlying disease mechanism.[2]

Precision approaches operate at finer biological resolution. Years of investigation have clarified the genetic basis of many diseases, and most disorders involve gene-level changes. The Human Genome Project produced a reference map of human genes, allowing investigators to observe how specific mutations contribute to disease and why conditions such as diabetes or cancer differ in presentation and treatment response between patients. This understanding supports more targeted therapeutic design.[3]

1.1 HISTORY

The concept of individualized treatment is not new. Hippocrates, often described as the founder of Western medicine, argued that "disease might be treated from their origin" and that "the treatment carried out should be opposed to the cause of disease," framing the clinical encounter around the individual patient rather than the prevailing superstitions of his period. In this respect, his approach anticipated later thinking in genomic medicine: that biological variation between individuals shapes both prognosis and response to therapy.[4]

This vision was operationalised in the 1990s, when DNA sequencing technology became faster, more automated, and higher in throughput. Initiatives launched in this period included the Human Genome Project (HGP; 1990–2003), which decoded approximately three billion base pair sequences of the human genome and made the data publicly accessible to investigators worldwide, and the International HapMap Project (2002–10), which catalogued patterns of human genetic variation associated with disease and allowed researchers to link gene variants to specific disorders.[5]

Although individualized drug therapies can be costly to the individual patient at the point of care, long-term savings may arise from prevention strategies that reduce poor health, more precise diagnoses, and more effective regimens. Pathophysiological and genetic data can therefore support more cost-effective drug development and create value for the pharmaceutical and medical device industries. Personalized approaches also support reliable diagnostic and treatment options, contribute to patient safety, and improve patient satisfaction.[6]

2.APPLICATION

(1) Diagnosis - Earlier identification of disease through targeted clinical surveillance, supporting more effective intervention.

(2) Prevention - Avoidance of drug-related complications and side effects that arise from generic "one size fits all" prescribing.[7]

(3) Oncology - Cancer care is a major focus of PM because of the intrinsic heterogeneity of malignant disease. Cancers involve mutations in driver genes that alter molecular pathways, and oncological genetic tests are relevant both to patients with established disease and to healthy individuals at risk.

(4) Pharmacogenomics - Pharmacogenomics examines how an individual's genetic makeup shapes drug response. It joins pharmacology with genomics and seeks to tailor drug selection, dosing, and regimen on the basis of genomic information, with the aim of maximizing efficacy while reducing the risk of adverse effects.

(5) Rare Genetic Disorder - Applying personalized medicine to rare genetic conditions can improve patient outcomes and add to the understanding of these complex disorders, supporting the development of new treatments. Whole-genome sequencing is a useful resource in this setting.[8]

ADVANTAGES

Lower healthcare costs.

A higher likelihood of achieving the intended outcomes, as a result of more precise treatments.

Greater focus on the prevention and forecasting of disease rather than reactive treatment.

Reduced risk of severe side effects.

Earlier diagnosis of disease.[9]

3. FOUNDATIONAL CONCEPT OF PERSONALIZED MEDICINE

3.1 GEMOMICS AND GENETIC VARIENT

Patients who present with similar clinical features can show different responses to the

same therapy when their genetic backgrounds differ. Without methods to identify the underlying genetic basis of a clinical picture, predicting which treatment will be most effective for a given patient may not be possible. Even when the cause of an illness is known, unrelated genetic variants can influence drug pharmacokinetics and modify therapeutic effect. For example, individuals carrying specific variants who received conventional doses of azathioprine, a long-term immunosuppressive agent, were documented to develop severe myelosuppression because the variant prevented the drug from being metabolized in the normal way.

PM aims to enable rapid and reliable prediction of disease, and clinicians are being supported with tests and information-technology resources that are both effective and economical. These resources help to manage the biological variation that underlies human disease. The associated precision-medicine "ecosystem" connects clinicians, laboratories, research organisations, and clinical information-system developers in new configurations, supporting the development of such tools. Genetic tests and the patient's health record are stored in Electronic Health Records (EHRs) and related systems. Genome and exome sequences are captured and retained for reuse in diagnosis, prevention, and treatment. The systems also issue pharmacogenomic alerts before and after testing, flagging potential interactions between specific medications and particular genetic variants. When a clinician proposes an action that depends on information from a genetic assessment for which no record exists, a pre-test is recommended; when a planned action would be inappropriate given the patient's genetic profile, a post-test alert is issued.[10]

3.2 GENETIC MARKERS

By using advanced sequencing technologies and comprehensive genome-wide association studies (GWAS), investigators are able to identify genetic markers linked to differential susceptibility across a range of diseases. Single nucleotide polymorphisms (SNPs) and more complex structural variants serve as genomic markers that act as individual fingerprints, allowing inferences about disease susceptibility. The resulting findings carry implications for risk assessment, early detection, and preventive intervention.

The detection of genetic markers for disease susceptibility is becoming an increasingly important component of personalized medicine. By interpreting the genetic signals contained in a patient's DNA, clinicians can adapt surveillance procedures, prevention

plans, and treatment selection in advance of clinical presentation. This shift defines an era in which interventions are tailored to the genetic composition of the individual patient.[11]

3.3 PHARMACOGENOMICS

Within pharmacogenomics, the work centres on locating genetic variants that influence how an individual responds to a drug, and on linking those variants either to altered pharmacokinetics or to altered pharmacodynamics. Pharmacokinetic effects act through changes in absorption, distribution, metabolism, or elimination; pharmacodynamic effects act on the drug's target or on the signalling cascades that govern sensitivity to the agent. The majority of relevant variants arise either de novo or by inheritance from a parent and reside in germline DNA.

Once a pharmacogenomic association has been validated, its uptake in clinical practice is not automatic and presents several practical obstacles. Where alternative agents exist for individuals carrying a high-risk genotype, prescribing decisions can be informed by the genetic finding. Successful uptake depends on system-level adjustment, on structured prescribing pathways, and on the integration of electronic clinical decision support delivered at the point of care.

Pharmacogenomic testing has long been positioned as a component of evidence-based precision medicine. Continued maturation of decision support tools, together with wider rollout of genotyping in routine clinical workflows, is consistent with that trajectory.[12]

4. ARTIFICIAL INTELLIGENCE IN PERSONALIZED MEDICINE

Artificial intelligence (AI) is an important enabling technology for personalized medicine, because it can analyse large datasets and produce insights that support clinical decision-making. Its role in precision medicine is multifaceted, encompassing predictive analytics, treatment optimization, and real-time monitoring. Predictive analytics involves AI algorithms processing genetic and phenotypic data to estimate disease risk and likely outcomes. Treatment optimization allows healthcare professionals to design tailored therapeutic strategies that adapt as the patient's clinical course unfolds.[13]

4.1 AI in disease diagnosis

Diagnostic precision has been reported to improve under a range of AI methods, including machine learning and deep learning. Drawing together inputs such as patient history, medical imaging, and genetic profile, AI can surface patterns and

associations that may escape an unaided clinician. Across diagnostic tasks, AI has shown gains in prediction rate, accuracy, sensitivity, and specificity over traditional approaches. In tasks spanning disease detection, classification, and decision-making, AI use within clinical diagnosis supports more appropriate treatment selection and contributes to better patient outcomes.[14]

Selected applications of predictive AI models in disease diagnosis are summarized in Table 1.

Table 1:Predictive AI Models In Disease Diagnosis

Disease	AI Model Type	Data Source	Accuracy
Breast Cancer	Deep Learning	Genetic Profile	94%
Diabetes	Machine Learning	Health Records	89%
Cardiovascular Disease	Neural Network	Patient History	92%

4.2 AI in Treatment Optimization

Patient-specific data and continuous feedback are increasingly used by AI methods to design therapeutic regimens, and this AI-assisted tailoring is reshaping individualized care. By moving selection and dose choices away from trial and error, treatment can be made both more effective and more cost-efficient. Large repositories of drug interaction information, recorded adverse-effect profiles, and prior patient histories can be queried by such software to surface the medications most appropriate for a given patient. In one example, the probable effectiveness of an agent for an individual can be estimated by a deep learning model from that patient's genetic profile, with the goal of lowering adverse events and improving response. Where monitoring is continuous, the regimen can be updated by AI in near real time; oncology is one setting in which response to chemotherapy can be tracked and adjustments to dose or schedule recommended to balance effectiveness against toxicity.[15]

4.3 Medical Utilisation Of AI

Progress in genomic AI has consequences for biomedicine more broadly and for precision medicine in particular. Within variant calling, AI methods are now embedded in workflows that identify genetic variants linked to disease susceptibility and treatment response. Pathogenic variant detection and inference of the functional consequence of a mutation are supported by tools including DeepVariant, AlphaMissense, and PrimateAI-3D, which together inform personalized treatment

planning for genetic disorders. Variant reclassification is a further use case: AI can assist in resolving a Variant of Uncertain Significance (VUS), producing clearer diagnostic interpretation that can in turn shape clinical decisions.[16]

4.4 AI in Drug Discovery and Design

AI is contributing to a reshaping of how new medicines are produced within the biopharmaceutical industry, and its influence extends across the full discovery workflow. That workflow conventionally moves through target identification, hit identification, lead optimization, preclinical evaluation, and clinical trials, and AI introduces a different mix of opportunities and constraints at each step.[17]

Computational drug discovery, virtual screening, and automated laboratory workflows can support the design, synthesis, screening, biological evaluation, and decision-making activities that make up an early discovery pipeline, and may help to address the modest success rates, extended timelines, and elevated spending that characterise conventional development. By drawing on data science, informatics, and AI, the field aims for gains in efficiency, lower financial burden, and reduced reliance on animal models, supporting the discovery of new and effective therapeutics. Interest in the intersection of large datasets and AI within drug discovery has continued to grow.[18]

4.5 AI techniques in personalized Medicine

4.5.1 Machine learning

Machine learning (ML) refers to a family of methods within AI in which computational models are trained on data so that they can identify and learn from patterns in high-dimensional inputs, with the goal of producing prediction or classification rules from the training set. ML approaches have been applied effectively to large genomic datasets, where the data volume and structural complexity make traditional statistical and linear methods less suitable. The value of ML in genomics is illustrated by a small number of well-documented cases in which ML applied to genomic data has addressed the challenges posed by such large and complex datasets and produced clinically informative results.[19]

4.5.2 Deep Learning Approaches

Deep learning (DL), a subfield of AI, performs a range of tasks by constructing deep neural networks (DNNs). One feature that distinguishes DL from other AI methods is its capacity for self-learning: components of the representation are derived automatically from the input training data rather than specified by hand. This property

makes DL well suited to the construction of self-optimizing models for specific problems, compared with manually engineered feature pipelines. Within precision medicine, DL algorithms can be applied to large and complex datasets, including genomic data, electronic health records, and imaging studies, to detect patterns and generate predictions about disease risk, treatment response, and patient outcomes.[20]

4.5.3 Natural Language Processing (NLP)

Natural Language Processing (NLP) methods have become an important set of tools for clinical text analysis in healthcare. They allow practitioners to extract usable information from the large volume of unstructured clinical text, including patient narratives, clinician notes, electronic health records (EHRs), and biomedical literature. NLP techniques, including deep learning, rule-based methods, and earlier machine learning approaches, are used to classify documentation that records advance care planning, chronic conditions, and the symptoms of chronic disease. Publicly available software and algorithms for major NLP technologies are evaluated and compared during literature mining for evidence-based therapeutic guidelines. Within electronic medical records (EMRs), there is a parallel need to capture treatments delivered to oncology patients in a structured, queryable form that supports treatment planning and targeted therapy. EMRs may contain both unstructured data, such as free-text clinical notes, and structured data, such as diagnostic and procedural fields. NLP-based extraction of information from unstructured notes has therefore been in high demand in recent years, since these notes carry information of clinical value.[21]

5.PERSONALIZED MEDICINE FOR CERTAIN DISEASE

5.1 Personalized medicine in Neurological Disorder

In neurological disease, personalized medicine has substantial potential to support diagnosis, treatment, and longitudinal management. Combining neuroimaging, clinical, and genetic data enables predictive models that may anticipate onset, progression, and treatment response in disorders such as Alzheimer's and Parkinson's disease. Imaging modalities such as MRI and PET scans provide detailed information on brain structure and function. Continued progress in genomics, neuroimaging, and computational biology is expected to further enhance the capacity to personalize medical care for patients with neurological illnesses.[22]

Implementation requires consistent and reliable testing protocols, with consideration of the patient's biomarker profile, age, and family history. A wide range of chronic conditions has been associated with oxidative stress. Crosstalk between the nervous, endocrine, and immune systems may offer the structural and functional framework through which the brain can influence disease progression. For Down syndrome (DS), reports of pharmacogenetic association studies are increasing in number.[23]

5.2 Personalized Medicine in Diabetes

Diabetes is among the more prevalent contemporary conditions, and personalized medicine in this area is important because it can supply information on the hereditary background of a patient with diabetes, on which plans for prevention, detection, treatment, or monitoring can be based.(24) Implementing personalized medicine for diabetes typically follows four steps:

1. Genes and biomarkers relevant to obesity are identified, since obesity is a common risk factor for type 2 diabetes alongside diabetes itself.

2. After such parameters have been identified, resource planning follows, with the aim of preventing or detecting the diabetes or obesity phenotype in high-risk individuals whose risk is determined by genotype.

3. Therapy is then tailored for the individual patient, including the agent to be prescribed, the dose to administer, and the recommended diet, with selection also informed by side-effect and toxicity profiles.

4. Circulating diabetes biomarkers are then assessed to monitor the response to preventive or therapeutic intervention.[24,25]

5.3 Personalized Medicine in Lungs Cancer

Systemic options in lung cancer remain comparatively narrow, although a number of targeted agents, including monoclonal antibodies (mAbs) and tyrosine kinase inhibitors (TKIs), are now in routine use. The bulk of the disease burden falls to non-small cell lung cancer (NSCLS), where the malignant cells exhibit the trait of unchecked growth. In this setting, examples of personalized care include positron emission tomography (PET) imaging and the use of radioactively labelled medications.[26]

In the setting of metastatic non-small cell lung cancer, the choice of pharmacological therapy is informed by algorithms that combine biomarker findings. Relevant inputs to such algorithms include histomorphological appearance (squamous cell carcinoma versus "nonsquamous"

subtypes), level of PD-L1 expression, and confirmed presence or absence of defined genomic markers. Among patients with lung squamous cell carcinoma, a subtype that represents around 30% of NSCLC cases in Germany, treatment direction is most strongly guided by PD-L1.[27]

5.4 Personalized medicine for Infectious Disease

Personalized medicine has not, as a rule, taken infectious disease as one of its showcase domains; comparatively few therapeutic tests addressing infection are cited in the review titled The Case for Personalized Medicine. That position is shifting, however, as clinical utility grows for biomarkers tied to host immune response, individual susceptibility to infection, the host-microbiota interface, and idiosyncratic reactions to antimicrobial drugs.[28]

Rapid identification of the specific pathogen behind an infection is now feasible with next-generation sequencing (NGS) and related high-resolution genomic sequencing methods. Quicker identification translates into a shorter delay before appropriate treatment can be started, and provides a basis for choosing antimicrobial therapy that is more precisely targeted. A detailed genetic analysis of the responsible pathogen, including separation of bacterial from viral strains, supports inferences about where the infection arose, how it has been transmitted, and which mechanisms of drug resistance may be in play. As an illustration, whole-genome sequencing of Mycobacterium tuberculosis allows drug-resistant strains to be identified and helps inform combination regimens that can curb the dissemination of resistant tuberculosis.[29]

5.5 Personalized Medicine for Rheumatoid Arthritis

Rheumatoid arthritis is a chronic, autoimmune, inflammatory disease affecting up to 1% of adults; it is characterised by synovitis and reduces life expectancy by approximately five years through joint erosion and progressive disability.[30]

5.5.1 Pain Management and Analgesic

In patients with arthritis, chronic pain is managed with paracetamol, used either alone or together with nonsteroidal anti-inflammatory agents. International rheumatology experts in the 3E Initiative (Evidence, Expertise, Exchange) advise that pain be assessed at regular intervals using validated instruments, among them the Visual Analogue Scale, the Numerical Rating Scale, and the Verbal Rating Scale. For inflammatory rheumatic disease, tricyclic antidepressants and neuromodulators that modify pain processing can also be considered. Muscle relaxants, which reduce muscular tone, and

benzodiazepines are not advised. Where current therapy is not effective, short-term courses of weak opioids may be considered; longer-term courses are possible but are then subject to regular review. Strong opioids, including morphine and its derivatives, are reserved for exceptional circumstances.[31]

5.5.2 Personalized Approach and Biomarker

Standard regimens for RA draw on disease-modifying antirheumatic drugs (DMARDs), biologic agents, and Janus kinase (JAK) inhibitors; the aim of personalized medicine in this context is to fit treatment to the patient's individual genetic, molecular, and clinical profile, with improved efficacy and a lighter side-effect burden as the goals. Biomarkers relevant to RA have been characterised in the published literature. According to a study in Advances in Rheumatology (BMC), serum biomarkers such as anti-citrullinated protein antibodies (ACPAs) and rheumatoid factor have the potential to improve both early diagnosis and the tracking of disease progression.[32]

6.CHALLENGES AND BARRIERS TO PERSONALIZED MEDICINE

6.1 Economic And Financial Barrier

6.1.1. COST

Cost is among the more substantive constraints on precision medicine. Technologies such as large-scale DNA sequencing carry a high price tag, and medicines that act on the underlying molecular or genetic basis of disease tend to be expensive in their own right. Targeted agents of this kind in turn create friction with third-party reimbursement, including from private insurers. Although broader uptake of personalized medicine could improve health outcomes, clinical care, and biomedical research, achieving those benefits depends first on closing infrastructural, equity-related, and knowledge gaps.[33]

6.1.2 Finances

Sustaining personalized medicine will require a substantial financial commitment. Trade-offs may be needed between the affordability of more intensive individualisation and the funding available for other categories of care. Decision support for those choices depends on updated clinical guidelines together with evidence-based and data-driven tools. The cost picture also calls for sharper approaches: sickness funds and health insurers need a regulatory framework that rewards long-term health gains and savings rather than only short-term containment, and the orientation of healthcare systems needs to shift toward value-based care. Additional resources must also flow into digitisation of health records and into interoperability, and governance

arrangements must be reorganised with financial incentives that match.[34]

6.1.3 Infrastructure

Implementation of personalized medicine will require coordinated planning of information technology infrastructure, biobanks, and genomic and molecular diagnostic services. Digital platforms for patient education and engagement, including informed consent, adherence to treatment, and feedback on treatment outcomes, are also necessary.[35]

6.2 Social, Cultural and Ethical Barriers

6.2.1 Social Barrier

6.2.1.1 Discrimination

Whether genetic information leads to rational or irrational treatment of an individual, and whether the resulting actions are lawful or not, depends on the specific circumstance. Researchers examining the ethical, legal, and social implications of the Human Genome Project flagged genotype-based discrimination as a concern early on. As personalized medicine narrows the grounds on which individuals are differentiated, the contribution to genetic discrimination may grow, since even modest genomic differences can correspond to economically significant outcomes. A genomic profile, for example, may signal both a higher likelihood of future illness and a poor probable response to conventional drug regimens, which together imply higher residual risk of morbidity and mortality.[36]

6.2.1.2 Traditional Treatment

Traditional healers (Gunias) are present in every tribal community and reside within those communities. Over generations, tribes have followed their own healing traditions or forms of naturopathy. Indigenous people often regard a health problem as a matter that involves the whole family and the wider community rather than the individual alone. Health practitioners may therefore find that decisions are constrained by collective community processes. Even when there is interest in engaging with modern medicine, social taboos and stigma can prevent individuals from accessing contemporary health services.[37]

6.2.1.3 Education

Highly trained staff with deep backgrounds in medical, technical, and scientific regulatory areas are required for personalized medicine. Recruiting such staff is difficult, as the number of professionals with this combination of expertise is limited. The integration of data science specialists is also necessary in order to use data-driven methods effectively in personalized medicine, but data science profiles may still

lack experience in clinical healthcare practice.[38]

6.2.2 Ethical Barrier

6.2.1 Privacy and Confidentiality

Personalized medicine depends on the collection and analysis of sensitive genetic and clinical information, which raises substantial privacy and confidentiality concerns. Genetic information is uniquely identifying, and inadvertent disclosure can have downstream consequences for insurance, employment, and family members of the patient. Strict access controls, de-identification protocols, and robust informed consent procedures are therefore preconditions for clinical implementation.

6.2.2 Use of Third-Party Services

Careful assessment of any external services and applications used in healthcare projects is required, both for legal compliance and for ethical acceptability; the same applies to telemedicine platforms. Regulatory frameworks for health data differ substantially across jurisdictions, particularly between the United States and the European Union, and these differences carry consequences for the handling of sensitive health information. Particular care is therefore warranted when reviewing services originating in the United States, and a jurisdiction-aware compliance review should form part of the procurement process.[39]

6.2.3 Cultural Barrier

In the rollout of precision medicine, cultural competency is an important consideration, since the degree of confidence placed in the healthcare system differs from one community to another. Lasting mistrust has been generated in some populations, notably within First Nations communities and ethnic minorities, by historical injustices that include unethical research practices and the exclusion of certain groups from research. That mistrust can in turn reduce engagement with the activities on which precision medicine depends, including genetic testing, clinical trials, and biobanking. Beliefs about health, about illness, and about inheritance can also affect the way patients receive and respond to precision approaches. Establishing trust depends on meaningful communication, respect for culture, open discussion of concerns, and the involvement of trusted community leaders in those discussions.[40]

6.3 Regulatory Barriers

Personalized medicine products fall under the oversight of three product-review centers operated by the FDA: CDER (the Center for Drug Evaluation and Research), CDRH (the Center for Devices and Radiological Health),

and CBER (the Center for Biologics Evaluation and Research). The rules administered by each center derive from statutes that have been in place for many years. Those rules were not designed for the dependencies that arise within personalized medicine, where the safety and efficacy of one product can hinge on another, and the resulting inconsistencies create regulatory friction for personalized medicine offerings.

Work is under way at the FDA to put center-level processes and policies into operation that would close those gaps and produce clearer expectations for oversight. A goal of the effort is a more streamlined premarket pathway for diagnostic products, with gains in the consistency and efficiency of decision-making. Examples of in vivo diagnostic instruments that fall within scope include assays, electroencephalography, electrocardiography, and diagnostic imaging devices.[41]

A selection of FDA-approved personalized therapeutics is summarised in Table 2.

Table 2: Status Of FDA Approved Personalized Drug

DRUG NAME	DISEASE	APPROVED YEAR
Crizonitinib	Non-Small Cell Lung cancer	2013
Erlotinib	Non-Small Cell Lung cancer	2013
Lynparza	Ovarian Cancer	2014
Cyrazma	Non-Small Cell Lung cancer	2014
Harvoni	Hepatitis C	2014
Nucala	Asthma	2015
Leqembi	Alzheimer's Disease	2023
Orkambi	Cystic Fibrosis	2015

7. STRATEGIES FOR INTEGRATING PM IN HEALTHCARE

7.1 Infrastructure & information management

Personalized medicine requires effective handling of large volumes of clinical and molecular data, together with coordination of the programmatic processes and services that accompany its application. Many organisations are working on these areas, and the resulting strategies need to be disseminated broadly if they are to influence the wider healthcare system. Health delivery organisations that have established personalized medicine programmes

alongside information management partners report that defined leadership structures, dependable decision processes, and alignment of programme policy across research and clinical activities are central to implementation. Building on this experience, electronic health records can be developed so that they incorporate individual genetic data together with embedded clinical support tools that flag potential clinical actionability; biomarker and outcomes data can be standardised and made interoperable across health information technology platforms.[42]

7.2 Data Protection

Ethical concerns arise from the way genetic information is collected and pooled, and one element of those concerns is that disclosing genetic data within a medical record may carry heavier downstream implications than disclosing other categories of clinical information. A further issue is whether accumulated datasets can be combined at all: among the many local, small, medium, and large initiatives that exist, formats and field definitions diverge, so additional archival material is often not reusable when the relevant permissions have not been put in place.

There are also constructive uses for genetic information. If both the complete genotype and the blood group of a patient were captured in the medical record, that information could, in principle, support health policy decisions aligned with the population's specific needs.[43]

7.3 Education &Awareness

Educational material covering personalized medicine remains in short supply, which complicates efforts to bring patients up to speed on the options that apply to their own care. Awareness among practising clinicians is also incomplete, since experienced clinicians have only limited time available for new technology, and medical curricula that have not been refreshed delay the preparation of incoming cohorts of physicians. To close the gap, both public-facing communication initiatives and structured education for clinicians are required, alongside continuing education within medical schools and across care delivery staff so that they remain abreast of progress.[44]

7.4 Healthcare System

Healthcare organisations themselves need reform. Training must extend beyond physicians and nurses to the other hospital-based professional groups whose participation underpins the delivery of individualized medicine. Adding case managers, or patient companions, is one proposed route; their function would be to help patients move through the system,

especially those with severe illness. As care becomes more individual-specific, counselling also becomes more important, and one open question is whether such counselling should remain a physician task or whether suitably trained staff with a clinical background could provide it as system-level support.[45]

8.FUTURE PROSPECTIVE FOR PERSONALIZED MEDICINE

8.1 Advances in Artificial Intelligence

Both AI and machine learning are now considered core instruments for personalized medicine. Sizeable datasets, drawn from genetic profiles, electronic health records (EHRs), and wearable device feeds, can be processed by AI algorithms to estimate disease risk, propose treatments, and underpin clinical decision-making. Reports indicate that AI-based models can match radiologist performance in breast cancer detection, can contribute to the discovery of new biomarkers for predicting disease, and can inform individualized pharmacotherapy.[46]

8.2 Personalized Mobile Health Application

Mobile health applications that incorporate pharmacogenomic information can allow patients to receive personalized medication advice and can support more direct communication between patients and clinicians. Blockchain technology can create decentralised networks that enable secure data exchange between institutions, facilitating collaboration in pharmacogenomics practice and research.[47]

8.3 Advancement In Clinical Practice

Bringing whole genome sequencing (WGS) into the clinic constitutes a significant step forward, given the importance of detecting DNA polymorphisms in coding and non-coding regions for inferring susceptibility to disease and predicting drug response. When coupled with standard DNA analysis, WGS also opens a window onto regulatory transcripts, including miRNA together with small nuclear, ribosomal, and transfer RNAs. Through WGS, a systematic survey of the non-coding fraction of the genome is now feasible for the first time, with implications for clarifying mechanisms in numerous rare disorders.[48]

8.4 ICPerMed View

According to ICPerMed (International Consortium for Personalized Medicine), advances in the biological, social, and economic sciences, together with technical development, are driving personalized medicine forward. Effective implementation therefore depends on substantial investment in research and innovation. On this basis, the

hypothesis is that, by 2030, personalized medicine will lead to the next step change in healthcare. The objective is to establish personalized medicine as a medical specialty grounded in the uniqueness of the individual, leading to better diagnostic, therapeutic, and preventive performance, greater economic value, and equal accessibility for all individuals through five key dimensions.[49]

8.5 Development in India

On 03 January 2020, India launched the Genome India Project, with a remit to map population genomes through genome-wide sequencing carried out across 20 research centers. Comparison of Indian population genomes with global reference genomes is also being pursued by the Indian Cancer Genome Atlas and by the Indian Genome Variation Consortium. Further forward-looking steps include the Unique Methods of Management and Treatment of Inherited Disorders programme, together with NIDAN (the National Inherited Disease Administration Kendra Network) launched in September 2019. Taken together, these developments make the outlook for precision medicine in the country positive.

9. CONCLUSION

As a model of healthcare, personalized medicine aligns clinical care with the distinct profile of the individual patient. Pulling together electronic health records, genetic testing, and current clinical data allows providers to move away from trial and error in treatment selection and to deliver care that more closely fits the patient. Continued progress in AI methods, including ML, NLP, and DLA, gives clinicians sharper tools for diagnosis, prevention, and treatment. When genomic data are combined with clinical history and family history, therapeutic efficacy can rise and the burden of adverse effects can fall. Under this model the role of the clinician shifts from sole authority to professional advisor, with patients participating actively in decisions about their care. A core task ahead is to make the benefits of personalized medicine equally accessible across populations.

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