

# The future of personalized medicine in Saudi Arabia

## Opportunities and challenges

Wedad A. Mawkili, MSc, PhD.

### ABSTRACT

الطب الشخصي هو نهج للرعاية الصحية يصمم خطة العلاج لكل مريض، مع الأخذ في الاعتبار العوامل الوراثية والبيئية ونمط الحياة. يستفيد هذا النموذج من المعلومات الجينومية والتشخيصات المتقدمة وتحليل البيانات للتعرف بمخاطر الأمراض وتحسين استراتيجيات الوقاية وتوفير علاجات مخصصة. وفي المملكة العربية السعودية، يكتسب الطب الشخصي زخماً، مدفوعاً بمبادرة رؤية 2030 في المملكة، والتي تهدف إلى تحويل قطاع الرعاية الصحية من خلال دمج التقنيات الطبية المتقدمة وتحسين تقديم الرعاية الصحية. خطت المملكة خطوات كبيرة في علم الجينوم والمعلوماتية الحيوية، من خلال مبادرات مثل برنامج الجينوم البشري السعودي والتقدم في المؤسسات، مثل مستشفى الملك فيصل التخصصي ومركز الأبحاث. وسيكون الاستثمار المستمر في البحث والتعليم والتكنولوجيا، إلى جانب التعاون الدولي، حاسماً في التغلب على هذه التحديات وتحقيق الإمكانيات الكاملة للطب الشخصي. تستكشف هذه المراجعة الوضع الحالي والتحديات والآفاق المستقبلية للطب الشخصي في المملكة العربية السعودية، مع تسليط الضوء على تأثيره التحويلي على تقديم الرعاية الصحية ونتائج المرضى.

Personalized medicine is a healthcare approach that designs treatment plans of each patient, considering genetic, environmental, and lifestyle factors. This model leverages genomic information, advanced diagnostics, and data analytics to predict disease risk, optimize prevention strategies, and provide customized treatments. In Saudi Arabia, personalized medicine is gaining momentum, driven by the country's Vision 2030 initiative, which aims to transform the healthcare sector by integrating advanced medical technologies and improving healthcare delivery. The Kingdom has made significant strides in genomics and bioinformatics, with initiatives such as the Saudi Human Genome Program and advancements in institutions i.e., King Faisal Specialist Hospital and Research Centre. Continued investment in research, education, and technology, alongside international collaborations, will be crucial in overcoming these challenges and realizing the full potential of personalized medicine. This review explores the current state, challenges, and future prospects of personalized medicine in Saudi Arabia, highlighting its transformative impact on healthcare delivery and patient outcomes.

**Keywords:** personalized medicine, Vision 2030 initiative, challenges, opportunities

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From the Department of Pharmacology and Toxicology, College of Pharmacy, Jazan University, Jazan, Kingdom of Saudi Arabia.

Address correspondence and reprint request to: Dr. Wedad A. Mawkili, Department of Pharmacology and Toxicology, College of Pharmacy, Jazan University, Jazan, Kingdom of Saudi Arabia.  
E-mail: wmauwkili@jazanu.edu.sa  
ORCID ID: <https://orcid.org/0009-0005-0710-6048>

**I. Introduction.** Personalized medicine, or precision medicine, is a healthcare approach that customizes medical care based on the unique characteristics of each patient. It takes into account factors such as genetics, environment, and lifestyle to create individualized treatment plans.<sup>1,2</sup> This approach leverages genomic data, advanced diagnostic tools, and data analytics to assess disease risk, enhance prevention strategies, and design treatments aimed at achieving optimal outcomes for each.<sup>2-4</sup> The key components of personalized medicine include applying an individual's genetic information to guide healthcare decisions, detecting biological markers that indicate disease risk or response to treatment, and data-driven Approaches which provide leveraging large datasets and advanced analytics to understand disease patterns and treatment responses.<sup>1-5</sup> Personalized medicine enables the development of treatments that specifically target the underlying mechanisms of disease in an individual, leading to more effective and efficient therapies.<sup>6</sup> Moreover, by understanding an individual's genetic predispositions, healthcare providers can predict disease risk and implement preventive measures, reducing the incidence and severity of diseases.<sup>7</sup> Nonetheless, personalized medicine can minimize adverse drug

reactions which present a significant clinical issue, responsible for 6.7% of all hospitalizations and ranking as the fourth to sixth leading cause of inpatient deaths in Western countries, thus, enhancing patient safety and treatment efficacy.<sup>6</sup> A prospective cohort study conducted in Riyadh, Saudi Arabia, reported an ADR rate of 6.1 per 100 hospital admissions.<sup>8</sup> Personalized medicine signifies a transformative departure from the conventional “one-size-fits-all” model of healthcare, moving towards a more customized approach that takes into account each person’s unique genetic makeup, environment, and lifestyle.<sup>3</sup> This shift is especially pertinent in Saudi Arabia, where the combination of genetic diversity, increasing rates of chronic diseases, and improvements in healthcare infrastructure make it an ideal setting for personalized medicine. Despite this, traditional medicine has generally adhered to a standardized treatment model, as seen in the management of essential hypertension or type 2 diabetes mellitus.<sup>9,10</sup> Recent advancements, however, such as high-throughput sequencing, mass spectrometry, microfluidics, and advanced imaging techniques, now enable comprehensive analysis of clinical samples.<sup>11</sup> Enhanced by analytics, these technologies are uncovering detailed insights into the molecular and cellular changes associated with various diseases, highlighting significant variability among individuals and patients at these levels.<sup>2,5</sup>

Personalized medicine facilitates the identification of individuals at elevated risk for specific diseases, allowing for early interventions and the implementation of preventive measures.<sup>3</sup> Customized screening programs can be designed based on genetic and lifestyle factors, improving early detection and increasing the chances of successful treatment.<sup>2</sup> By providing the right treatment to the right patient at the right time, personalized medicine reduces the trial-and-error approach, leading to more efficient use of healthcare resources.<sup>6</sup> Preventive measures and targeted treatments can reduce the long-term costs associated with chronic diseases and their complication.<sup>4</sup> Personalized medicine drives advancements in genomic research, leading to the discovery of new biomarkers and therapeutic targets.<sup>1</sup> The insights gained from personalized medicine research contribute to the development of novel therapies and drugs tailored to specific patient populations.<sup>7</sup>

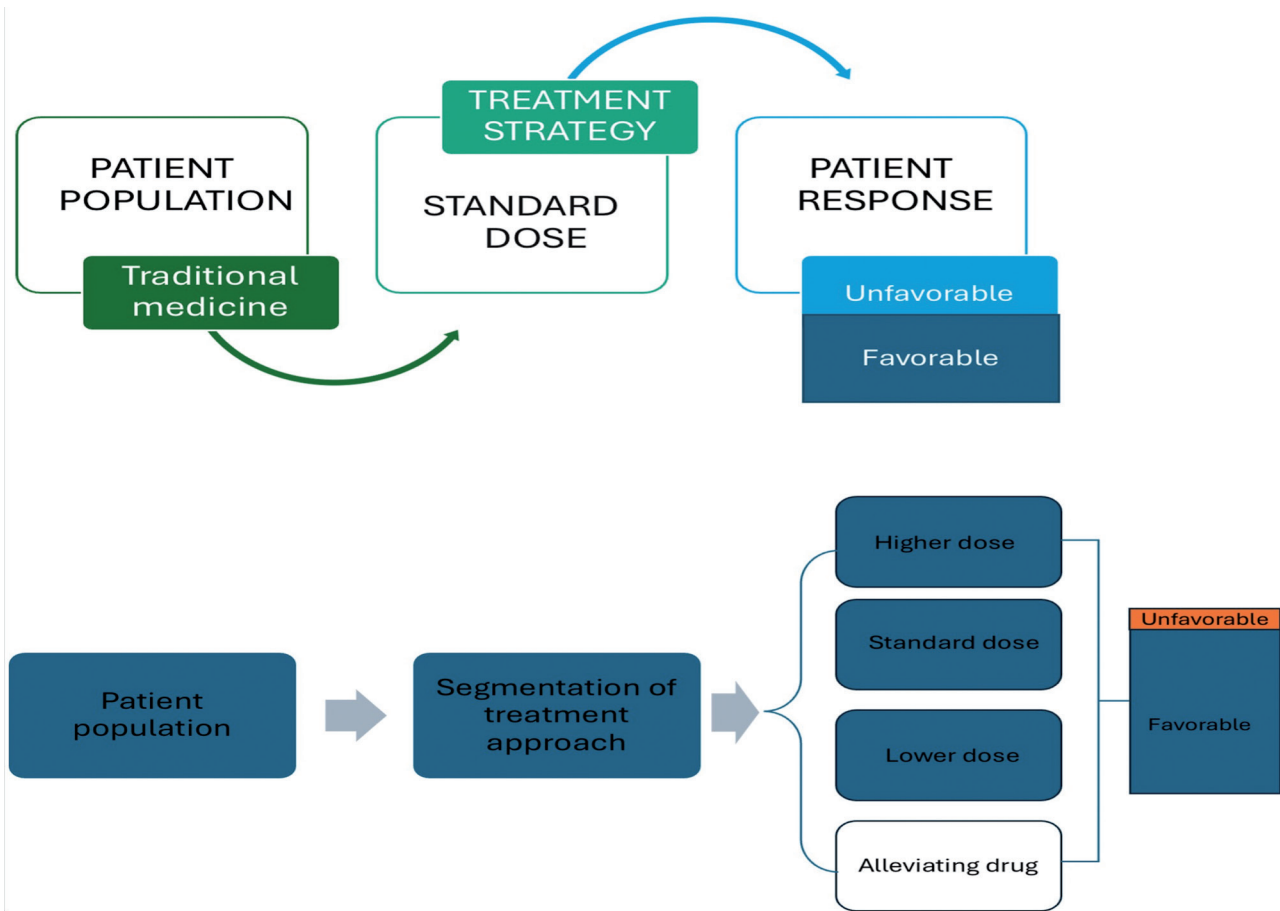
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Overall, personalized medicine marks a transformative shift in healthcare, transitioning from a one-size-fits-all approach to a more precise and individualized model. By leveraging genetic information, advanced diagnostics, and data analytics, personalized medicine aims to improve patient outcomes, enhance disease prevention and early detection, reduce healthcare costs, advance medical research, and empower patients in their healthcare journey.<sup>2,4</sup>

This review aims to explore the current state and future prospects of personalized medicine in Saudi Arabia, examining the technological advancements, potential benefits, challenges, and strategic initiatives required to successfully integrate personalized medicine into the healthcare system. By addressing these aspects, the review seeks to provide a comprehensive understanding of how personalized medicine can transform healthcare delivery in Saudi Arabia, leading to better health outcomes and a more efficient healthcare system.

*Current state of personalized medicine in Saudi Arabia.* Saudi Arabia has a well-established healthcare system that has been rapidly evolving, especially under the Vision 2030 initiative. This initiative aims to transform the Kingdom’s healthcare sector by increasing its efficiency, accessibility, and quality.<sup>12,13</sup> The kingdom has numerous hospitals and healthcare centers equipped with advanced medical technologies.<sup>14</sup> Saudi Arabia’s Vision 2030 is a comprehensive plan to diversify the economy and develop public service sectors, including healthcare.<sup>13</sup> Under this vision, the healthcare sector has seen significant investments aimed at modernizing facilities, improving healthcare delivery, and integrating advanced medical technologies, including personalized medicine.<sup>15</sup>

Vision 2030 emphasizes leveraging technology and innovation in healthcare, increased funding for healthcare research and development, and partnerships with international healthcare organizations and institutions.<sup>13</sup> The vision also includes specific policies supporting personalized medicine, such as initiatives to promote genetic research and precision medicine, development of national databases and biobanks to support personalized medicine research, and regulations to ensure ethical practices in genetic testing and data privacy. Saudi Arabia has made considerable strides in various technological and scientific fields that are crucial for the advancement of personalized medicine.<sup>16</sup> For instance, the Saudi government has allocated substantial funding to programs such as Saudi Human Genome Program (SHGP), which aims to map the genetic makeup of the Saudi population, providing



**Figure 1** - Hypothetical schematic of traditional versus precision medicine approaches.<sup>11</sup>

a foundational database for personalized treatment development.<sup>17</sup> Moreover, vision 2030 has prioritize the establishment of national biobanks and advanced data system to facilitate genetic and health data analysis including creating ethical and legal frameworks for genetic testing and data privacy.<sup>18</sup> All together aim for enabling precision diagnostics and personalize the treatments.

In the field of genomics and bioinformatics, the establishment of genomic research centers, such as the King Abdulaziz City for Science and Technology (KACST) and the Saudi Human Genome Program, aims to sequence the genomes of thousands of Saudis to create a comprehensive genetic database.<sup>17,19</sup> Recent advancements include the launch of AI-powered platforms for analyzing genetic data, facilitating faster identification of disease markers. Moreover, KACST in collaboration with King Faisal Specialist Hospital & Research Centre (KFSHRC) has developed personalized oncology protocols, particularly in breast and colorectal cancer treatment.<sup>20</sup> These protocols are tailored based

on tumor genetic profiling.<sup>21</sup> Through collaboration with international genomic research initiatives, such as the Mayo Clinic and Harvard Medical School, KACST has also introduced advanced diagnostic methods, including genome editing technologies (CRISPR) and next generation sequencing (NGS) platforms.

**II. Challenges and opportunities.** By addressing the challenges and using the opportunities, Saudi Arabia can pave the way for a transformative healthcare system that benefits from the advancements in personalized medicine. There are many challenges that can arise when the government tries to make a step forward to the next phase in personalization of healthcare. Establishing clear and comprehensive regulations and ethical guidelines for personalized medicine, including genetic testing and data privacy, is crucial.<sup>15</sup> There may be concerns about data security, patient consent, and the use of genetic information.<sup>22</sup> Moreover, developing the necessary infrastructure, such as advanced laboratories, data storage, and analysis capabilities, can be costly and

time-consuming.<sup>16</sup> For example, the estimated cost of building a fully equipped genomic research facility in Saudi Arabia range from SAR 50 million to SAR 100 million per facility.<sup>23</sup> Maintaining and upgrading this infrastructure, including storage and analysis of vast genomic datasets, adds ongoing financial pressure. Ensuring interoperability between different healthcare systems is also a challenge.<sup>12</sup>

Nonetheless, there is a need to train healthcare professionals in genomics, bioinformatics, and personalized medicine techniques. A recent survey conducted by Saudi Society of Medical Genetics revealed that only 25% of healthcare professionals felt confident in interpreting genetic test results.<sup>24</sup> Another study highlighted that only 30 % of pharmacists in Saudi Arabia had formal training in genomics, indicating a significant gap in the workforce's preparedness to adopt personalized medicine practice.<sup>25</sup> This requires updated curricula in medical schools and ongoing professional development. Educating the public about the benefits and limitations of personalized medicine is essential. Cultural attitudes towards genetic testing and personalized treatments may affect acceptance and adoption.<sup>15</sup> Given that personalized medicine can be expensive, potentially leading to disparities in access, ensuring equitable access to personalized treatments and technologies is a significant challenge.<sup>22</sup> One of the main challenges is managing and integrating large volumes of genomic and health data from diverse sources while ensuring accuracy and privacy is complex.<sup>19</sup> This includes developing robust bioinformatics tools and databases.<sup>17</sup> Collaboration between various stakeholders, including government agencies, healthcare providers, research institutions, and private companies, is essential but can be challenging to coordinate.<sup>16</sup>

Despite all these challenges, personalized medicine can lead to more effective and targeted treatments, reducing trial-and-error approaches and improving patient outcomes.<sup>12</sup> By understanding genetic predispositions, personalized medicine can enable earlier interventions and preventive measures, potentially reducing the incidence of certain diseases.<sup>15</sup> The adoption of personalized medicine can drive innovation in healthcare technologies, including genomics, bioinformatics, and precision therapies, fostering a culture of research and development. Developing a robust personalized medicine sector can create new economic opportunities, including jobs in research, healthcare, and biotechnology industries.<sup>16</sup> A report by the Saudi Ministry of Economy and Planning estimates that personalized medicine could generate over 5,000 new jobs by 2030, including roles in genetic counselors,

bioinformatics specialists, and precision medicine researchers. Moreover, according to National Industrial Development and Logistics program, the biotechnology sector, which includes personalized medicine, is projected to contribute approximately SAR 20 billion to Saudi Arabia's gross domestic product GDP by 2030. Nonetheless, investments in personalized medicine have the potential to reduce healthcare costs by enabling early disease detection and prevention. For instance, a pilot project in Saudi hospitals demonstrated that genomic screening programs could lower long-term treatment costs for genetics disorders by up to 30%. By investing in personalized medicine, Saudi Arabia can position itself as a leader in the Middle East and globally in advanced healthcare technologies and research.<sup>15</sup> Opportunities for international collaboration in research and clinical trials can arise, enhancing the global knowledge base and bringing cutting-edge treatments to Saudi Arabia.<sup>26</sup> Moreover, tailoring treatments to individual genetic profiles can lead to more effective and efficient care, reducing adverse drug reactions and improving patient satisfaction.<sup>21</sup> Utilizing big data and AI in healthcare can lead to more informed decision-making processes, optimizing resource allocation and treatment strategies.<sup>17</sup>

### III. Examples of successful personalized medicine initiatives in Saudi Arabia. *Saudi Human Genome Program.*

The Saudi Human Genome Program (SHGP) is one of the most prominent initiatives in the field of personalized medicine in Saudi Arabia. Launched by King Abdulaziz City for Science and Technology (KACST) in collaboration with the Ministry of Health and other institutions, the SHGP aims to sequence the genomes of thousands of Saudis to identify genetic variants associated with various diseases.<sup>17</sup> The program aims to create a comprehensive genetic database that can be used to develop personalized treatments and preventive strategies for genetic disorders prevalent in the Saudi population. The SHGP has already identified numerous genetic mutations linked to inherited diseases, enabling early diagnosis and the development of targeted therapies.<sup>19</sup>

*King Faisal Specialist Hospital & Research Centre (KFSHRC).* King Faisal Specialist Hospital & Research Centre is a leading institution in personalized medicine in Saudi Arabia. It has several programs and initiatives focused on integrating genomic data into clinical practice. The Genomic Medicine Unit conducts advanced genomic research and provides personalized treatment plans based on genetic information.<sup>21</sup> It collaborates with international institutions to stay at the



forefront of genomic medicine. KFSHRC has developed personalized cancer treatment protocols based on the genetic profiles of tumors. This approach has improved treatment outcomes for patients with various types of cancer. For example, KFSHRC uses genomic profiling to identify specific mutations, such as BRCA1/BRCA2, which guide targeted therapies like PARP inhibitors. This approach has improved treatment outcomes and minimized side effects. Recent data from KFSHRC demonstrate a 30%, 20%, and 40% improvement in overall survival, remission, and tumor progression rates, respectively, for breast and colorectal cancer, leukemia, and lung cancer patients undergoing personalized treatment compared to conventional protocols.

**Personalized diabetes management programs.** Diabetes is a significant health issue in Saudi Arabia. Various hospitals and research centers are implementing personalized medicine approaches to manage and treat diabetes more effectively. King Saud University Medical City (KSUMC) has implemented personalized diabetes management programs that use genetic and metabolic information to tailor treatment plans for patients. These programs have shown improved glycemic control and reduced complications.<sup>15</sup>

**Telemedicine and digital health initiatives.** Telemedicine and digital health platforms are being leveraged to provide personalized care, especially in remote and underserved areas. Launched by the Ministry of Health, Seha Virtual Hospital uses telemedicine to connect patients with specialists and provide personalized care plans based on individual health data.<sup>16</sup> Moreover, the implementation of electronic health records (EHRs) across healthcare facilities in Saudi Arabia enables the collection and analysis of patient data to support personalized treatment decisions.<sup>15</sup> These initiatives demonstrate Saudi Arabia's commitment to advancing personalized medicine and integrating it into the healthcare system. Through genomic research, innovative treatment protocols, and the use of advanced technologies, these programs aim to improve patient outcomes and provide tailored healthcare solutions.<sup>13</sup>

**IV. Future perspectives.** The future prospects of personalized medicine in Saudi Arabia are promising, driven by significant investments, ongoing research, and a strong commitment to innovation. Here are some key prospective developments:

**Advancements in genomic research.** Saudi Arabia is likely to continue its investment in genomic research. Initiatives like the Saudi Human Genome Program (SHGP) will expand, providing a more comprehensive understanding of the genetic makeup of the Saudi

population.<sup>17</sup> This will facilitate the development of more targeted and effective treatments for various genetic disorders and diseases prevalent in the region.

**Integration of AI and big data analytics.** The integration of artificial intelligence (AI) and big data analytics into healthcare will revolutionize personalized medicine in Saudi Arabia. AI can analyze vast amounts of genomic and health data to identify patterns and predict disease risks, enabling more precise and timely interventions.<sup>19</sup> This will optimize treatment plans and improve patient outcomes.<sup>15</sup> The Saudi Diabetes AI Program, developed in collaboration with King Abdulaziz University, uses machine learning to identify high-risk patients based on genomic and clinical data, enabling early interventions.<sup>27</sup> AI-driven platforms like PharmaPredict, implemented in collaboration with KACST, predict individual responses to specific drugs based on genetic and biochemical markers. This has significantly reduced adverse drug reactions in pilot programs, cutting ADR rates by 20% in oncology patients.

**Enhanced training and education programs.** To fully realize the potential of personalized medicine, there will be a greater emphasis on training healthcare professionals in genomics, bioinformatics, and personalized medicine techniques. Medical schools and institutions will likely update their curricula and offer specialized programs to ensure that the workforce is well-equipped with the necessary skills and knowledge.<sup>12</sup>

**Expansion of telemedicine and digital health.** Telemedicine and digital health platforms will continue to grow, providing personalized care to remote and underserved areas. The use of electronic health records (EHRs) and other digital tools will support the collection and analysis of patient data, facilitating more personalized treatment decisions and improving healthcare accessibility.<sup>16</sup>

**Development of personalized treatment protocols.** Research institutions and healthcare providers in Saudi Arabia will develop more personalized treatment protocols for various conditions, including cancer, cardiovascular diseases, and diabetes. These protocols will be based on individual genetic profiles and other personal health data, leading to more effective and efficient treatments.<sup>21</sup>

**Collaborations and partnerships.** Saudi Arabia will likely seek more collaborations and partnerships with international healthcare organizations, research institutions, and private companies. These partnerships will enhance the country's capacity for personalized medicine research, clinical trials, and the development of new therapies and technologies.<sup>26</sup>

**Regulatory framework and ethical guidelines.** The establishment of robust regulatory frameworks and ethical guidelines for personalized medicine will ensure that genetic testing and data privacy are managed appropriately. This will build public trust and encourage the adoption of personalized medicine.<sup>15</sup>

**Economic opportunities and industry growth.** The growth of personalized medicine will create new economic opportunities in Saudi Arabia. The biotechnology and healthcare sectors will expand, generating jobs and fostering innovation. Saudi Arabia could position itself as a regional leader in advanced healthcare technologies, attracting investment and talent.<sup>16</sup>

**Improved patient outcomes and healthcare efficiency.** Ultimately, the adoption of personalized medicine will lead to improved patient outcomes and greater healthcare efficiency. By providing tailored treatments and preventive measures, personalized medicine can reduce the incidence and severity of diseases, minimize adverse drug reactions, and enhance patient satisfaction.

**Public awareness and acceptance.** Increasing public awareness and acceptance of personalized medicine will be crucial. Educational campaigns and community engagement initiatives will inform the public about the benefits and limitations of personalized medicine, encouraging more people to participate in genetic testing and personalized healthcare programs.<sup>13</sup> The Saudi human Genome Program has launched national campaigns to raise awareness about the benefits and safety of genetic testing, particularly focusing on inherited diseases. Moreover, Digital platforms, such as Seha Virtual Hospital, are being used to educate patients during consultations, AI-powered chatbots provide easy-to-understand explanations of genetic testing and personalized treatment options, ensuring informed decision-making. To build awareness from an early age, concepts related to genetics and personalized medicine should be integrated into high school biology curricula under the guidance of the Ministry of Education.

**V. Conclusion.** Saudi Arabia is actively working towards integrating personalized medicine into its healthcare system. Through significant investments in healthcare infrastructure, genomic research, and advanced technologies like AI and telemedicine, the Kingdom is setting a strong foundation for the future of personalized medicine. However, continuous efforts in policy-making, public awareness, and education are essential to fully realize the potential of personalized medicine in Saudi Arabia offering more precise, effective, and fair healthcare solutions to its population

The future of personalized medicine in Saudi Arabia holds great promise, driven by the nation's commitment to healthcare innovation and its Vision 2030 agenda. Personalized medicine offers the potential to revolutionize healthcare by providing more precise, effective, and individualized treatments. The opportunities in this field are vast, including advancements in genomics, the integration of AI and big data, and the development of targeted therapies.

However, realizing this potential requires addressing several challenges. These include ensuring the availability of high-quality genetic data, establishing robust regulatory frameworks, addressing ethical considerations, and investing in education and training for healthcare professionals. Furthermore, fostering public awareness and acceptance of personalized medicine is crucial for its successful implementation.

Saudi Arabia's strategic initiatives, such as the establishment of research centers and the promotion of public-private partnerships, are steps in the right direction. By continuing to invest in infrastructure, technology, and human resources, Saudi Arabia can position itself as a leader in personalized medicine. In conclusion, while challenges remain, the opportunities presented by personalized medicine are significant. With continued commitment and strategic planning, Saudi Arabia has the potential to transform its healthcare landscape, ultimately improving patient outcomes and setting a precedent for other nations to follow.

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