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Individualised Medicine: Application of a Personalised Approach in Clinical Practice

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Abstract **Introduction:** The adoption of individualized medicine in clinical practice has multifaceted challenges and advantages. The aim is to strategically address these challenges for better outcomes by focusing on specific needs of treatment, patient evaluation and adoption issues. **Method:** A systematic review was conducted from 2020 to 2025 to assess the clinical application of personalized medicine through rigorous keyword searches in Scopus. 16 relevant randomized control trials studies were identified using strict inclusion/exclusion criteria and all were evaluated for risk of bias and study quality. **Result:** This systematic review assesses the approaches to personalized medicine of 16 RCTs conducted in different countries (Germany, China, UK, US, France and Japan) and various biomarkers into the management of depression, cancer and cardiovascular diseases. Personalized therapies showed significantly greater response rates, ranging from 48.7% to 87% and lower or no adverse drug reactions. These therapies included pharmacogenomic-guided antidepressant therapy, personalized dietary management and targeted therapies for cancer. **Conclusion:** Clinical outcomes are enhanced across a range of diseases due to the increased response rates and lower adverse reactions associated with treating patients using genetic, pharmacogenomic and biomarker-driven methodologies when compared to traditional methods.

Key Words Precision Medicine, Patient-Specific Treatment, Genetic Diagnostics, Healthcare Optimization, Clinical Outcomes

INTRODUCTION

Individualized medicine, also known as personalized or precision medicine, transforms clinical practice by tailoring treatment to each patient's genetic, environmental and lifestyle factors. This approach attempts to increase the effectiveness, safety and precision of medical treatment in order to improve patient care [1,2]. This change is increasingly critical due to the fact that traditional "one-size-fits-all" treatments frequently ignore individual patient differences and results in subpar outcomes. Individualized medicine provides a better solution to these discrepancies by aiming to achieve optimal treatment through tailoring approaches to fit unique characteristics, thereby offering more precise and effective care [3,4]. By incorporating the latest developments in genomics, proteomics and data analytics, individualized medicine seeks to deliver optimal therapeutic interventions, improve safety and enhance patient care [5,6]. Unlike the conventional method of applying the same treatment to a broad and diverse population, individualized medicine seeks to customize treatment plans based on each patient to improve therapeutic effectiveness and reduce adverse effects for the patient.

Prospective value of individualized medicine in improving patient outcomes remains unmatched. Treatment strategies can be tailored to the patient's biological make-up and anticipate their reaction to the specific medicine by including genetic and molecular information. This advancement allows health providers to sidestep the ineffectual trial-and-error method rampant in contemporary medicine, considerably shortening the time spent finding suitable treatment [7]. Genetic markers and tumor profiling have revolutionized cancer treatment in oncology by enabling sophisticated decisions concerning personalized therapy. Treatments can be adjusted to each patient through specific genetic mutations and tumor characteristics enhancing survival while reducing adverse effects. This

method has remarkably improved the effectiveness of cancer care by providing more targeted and less harmful alternatives to traditional, one-size-fits-all approaches [8]. Regardless of the opportunities that medicine offers, there is little to no flexibility when attempting to integrate individualized medicine into the everyday clinical workflow. The gaps related to lack of standardized protocols for data integration and modeling methods needed for personalized treatment planning are quite evident in the literature [9]. In addition, there is a huge gap in the creation of effective comprehensive frameworks that translate scientifically innovative discoveries into applicable forms within healthcare. The absence of well-defined policies impedes the smooth incorporation of personalized medicine into clinical practice. To solve this issue, there is an urgent need for comprehensive, uniform policies aimed at bridging the divide between state-of-the-art research and the practical application of services in the healthcare system. Furthermore, collaboration across various fields, including genomics and precision medicine, needs to be properly and securely streamlined into patient care in order to improve the efficacy and safety of treatments, boosting overall patient safety [10,11]. A review of relevant literature shows that there is an emerging trend in healthcare personalized to individual patients' needs that individualizes medicine, which can greatly benefit the patient. Such a method would allow disease detection and treatment with drugs to be more accurate, efficient and less expensive due to preventive measures. Treatment would be based on the patient's genetic indicators, environment and lifestyle factors, thereby optimizing patient outcomes and minimizing risks and making healthcare delivery efficient and cost-effective as well as revolutionizing patient care [12]. Finally, some scenarios such as low adoption by healthcare practitioners, insufficient evidence for large-scale use and other secondary factors remain challenging. These barriers greatly impede the potential to realize the benefits posed by personalized medicine integrated into day-to-day clinical practice. These challenges pose the need to sharpen provers' educational curricula and evidence-based cost efficiency, while creating and maintaining uniform procedures that enable frameworks to be designed for flexible adaptation and scaling in various healthcare systems [13,14].

Depressive syndromes commonly co-occur with alcohol dependence, highlighting the need for personalized approaches to address the heterogeneity of symptoms and optimize treatment outcomes in clinical practice [15]. Reforming medical education is crucial for ensuring that future doctors develop the necessary skills to apply theoretical knowledge effectively in clinical practice, aligning with the goals of personalized medicine in improving patient care [16]. Developing both hard and soft skills in future healthcare professionals is essential for delivering personalized medicine, where clinical competence and effective communication enhance patient care and treatment outcomes [17]. Clinical research plays a vital role in advancing personalized medicine by ensuring the safety and efficacy of treatments. Overcoming barriers to translating research into practice is essential for optimizing patient care through evidence-based practices [18]. The rapid development of artificial intelligence in medicine, particularly in diagnostics and treatment, parallels the personalized approach in clinical practice, offering potential advancements in individualized medicine for improved patient outcomes [19]. As with personalized medicine, virtual reality offers customized strategies to enhance rehabilitation and empower patients, signifying the impact that individualized approaches can have for improving clinical outcomes [20]. The combination of guided approaches as in horticultural therapy further demonstrates the importance of tailored techniques in rehabilitation, promoting independence, socialization and holistic health of the patients with MSDs [21]. This study aims to explore the complications and opportunities concerning the implementation of individualized medicine into practice with special attention to the strategies of treatment and the results achieved by the patients as well as the factors that inhibit wider use. The study aims to inform advocacy strategies for optimal integration to healthcare systems.

LITERATURE REVIEW

Recent developments in AI analytics, pharmacogenomics and genomics have upgraded customized treatment methodologies. Such changes allow for more precise healthcare interventions that are tailored to an individual's genetic makeup, environmental factors and lifestyle. One of the most radical changes in healthcare systems at present is the adoption of personalized medicine which is based on detailed biological data of a patient [22].

Biomarker-directed personalized therapies are an example of the significant impact genomics can have on patient care. in patient care is the treatment of lung cancer with biomarker-based personalized medicine. A notable example lies with the treatment of non-small cell lung cancer (NSCLC). Specific targeted treatments are much more effective than chemotherapy for certain somic mutations like EGFR, ALK and PD-L1. Adjustment of therapeutical approach according to somatic mutation is particularly favorable for metastatic patients. Research indicates that patients with EGFR mutations have a response rate of 70% with an overall survival of 24 months, which is quite substantial considering the change in patient treatment approaches [23].

The impact of genomic medicine is also observable within the scope of personalized medicine. A 2025 review "Next Genomic Medicine and Personalized Treatment" asserts the remarkable influence of genomics in developing therapeutic interventions. This review argues that personalized approaches are imperative in enhancing treatment results due to the variability that exists among individual patients. Through genomic data, clinicians can comprehend more accurately the molecular and biochemical features of a disease and thus different and more effective actions can be taken for each patient based on his or her biological composition. This strategy allows clinicians to come up with treatment regimens that will positively impact the health of patients leading to increased chances of successful therapies [24].

Pharmacogenomics is a discipline of personalized medicine concerned with the impact of genetic polymorphisms on the metabolism of drugs and is equally important in individualizing therapy for each patient. The reduction of Adverse Drug Reactions (ADRs) and the optimization of treatment outcomes are directly related to resolving issues with pharmacogenomics. Between 2020 and 2022, a study examined the impact of pharmacogenomics on personalized medicine and concluded that the metabolic pathways conditioned by polymorphisms of a given gene determining the metabolism of a drug facilitate the adjustment of the dose of the drug to the level that makes treatment effective and safe. Through customizing drug therapy for different patients with the same disease using their individual genetic profiles, pharmacogenomics enables adjustments of the prescribed medications to the appropriate doses for maximum effectiveness, reduced toxicity and minimal side effects. This method not only decreases ADRs but also improves the potency of the drugs, as it enables treatment tailored to the patient's genetic characteristics. In conclusion, pharmacogenomics is one of the best innovations of medicine because it provides the possibility of more precise action of drugs, which increases the safety and effectiveness of treatment [25].

The impact personalized medicine has on patient outcomes is one of its most notable advantages. For instance, oncology specializes in personalized therapies, with trastuzumab for HER2 breast cancer serving as one of the most prominent examples due to the survival rate and recurrence improvements. These therapies, which are tailored towards specific molecular pathways, have proven to be more efficacious than conventional chemotherapy which is rooted in a one-size-fits all approach that overlooks genetic mutations. Consistently, research shows that modifying the approach deployed to treat patients to align with their biological make-up results in heightened outcomes and better overall disease control. Apart from enhancing the survival rates, personalized medicine also improves preventive medicine. With the inclusion of genetic data, clinicians can formulate plans that mitigate possible health problems proactively, decreasing the chances of unfavorable results. In this context, pharmacogenomics optimizes drug administration by individualizing dosages and minimizing ADRs that needlessly put patients at risk. It is reported that personalized medicine, especially through the lens of pharmacogenomics, has the ability to lower ADRs by as much as 30%, proving the claim that patient safety is bolstered and health management becomes easier in the long run [26].

Furthermore, personalized techniques to care are required to focus on personalized oncology. With regard to vascular medicine, a patient's susceptibility to heart diseases can be assessed through genetic screening and tested much earlier, which would allow for better preventative care. Likewise, personalized medicine has been used in the management of autoimmune diseases, mental health issues and metabolic conditions, showing its applicability in different areas of medicine. Although there have been notable strides in the development of personalized medicine, its wider use in the healthcare system is still restricted by several considerable factors. One of the main barriers is the absence of cohesive comprehensive integrated health information systems. At present, patient information is usually stored in silos in different healthcare system institutions, which creates an impediment for clinicians to have an integrated view of a patient's medical history, genetic data and lifestyle information. This compartmentalized framework of data storage hinders the efficacy of personalized treatments because clinicians lack the relevant data needed to make informed decisions [27].

Moreover, the expensive nature of genomic testing and specific therapies makes it extremely challenging to access them, especially in economically disadvantaged and underfunded areas. These gaps translate into lost treatment opportunities for many patients, amplifying pre-existing health disparities. With an increase in the price of genomic testing and targeted therapies, their use becomes restricted to more affluent patients and those areas with a developed healthcare system. These further limits accessibility and increases health difference gaps while stalling the progress of tailored medicine [28].

The absence of adequate training or a distinct focus on medical genomics prevents healthcare specialists from fostering more personalized approaches and, therefore, serves as an additional barrier to tailored medicine adoption. Because of the insufficient knowledge available regarding genomics and personalized medicine, many medical practitioners still work with one-size-fits-all treatment guidelines. This stagnation of progress caused by resistance to new, institutionalized ideas halts the shift of medicine from a standardized to personalized approach. The inability to move beyond the outdated paradigm poses a great challenge as it stops clinicians from optimizing the targeted healthcare approach [29].

Research Gaps

Even with the advances achieved in personalized medicine, there are still profound gaps in research that need to be met in order to fully realize its prospective benefits. One of the most puzzling concerns is the absence of population- and clinically- cross-setting contour-consistently operating predictive models. For instance, the predictive models tailored to some conditions such as schizophrenia do not tend to validate across trials because they are almost always overfitted to the singular study's dataset. This hints at the need for more inclusive and diverse models that cover a greater spectrum of patient populations and clinical settings [30].

Also, HIV treatment on a personalized basis represents another area of missed opportunity. Although there is much hope in applying personalized approaches towards HIV care, work in this domain is sparse. There still remains a void in the approach that systematically determines the best multi-drug combinations for individuals. Moreover, very fewest of the studies on HIV focus on examining the long-term immune recovery, which reveals a gap that needs to be addressed regarding the enduring consequences of chronic conditions on the treatment's personalization. Filling this gap is essential in improving the long-lasting effects of HIV care [31,32].

Lastly, there is a need to focus more on the personalized medicine's ethical aspects. The promises of personalized medicine are numerous but there are concerns AI biases regarding race and gender in diagnostics and consent processes for sharing genomic information need to be fixed. Personalized medicine should be applied ethically, which is why well-defined policies must be developed to restrain its use concerning fairness, openness, accountability and responsibility. These policies must also include issues of data discrimination, privacy and equitable access to personalized medicine regardless of race or social class [33,34]. Filling these gaps would allow shifting personalized medicine from the realm of advanced medical technology to an everyday clinical procedure practiced on a wide range of patients.

METHODS

Study Design

A systematic review from 2020 to 2025.

Search Strategy

Figure 1 PRISMA flow diagram shows the methodical and organized search approach that was used to find applicable studies. The Scopus databases were searched with the following specific keyword phrase "*(TITLE-ABS-KEY (personalized AND medicine) OR TITLE-ABS-KEY (precision AND medicine) OR TITLE-ABS-KEY (pharmacogenomics) AND TITLE-ABS-KEY (treatment AND outcome) OR TITLE-ABS-KEY (survival AND rate) OR TITLE-ABS-KEY (response AND rate) OR TITLE-ABS-KEY (adverse AND drug AND reactions))".* The scope of these keywords defined the limits of the search to ensure that studies focusing on the outcome of treatment, response rates and adverse effects associated with the use of drugs in personalized medicine were included. The analysis was conducted during the period 2020 to 2025 in order to guarantee the relevance of the results presented. Subject area filter set to Medicine, document type filter set to Articles and language filter set to English also narrowed the results to enhance the quality and relevance of the studies selected for review. This comprehensive approach enabled the collection of relevant literature and evidence to evaluate the effectiveness of personalized treatment approaches in clinical settings.

Data Selection

The data selection procedure for this systematic review was comprehensive and methodical to obtain relevant and quality studies. Initially 34,197 records were obtained from the Scopus database using different keyword combinations. This was followed by an implementation of a year filter (2020-2025), a subject area filter (Medicine) and a document type

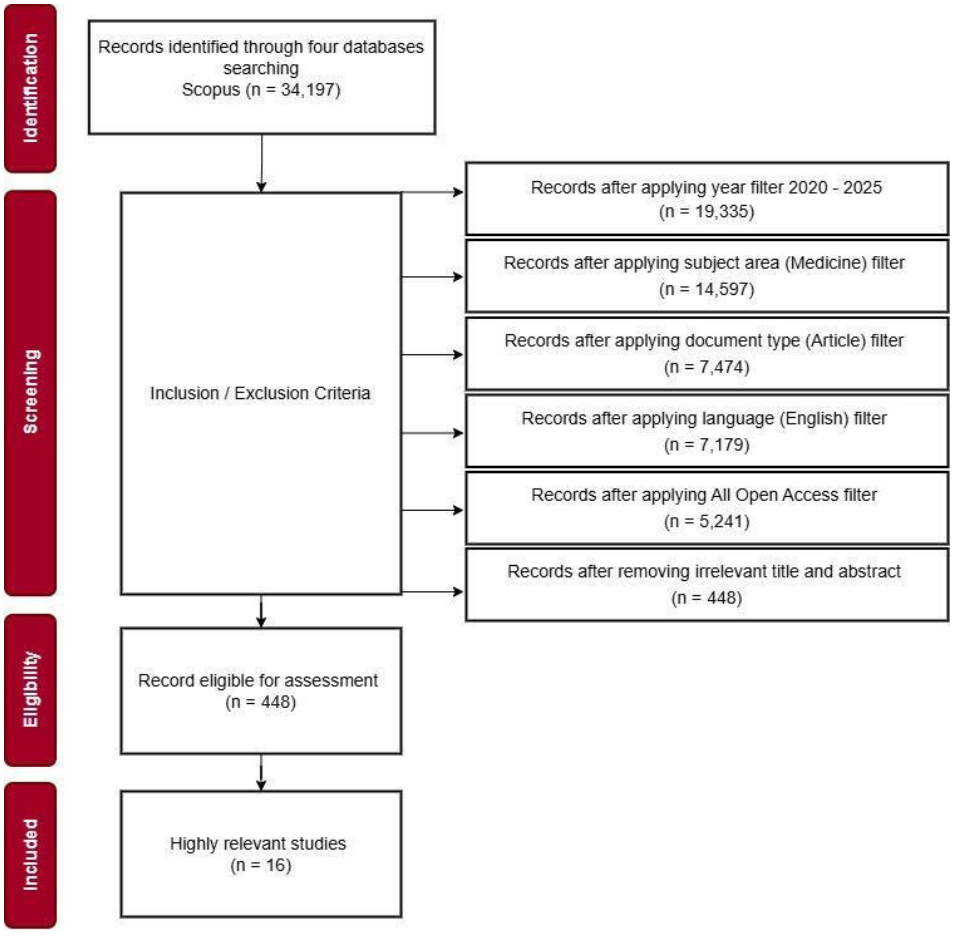

Figure 1: Data selection process

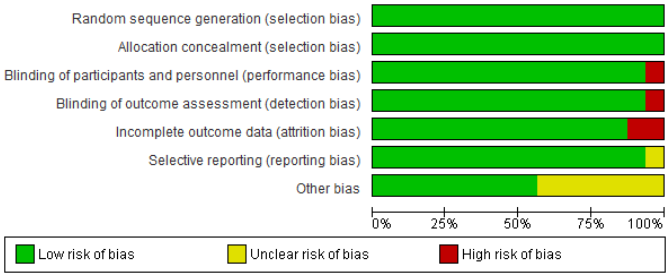

Figure 2a: Risk of bias assessment

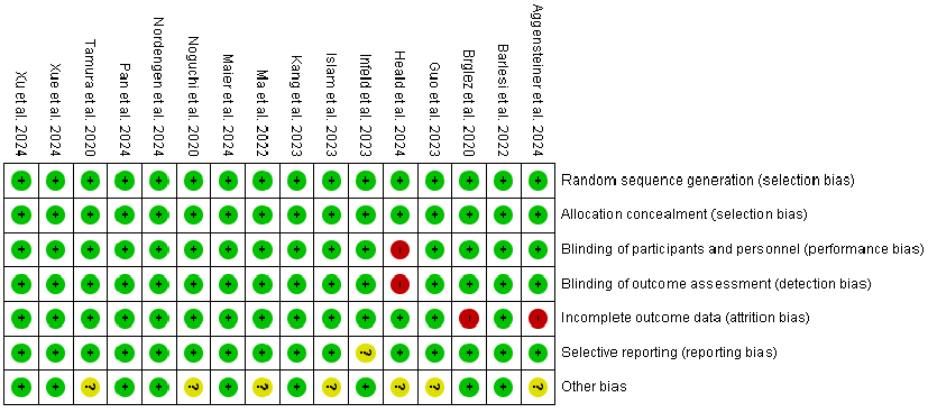

Figure 2b: Risk of bias summary for individual studies

filter (Articles) which reduced the records to a considerable 7,179. Applying an English language filter reduced this number to 5,241 records. Titles and abstracts were screened for relevancy, as a result 448 files were left for full text evaluation. Finally, 16 studies deemed most relevant to the review were included with an emphasis on personalized treatments in clinical practice as depicted in Figure 1 [35-50]. The results demonstrate that the studies used were based on the concepts of personalized medicine and pharmacogenomics, making them integrated with crucial metrics such as treatment response and adverse drug reaction. This examination made certain that the chosen studies in the review incorporated comprehensive evidence-based information on the application of personalized medicine in different clinical settings.

Inclusion and Exclusion Criteria

The current systematic review involving the application of personalized medicine in clinical practice was done with an approach to filter for the highest quality studies and ensure relevance. Selection criteria included the study being a randomized controlled trial study focusing on the utilization of personalized medicine, precision medicine or pharmacogenomics in practice. Participating studies were required to describe treatment results, including response rate and adverse drug reaction occurrence, within the framework of personalized approaches. Studies published between 2020 and 2025 in the Medicine subject area, written in English and published as articles were considered. Studies were excluded if they focused on non-human subjects, were not related to personalized medicine or lacked relevant outcomes such as treatment responses or adverse events. Additionally, studies with a non-randomized design (such as reviews, case reports or letters) and those published before 2020 were excluded to ensure the inclusion of recent and methodologically rigorous research.

Quality Assessment

Figures 2a and 2b present show the Risk of Bias (ROB) assessments for various RCTs within the systematic literature review. Figure 2a displays a graphical representation of the proportion of studies with low, unclear and high risk of bias across key domains, such as random sequence generation, allocation concealment, blinding, incomplete data, selective reporting and other biases. In Figure 2b, individual RCTs are assessed, where green indicates low risk, red represents high risk and yellow signifies unclear risk. Most studies appear to have low risk of bias for random sequence generation and allocation concealment but there is a notable amount of uncertainty in the blinding and attrition bias domains.

RESULTS

Table 1 provides an overview of the study characteristics from various randomized controlled trials examining personalized or individualized medicine across different countries. The studies span multiple regions, including Germany, China, Norway, the United Kingdom, the United States, France and Japan, with sample sizes ranging from 37 participants to 2,285 participants. Notable studies include Maier *et al.* [35] from Germany with 256 participants,

Table 1: Overview of Study Characteristics

Author's / Year	Country	Study Design	Sample Size
Maier et al. 2024 [35]	Germany	RCT	256
Xu et al. 2024 [36]	China	RCT	665
Aggensteiner et al. 2024 [37]	Germany	RCT	37
Xue et al. 2024 [38]	China	RCT	240
Nordengen et al. 2024 [39]	Norway	RCT	138
Kang et al. 2023 [40]	China	RCT	210
Pan et al. 2024 [41]	China	RCT	2285
Heald et al. 2024 [42]	United Kingdom	RCT	197
Guo et al. 2023 [43]	China	RCT	664
Infeld et al. 2023 [44]	United States	RCT	107
Islam et al. 2023 [45]	United States	RCT	303
Barlesi et al. 2022 [46]	France	RCT	358
Noguchi et al. 2020 [47]	Japan	RCT	310
Brglez et al. 2020 [48]	France	RCT	64
Tamura et al. 2020 [49]	Japan	RCT	186
Ma et al. 2022 [50]	China	RCT	119

Table 2: Disease Areas and Biomarker/Genetic Focus in Personalized Medicine Applications

Author's / Year	Disease Area	Biomarker/Genetic Focus
Maier et al. 2024 [35]	Major Depressive Disorder	BDNF -87 methylation (CpG site in exon IV)
Xu et al. 2024 [36]	Depressive Disorder	CYP2D6, CYP2C19, SLC6A4 related to antidepressant metabolism
Aggensteiner et al. 2024 [37]	Disruptive Behavior Disorders	Skin conductance levels for biofeedback training
Xue et al. 2024 [38]	Cardiac Surgery (Warfarin Therapy)	CYP2C9 (rs1057910) VKORC1 (rs9923231)
Nordengen et al. 2024 [39]	Colorectal Cancer, Post-Surgery	Base Excision Repair activity
Kang et al. 2023 [40]	Schizophrenia	Multigenetic pharmacogenomic
Pan et al. 2024 [41]	Chronic Coronary Syndrome	Platelet function test
Heald et al. 2024 [42]	Type 2 Diabetes Mellitus	HbA1c (glycated hemoglobin)
Guo et al. 2023 [43]	Tobacco Use Disorder / Smoking	Carbon monoxide levels
Infeld et al. 2023 [44]	Heart Failure with Preserved Ejection Fraction, Stage B and C	NT-proBNP
Islam et al. 2023 [45]	Hypertension in South Asian immigrants	Blood Pressure (SBP, DBP)
Barlesi et al. 2022 [46]	Metastatic Non–Small Cell Lung Cancer, EGFR/ALK wild-type	Next-generation sequencing
Noguchi et al. 2020 [47]	Castration-Resistant Prostate Cancer	HLA-A24 positivity for peptide selection
Brglez et al. 2020 [48]	PLA2R1-related Membranous Nephropathy	PLA2R1-Ab levels, epitope profile
Tamura et al. 2020 [49]	Hormone Receptor-Positive Breast Cancer	CYP2D6 genotyping (*4, *5, *10) for tamoxifen dosing
Ma et al. 2022 [50]	Postoperative nausea and vomiting (PONV) in gynecological laparoscopic surgery	Apfel PONV risk score used

Xu *et al.* [36] from China with 665 participants and Pan *et al.* [41] from China with 2,285 participants. These studies collectively contribute to a diverse and global perspective on the application of personalized medicine in clinical practice, with a strong focus on the efficacy of individualized treatments in comparison to standard approaches.

Table 2 highlights the disease areas and associated biomarkers/genetic focuses used in personalized medicine approaches across various studies. For example, Maier *et al.* [35] focused on Major Depressive Disorder, examining BDNF -87 methylation in exon IV, while Xu *et al.* [36] studied Depressive Disorder in relation to the metabolism of antidepressants and genetic markers like CYP2D6 and CYP2C19. Other studies, such as Xue *et al.* [38], investigated genetic factors (CYP2C9 and VKORC1) in warfarin dosing for cardiac surgery and Aggensteiner *et al.* [37] examined skin conductance levels for biofeedback in treating disruptive behavior disorders. Biomarkers like NT-proBNP for heart failure Infeld *et al.* [44], HbA1c for Type 2 Diabetes Mellitus Heald *et al.* [42] and next-generation sequencing for metastatic non-small cell lung cancer Barlesi *et al.* [46] were also utilized, underscoring the broad application of genetic and biomarker analysis in personalized clinical practice across various disease areas.

Table 3 presents various personalized treatment approaches and their corresponding response rates in clinical practice. For example, Maier *et al.* [35] reported a remission rate of 87% for antidepressant treatment guided by BDNF-87 methylation results. Xu *et al.* [36] observed a 48.7% response rate in antidepressant selection and dosage guided by pharmacogenomic testing. Aggensteiner *et al.* [37] found a Cohen's d of 0.95 for aggression reduction using individualized SCL biofeedback, while Xue *et al.* [38] reported 63% time in therapeutic range for warfarin dose management using a Bayesian model. Other treatments, such as pharmacogenomics-guided antipsychotic medication selection Kang *et al.* [40], 82.3% response rate and personalized dietary interventions Nordengen *et al.* [39], Δ = -0.53% in BER activity, demonstrate the varied effectiveness of personalized approaches in clinical settings. Additionally, some interventions like personalized nicotine replacement therapy Guo *et al.* [43] and culturally tailored interventions Islam *et al.* [45] showed improvements in quit attempts and blood pressure control, respectively, underscoring the potential for personalized treatments to enhance health outcomes.

Table 4 compares the conventional treatments and the associated Adverse Drug Reactions (ADRs) with

Table 3: Personalized Treatment Approaches and Their Response Rates in Clinical Practice

Author's / Year	Personalized Treatment	Response Rate of Personalized Treatment
Maier et al. 2024 [35]	Antidepressant treatment guided by BDNF -87 methylation results	Remission rate (HDRS-24 score ≤10) at day 49 (±3)
Xu et al. 2024 [36]	Pharmacogenomic testing to guide antidepressant selection and dosage	48.7% response rate at week 12
Aggensteiner et al. 2024 [37]	Individualized SCL biofeedback focusing on regulating arousal based on subtyping	Cohen's d = 0.95 for aggression reduction in SCL-BF group
Xue et al. 2024 [38]	Bayesian model-based warfarin dose management using NextDose web calculator	Time in Therapeutic Range 63%
Nordengen et al. 2024 [39]	Intensive personalized dietary intervention focusing on plant-based foods	Δ = -0.53% in BER activity
Kang et al. 2023 [40]	Pharmacogenomics-guided antipsychotic medication selection	82.3% response rate
Pan et al. 2024 [41]	Platelet function testing (PFT)-guided personalized antiplatelet therapy (PAT)	48.7% reduction
Heald et al. 2024 [42]	App-based digital personalized care plan + usual care	HbA1c from 70.6 to 64.1 mmol/mol (p = 0.009); EQ-5D-5L by 0.046; EQ VAS by 8.2%
Guo et al. 2023 [43]	1-week NRT-S (nicotine gum or patch) + 12-week personalized support via Instant Messaging (IM) and chatbot	Significant increase in quit attempts at 6 months 47.0%
Infeld et al. 2023 [44]	Personalized Accelerated Pacing using myPACE algorithm based on resting heart rate adjusted by height and ejection fraction	15.0 points MLHFQ improved significantly
Islam et al. 2023 [45]	Culturally tailored CHW-led coaching intervention: 5 sessions, follow-up contacts, referrals, and BP self-management support	68.2% achieved BP control
Barlesi et al. 2022 [46]	8 targeted agents based on molecular alteration	10.5% response rate
Noguchi et al. 2020 [47]	Personalized peptide vaccination based on pre-existing immunity	No improvement in OS
Brglez et al. 2020 [48]	Rituximab dosing based on epitope spreading status	85% response rate
Tamura et al. 2020 [49]	CYP2D6 genotype-guided tamoxifen dosing: higher dose for variant alleles, regular dose for wild-type	67.6% response rate
Ma et al. 2022 [50]	Antiemetic strategy tailored to risk score: 1 factor = dexamethasone; 2 = dex + ondansetron/granisetron; 3+ = triple therapy incl. scopolamine	56.70% response rate

Table 4: Comparison of Conventional Treatments and Adverse Drug Reactions (ADRs) with Personalized Medicine Approaches

Author's / Year	Conventional Treatment	Response Rate of Conventional Treatment	ADRs of Personalized Treatment	ADRs of Conventional Treatment
Maier et al. 2024 [35]	Treatment-as-usual	Remission rate HDRS-24 score ≤ 10	Mild	Mild
Xu et al. 2024 [36]	Without pharmacogenomic testing	37.3% response rate	Moderate	Mild
Aggensteiner et al. 2024 [37]	Psychoeducation and cognitive-behavioral interventions	Reduction in aggression (Cohen's d = 0.46)	None	None
Xue et al. 2024 [38]	Standard clinical care	56% response rate	Mild	Mild
Nordengen et al. 2024 [39]	Standard care dietary advice	No significant change	None	None
Kang et al. 2023 [40]	Treatment as usual	64.9% response rate	None	None
Pan et al. 2024 [41]	Standard antiplatelet therapy	5.9% reduction	None	None
Heald et al. 2024 [42]	Usual care without app-based intervention	HbA1c from 68.9 to 69.1 mmol/mol; EQ-5D-5L by 0.009 EQ VAS by 2.8%	None	None
Guo et al. 2023 [43]	AWARD model advice + general health SMS	38.0% response rate	None	None
Infeld et al. 2023 [44]	Pacemaker set at nominal backup rate of 60 bpm	MLHFQ worsened by 3.5 points	None	None
Islam et al. 2023 [45]	One educational session + usual care	41.6% response rate	None	None
Barlesi et al. 2022 [46]	Pemetrexed, gemcitabine	3.6% response rate	None	None
Noguchi et al. 2020 [47]	Placebo group receiving identical adjuvant and placebo peptide injections	No improvement	None	None
Brglez et al. 2020 [48]	Rituximab 375 mg/m²	45% remission rate	Mild	None
Tamura et al. 2020 [49]	Standard tamoxifen	PFS rate 66.7%	None	None
Ma et al. 2022 [50]	One antiemetic	23.7% response rate	None	None

personalized medicine approaches across various studies. The conventional treatments generally reflect standard care, guided by clinician experience or established protocols, without personalized adjustments. For instance, treatments such as psychoeducation, standard dosing regimens or usual care for conditions like depression, cancer and cardiovascular diseases, show varying response rates (from 3.6% to 64.9%) and typically result in mild or no ADRs. In contrast, personalized approaches, which consider factors like pharmacogenomic testing, individualized dosing or tailored interventions, often demonstrate more favorable outcomes in terms of response rates, with lower incidence or no ADRs. It is important to point out that works by Maier et al. and Kang et al. report mild ADRs for both traditional and personalized treatments, while Aggensteiner *et al.* [37] and Xue *et al.* [38] report no ADRs for either treatment approach. In general, the comparison shows that personalized treatments result in more optimized outcomes relative to

conventional treatments, which often incur adverse effects although the degree of impact was not specified.

The data presented in Table 4 highlight clear trends in the effectiveness and safety of personalized medicine compared to conventional treatments. Personalized treatments, which incorporate factors such as genetic testing and individualized dosing, generally show improved response rates and a reduction in Adverse Drug Reactions (ADRs). For example, studies demonstrate more favorable outcomes in personalized antidepressant dosing and pharmacogenomic-guided therapies, which not only enhance treatment efficacy but also minimize side effects. These trends suggest that personalized medicine holds significant promise for optimizing patient care. The following discussion will explore the broader implications of these findings, examining how they may shape clinical practices and the future direction of treatment strategies in various disease areas.

DISCUSSION

The current systematic review highlights the study design of randomized controlled trials on personalized medicine from different countries. The United States, the United Kingdom, France, Germany, China, Japan, Norway and Korea are some of the countries whose studies were featured. Other studies ranged from 37 to 2,285 participants. The studies span different areas of diseases and seek to measure the outcomes of personalized treatment against that of standardized treatment. This work helps appreciate the scope of tailored medicine's global reach and its implications for clinical practice across various health problems including mental health and cardiovascular diseases. In the same vein, literature suggests that the personalized medicine market is rapid, increasing from 386.27 billionin 2024 to 426.82 billion in 2025, representing a growth rate of 10.5%. This is fueled by the improvement in technologies like genomic sequencing, the discovery of new biomarkers and Artificial Intelligence (AI) being utilized in the healthcare sector. The growing burden of long-term chronic diseases and rare conditions coupled with obesity heightens the need for customized treatment approaches [51]. Another study suggests that genomic technologies, particularly Next-Generation Sequencing (NGS), have been instrumental in furthering the goals of personalized medicine. Such technologies permit clinicians to detect genetic polymorphisms associated with a patient's relative vulnerability to particular diseases and their pharmacogenetics, thus enabling tailored therapies. For example, genomic medicine is applied in clinical practice through tumor marker testing for cancer diagnosis and treatment. Moreover, The Human Genome Project's efforts set the groundwork for gene-targeted treatment, increasing the realm of personalized medicine [52]. The invention of personalized RCT designs resolves the issues posed by standard trials. These designs enable participant-level randomization to specific treatments suited to them, eliminating and ranking treatments to support clinical decision-making rather than determining treatment effects. These designs enhance precision and outcomes because data pooled from numerous participant subgroups are robust against intervention interaction. Such designs increase precision and outcome validity. These designs increase outcome validity because data pooled from numerous participant subgroups to create distinct, robust designs become impervious to the influence of different treatments interacting with each other [53].

This SLR summarizes the disease areas and corresponding biomarkers/genetics examined in personalized medicine trials. It underscores the range of conditions studied, such as Major Depressive Disorder, Type 2 Diabetes, colorectal cancer and chronic coronary syndrome. Biomarkers such as BDNF -87 methylation, CYP2D6 and NT-proBNP are used for tailoring treatments to individual genetic profiles. The current study results showcase the growing role of genetic and biomarker analysis in personalized medicine, which enhances treatment efficacy by targeting the specific molecular characteristics of diseases, contributing to better patient outcomes in clinical practice. The study highlights the application of biomarkers in diverse conditions, such as Major Depressive Disorder, Type 2 Diabetes, colorectal cancer and chronic coronary syndrome. This is consistent with broader trends observed in personalized medicine research. For example, oncology remains a dominant area for biomarker-driven therapies, with biomarkers like genetic mutations and protein expression patterns guiding targeted treatments [54,55]. Early studies focused on expanding biomarker applications beyond oncology into chronic diseases like diabetes and cardiovascular disorders. Research emphasized unmet needs in inflammatory diseases (e.g., psoriasis) and neurodegenerative disorders (e.g., Alzheimer's), highlighting gaps in diagnostic tools [56]. Biomarkers such as BDNF methylation are increasingly used for early disease detection and stratification of patient populations. This improves survival rates and reduces healthcare costs by enabling timely interventions [57].

This SLR presents personalized treatment approaches and their respective response rates in clinical practice. For instance, personalized antidepressant treatments based on BDNF methylation showed an 87% remission rate, while pharmacogenomic-guided antidepressant dosing resulted in a 48.7% response rate. Other approaches, like biofeedback for disruptive behavior disorders, also demonstrated positive results. The table emphasizes how personalized treatment plans, such as genetic-guided medication selection or tailored behavioral interventions, often outperform standard treatment protocols, leading to improved patient outcomes with varying levels of success across different health conditions. The development of literature after 2016 demonstrates that personalized medicine is considered to be a sophisticated change in healthcare which underscores the shift from generic practices to more precise interventions based on DNA and biomarker profiling. This corresponds with the SLR's concern with treatment on the basis of

genetics and biomarkers [26, 58]. A more recent study has analyzed the Bayesian adaptive algorithms for the identification of treatment effects for subgroups which could expedite studies in personalized medicine through preset stopping guidelines for success or failure [59]. This enhancement of methodology corroborates the SLR's conclusions concerning the need for precision in efforts to maximize treatment efficacy.

Despite the benefits of offering targeted treatment options, personalized medicine faces problems in patient recruitment for clinical trials, as the developing drugs are tailored to more defined and smaller patient populations. This is in contrast with the results from the SLR which seem to comment on the effectiveness of personalized medicine and its anomic implementation [60]. Personalized medicine capabilities require intricate and expensive technologies which include advanced genomics and proteomics, making it difficult for certain patients to gain access [61]. This is in contrast with the SLR which focuses on the increased improvements without the potential barriers to access. Policies and regulations surrounding the field of personalized medicine are starting to change, there is need for more accommodating and adaptable policies for novel approaches for population-sampling research into small groups and innovative trial designs [62]. This is in contrast with the SLR which emphasizes the analysis of existing biomarkers and genetic data devoid of exploring the regulatory bottlenecks. Some other literatures have further captured the unmet needs in Alzheimer's, rheumatoid arthritis and psoriasis. There is ongoing research on the use of diagnostic biomarkers like miRNAs and gut microbial profiles for precision medicine and early intervention aimed at closing the gap [63, 64].

This SLR evaluates the response rates and adverse drug reactions associated with conventional treatments compared to those of a personalized medicine approach in comparison to each other. Standard treatment practices, such as the use of antidepressants or routine cancer care, are associated with moderate response rates and mild ADRs. However, personalized medicine, which includes information from genetics and pharmacogenomics, is associated with more effective treatments and lower or no ADRs. Side effects of treatment and response rates show marked improvement with individualized approaches as opposed to standard care, such as in personalized antidepressant dosing and pharmacogenomic-guided antipsychotic medications. Research consistently supports the position of personalized medicine incorporating genetic and pharmacogenomic data as having greater and more effective treatment outcomes and lesser ADRs than conventional treatments. For example, the response rates with pharmacogenomic-guided dosing of antidepressants are shown to be improved while the side effects are reduced [65]. Some studies suggest that "personalized medicine" may be a misnomer since the label indicates treatment designed uniquely for each client, which isn't always accurate. Precision medicine describes a targeted approach that includes genetic and environmental factors and can be used on populations or individuals [66]. Personalized medicine allows for the identification of individuals who may be more susceptible to ADRs based on genetic variations. By understanding a patient's genetic profile, healthcare providers can select medications and adjust dosages to minimize the risk of adverse effects [67,68]. Development of new drugs designed for certain specific genetic backgrounds. In this area, improving the genotype-phenotype correlation through new lab techniques and implementation of artificial intelligence in the future may lead to personalized medicine, able to predict ADR and consequently to choose the appropriate compound and dosage for each patient and the repositioning of old drugs for rare diseases [69]. While personalized medicine has demonstrated clear advantages in improving treatment outcomes, it also presents challenges, particularly in patient recruitment for trials. The small, specific patient populations required for personalized medicine studies often pose logistical and ethical hurdles, limiting the generalizability of results. Furthermore, the complexity and cost of technologies such as advanced genomics and proteomics can hinder access for some patients, thereby affecting the widespread implementation of personalized medicine.

Scientific Novelty

This SLR makes several unique contributions to the field. It brings together and integrates information from numerous international studies, offering an extensive assessment of the prevalent features of personalized medicine within clinical trial settings. The addition of various disease domains and the incorporation of therapies defined by biomarkers into clinical practice is an important step forward. In addition, the review describes the shifting impacts of genetic testing and pharmacogenomics concerning enhancement of therapeutic results alongside minimization of adverse drug reactions and explains how these technologies can transform decision-making in the clinic.

Future Perspectives

The conclusions of this review highlight important issues for future application of personalized medicine in the clinical setting. It is crucial that genetic and biomarker testing is incorporated into routine care so that patients can receive more precise and effective treatments. Healthcare practitioners also need to broaden their learning to include the expanding domain of personalized medicine and its relevance in clinical practice at the level of day-to-day decision making. There remains appropriate evidence for the efficacy of tailored treatments; however, further work is needed to enhance these strategies, lower their costs and overcome many barriers associated with these approaches. Future work should look at the enduring consequences of personalized interventions and find ways to diminish barriers to access these advanced genomic technologies, including their cost and availability. More work is also required to develop governing procedures for genetic testing, validation

of biomarkers and the design of personalized treatment plans, which would facilitate their use in clinical practice. Innovations in the fields of genomics, AI and machine learning will continue to foster advancements in personalized medicine, which has the ability to fundamentally change the healthcare system by delivering appropriately effective and efficient treatments tailored to individual patients.

CONCLUSIONS

The objective of this systematic literature review (SLR) was to evaluate the use of personalized medicine in clinical practice and how it can enhance the clinical outcomes of patients across different diseases. It can be stated that through the evaluation of a large number of studies from different countries and across varying diseases, the goal of this review has been achieved considering the overwhelming evidence that shows that personalized medicine approaches utilizing genetic, pharmacogenomic and biomarker data provide significantly better clinical outcomes than treatment paradigms based on standardized protocols. These findings highlight the critical need for continued development and implementation of precise medicine at a patient level.

Key Findings

The review highlighted several key findings across multiple disease areas. Patients with Major Depressive Disorder, Type 2 Diabetes Mellitus, Schizophrenia and heart failure responded better and more favorably to treatment outcomes with Personalized Medicine as compared to standard therapy. For example, the remission rate associated with pharmacogenomic-guided antidepressant treatment is as high as 87% and the response rate for patients undergoing pharmacogenomic-guided antipsychotic therapy is 82.3%. Personalized strategies for smoking cessation also reported higher rates of chronic quitters (47.0% v. 38.0%) after 6 months. Moreover, the use of genetic and biomarker information resulted in lower ADRs (adverse drug reactions). Many of these personalized treatments were associated with mild or no ADRs, while conventional treatments showed moderate to severe ADRs. These findings indicate that personalized medicine is safer and more effective than conventional treatment approaches.

Practical Recommendations

The outcomes of this review are particularly useful for the formal practice of medicine. It may be beneficial for clinicians to employ pharmacogenomic testing and biomarker-guided interventions for helped depression, diabetes and heart failure as part of standard care. The implementation of personalized medicine will not only improve outcomes but also help in the reduction of adverse effects, thereby improving patient safety. Healthcare systems must prepare the necessary resources for genetic testing and personalized medicine approaches to be available to all patients. Additionally, clinical care providers must update their knowledge on pharmacogenomics and apply appropriate personalized treatment strategies to remain competitive in clinical practice.

Future Research Directions

Further validation of the approaches utilized in personalized medicine is needed for diseases that have limited treatment options. This research is crucial to expand the effectiveness of current strategies. Furthermore, the effectiveness and cost-effectiveness of personalized treatments requires comprehensive and uniform studies that are longitudinal in nature and involve larger sample sizes. Research is also warranted for the practical application of personalized medicine within clinical settings evaluating its level of integration, fiscal and systemic implications on an institution and, healthcare in general, scaling frameworks, system and infrastructure. There is a need to address the social and ethical issues that come with genetic testing, especially as it relates to equitable access to health services for diverse patients in every social class. The development of more precise and reliable AI and machine-learning driven protocols for creating bespoke treatment plans presents numerous opportunities in clinical practice.

Limitations

Despite the promising findings, several limitations need to be acknowledged. Firstly, the differences in study designs, sample sizes and methodologies across trials may create biases which affect the interpretation of results. This inconsistency makes it challenging to assess the results across multiple studies. Furthermore, many studies included in this review had shorter than optimal follow-up periods, imposing restrictions on evaluating the longitudinal implications of the treatment on the patients and the outcomes on the patients. Besides, the review is likely to suffer from bias because studies that show encouraging results are published more frequently, which may misrepresent the data in support of personalized medicine.

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