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Artificial Intelligence (AI) and the future of Iran's Primary Health Care (PHC) system

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Abstract

Objective The rapid adoption of Artificial Intelligence (AI) in health service delivery underscores the need for awareness, preparedness, and strategic utilization of AI's potential to optimize Primary Health Care (PHC) systems. This study aims to equip Iran's PHC system for AI integration by envisioning potential futures while addressing past challenges and recognizing current trends.

Method This study developed a conceptual framework based on the "Future Triangle" (FT) and the "Health Systems Governance" (HSG) models. This framework delineates the characteristics associated with the 'pulls on the future' for desired and intelligent PHC, as identified by a panel of experts. Additionally, the 'weights of the past'—referring to the challenges faced by Iran's PHC system in utilizing AI—, and the 'push of the present'—which captures the impacts of AI implementation in global primary care settings—were extracted through a review of relevant literature. The integration and analysis of the collected evidence facilitated the formulation of a range of potential future scenarios, including both optimistic and pessimistic scenarios.

Findings The interaction between the three elements of the FT will shape the future states of Iran's PHC, whether optimistic or pessimistic. Building an optimistic scenario for an AI-driven PHC system necessitates addressing past challenges, including deficiencies in the referral and family doctor systems, the absence of evidence-based decision-making, neglect of essential community health needs, fragmented service delivery, high provider workload, and inadequate follow-up on the health status of service recipients. Consideration must also be given to the current impacts of AI in primary care, including comprehensive, coordinated, and need-based service delivery with systematic and integrated monitoring, quality improvement, early disease prevention, precise diagnosis, and effective treatment. Furthermore, fostering a shared vision among stakeholders by defining and advocating for a future system characterized by foresight, resilience, agility, adaptability, and collaboration is essential.

Conclusion Envisioning potential future states requires a balanced consideration of the influence of past, present, and future, recognizing the dual potential of AI to drive either positive or negative outcomes. Achieving the optimistic future or the "utopia of intelligent PHC" and avoiding the pessimistic future or the "dystopia of intelligent PHC" requires coherent planning, attention to the tripartite considerations of the future, past, and present, and a clear understanding of the roles, expectations, and needs of stakeholders.

Keywords Artificial intelligence, Primary care, Future of health, Primary health care in Iran, Future triangle

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Introduction

The Primary Health Care (PHC) system is regarded as the heart of the health system, playing an outstanding role in addressing health needs. Following the International Alma-Ata Conference and its global declaration, this system was recommended as a global strategy for health promotion [1], committing all countries to provide health for all and equitable access to health services. Fulfilling this commitment means delivering essential care that covers an individual's health-related needs through disease prevention, health promotion, treatment, rehabilitation, and palliation [2]. In line with the historical decision on a global scale and considering the geographic and social diversity of the country, Iran has designed a PHC network at three levels: national (Ministry of Health), provincial (public medical sciences universities), and district (provincial and district health networks) [3]. Established over a continuous and collaborative 15-year effort [4], this network now possesses internationally recognized strengths [2]. Although the benefits of Iran's PHC network in extensive population coverage and health service delivery, especially to rural areas [5, 6], are undeniable, evidence indicates that the system has struggled to adapt to evolving needs and challenges, especially amidst recent changes [7–9].

Besides the significance of this historical and prominent decision, it is essential to acknowledge that the future—characterized by its complexity and dynamism [10]— is influenced by a multitude of changes, including technological, economic, and social transformations [11]. These shifting factors have profound implications for various sectors of society, particularly PHC systems [12]. This reality necessitates a concerted focus on preparedness and responsiveness to such changes. In this context, futures studies and foresight methodologies are critical as they create a holistic picture of all possibilities and alternatives. These approaches are considered an essential tool [13] in identifying and navigating the disruptions and transformations arising in the modern world [14, 15]. The rapid changes occurring, coupled with the pivotal role of PHC systems in addressing diverse health needs within communities, underscores the indispensable application of these analytical tools [16, 17]. Futures studies facilitate a comprehensive and in-depth analysis of changes and their implications for all stakeholders, enabling a reassessment of fundamental assumptions [13].

One significant change in contemporary PHC systems is the advancement of technology, which unequivocally impacts their operations and effectiveness [18]. Artificial Intelligence (AI) stands out among these changes as one of the most significant emerging technologies, widely recognized for its profound impact on various fields, including primary care [19–21]. AI, as a branch of computer science, seeks to mimic human cognitive processes, learning capabilities, and knowledge storage [22]. This field and its approaches, such as machine learning, deep learning, neural networks, natural language processing, and smart robots, offer numerous opportunities for health [23, 24], contributing to their global popularity [25]. This technology, with all its allure, fears, and promises, is termed the "medical stethoscope of the 21st century" [26], symbolizing the transformation of the PHC setting as the first point of contact for individuals, families, and communities with the health system [27, 28]. Indeed, the PHC setting is where the power, potential, and future of AI are realized on the most extensive and ambitious scale [29, 30]. This broad application of AI introduces further uncertainties about the future of this setting, eliciting diverse reactions such as fear of falling behind, retreat, acceptance, and proactive advancement. Consequently, it is imperative to employ appropriate models for managing such conditions, ensuring that the healthcare system is adequately equipped to address these challenges and adapt to the rapid advancements in technology.

Existing models such as "Horizon Scanning" are implemented as systematic processes designed to identify and assess new and emerging health technologies [31, 32]. However, these models face significant limitations when applied to rapidly evolving and complex technologies like AI, due to the difficulties in refining prioritization criteria, managing inherent uncertainties, and effectively disseminating identified issues [32]. Moreover, the WHO's 'Digital Transformation Handbook for Primary Health Care' focuses on optimizing person-centered service systems, offering valuable insights into the broader framework for digital health transformation [32]. As such, while it offers a comprehensive perspective, it lacks direct applicability to the rapid and specialized advancements associated with AI integration within PHCs, which is the primary focus of this study. Furthermore, a scoping review examining implementation frameworks for AI in healthcare practice suggests that the field is still in its early developmental stages. This review recommended additional research to provide the necessary knowledge to formulate effective implementation frameworks that can guide the future integration of AI into health systems [33]. This highlights the necessity to identify such changes—particularly in the context of AI—, and to analyze their impacts on all aspects of PHC.

The Future Triangle (FT) approach, in futures study methodologies, offers a holistic perspective on potential future scenarios. Considering current trends as push, past challenges as weight, alongside future visions as pull evaluating related opportunities and challenges [34]. Cheng Y, Sul S. employed FT to explore and develop three future scenarios for the smart home service experience in China in the year 2050. In their study, they defined the

vision related to future smart home service experiences as pull, identified the trends influencing the development of these experiences as push, and highlighted the situations that prevent the development of future smart home experiences as weight [35]. Also, Fergnani, A. conducted an exploration of the future of medical operations globally in 2050 utilizing FT analysis. In the presented case study, four distinct scenarios were developed, informed by three identified dimensions of FT and a 2 × 2 scenario planning approach. The scenarios outlined several critical factors: fully automated operations and the availability of easily reproducible artificial organs were identified as pulls; big data-driven diagnoses, the partial integration of robotics, and the application of three-dimensional printing technologies in the medical field were recognized as pushes; conversely, resistance to new medical technologies, ethical dilemmas, a scarcity of raw materials, existing legal loopholes, and potential unemployment among medical professionals were categorized as weight [36]. The usability and flexibility of the FT in facilitating deliberate and systematic discussion of the three dimensions across various scenarios have been emphasized in these sample studies [35, 36]. This approach enhances the comprehensive exploration of emerging issues and the development of diverse scenarios, ultimately contributing to the advancement of sustainable and resilient PHC systems.

Despite several studies examining Iran's PHC—focusing on its achievements and challenges across various regions—there remains a notable absence of research concerning its future trajectory [8, 37, 38]. A related study has identified future trends within Iran's PHC, including demographic and epidemiological transitions, social and cultural changes, as well as the emergence of modern technologies [1]. However, there is currently no research that focuses on a specific emerging technological change and its impacts across the diverse facets of Iran's PHC. Similar to other PHC systems, Iran's PHC is set to experience significant transformation by emerging technologies [1]. As mentioned, AI represents a significant technological advancement that carries extensive and rapid implications for PHC systems worldwide [26, 39]. its increasing relevance, many PHC systems, including those in Iran, have encountered difficulties in effectively responding to these transformative changes [30, 40]. The rapid pace, complexity, and widespread and far-reaching impact of AI present considerable challenges for health systems to address [41–43]. This issue is not confined to Iran alone; it raises similar inquiries for numerous countries across the globe. Central questions include the evolving roles of healthcare providers, the transformation of operational processes and functions, and the adaptation of Ministry of Health structures, all of which remain largely unresolved. The questions surrounding the impact of AI on roles, processes, structures, and education within health systems are not exclusive to Iran; they are relevant to numerous countries worldwide, each with distinct PHC systems. Addressing these inquiries necessitates the development of a comprehensive framework capable of providing initial data and critical insights. Such a framework would not only benefit Iran but also offer valuable guidance to other nations confronting similar challenges.

To address the existing gap, this study aims to clarify the future trajectory of Iran's PHC in light of the advancements in AI, considering the future visions, past challenges, and current trends of this system and its key stakeholders. This analysis will not only inform current strategic actions in response to this significant transformation but will also enhance awareness, facilitate thorough preparation, establish relevant policies, devise adaptive strategies, and reform existing practices. Given the complexity and rapid evolution of AI technologies, this study employs established foresight models to confront these challenges, ultimately selecting a comprehensive approach. This model possesses the flexibility to be adapted and implemented in other healthcare systems worldwide, particularly those encountering analogous challenges with AI integration. By considering the interactions among past, present, and future dynamics of healthcare systems for key stakeholders, this approach provides valuable insights and strategies that can be applied in diverse contexts, facilitating a more universal understanding of AI integration in PHC settings.

Method

Through a qualitative methodology, a conceptual framework was developed to incorporate diverse concepts and perspectives [44]. This framework proved beneficial in redefining key terms, establishing a network of interconnected concepts, and applying flexible approaches [45]. The study's conceptual framework is founded upon the FT model, which aims to depict potential futures ranging from optimistic to pessimistic scenarios by closely examining past, present, and future conditions of Iran's PHC.

The FT, a simple yet powerful model, creates a profound discussion and organized dialogue about potential futures through a tripartite interaction among the 'Weights of the Past' (WP), the 'Push of the Present'(PP), and the 'Pulls of the Future'(PF) [36]. Developed by Sohail Inayatullah, this model serves as a framework to identify and analyze three factors affecting the future of the discussed topic [34]. PF represents the vision and insight into the future, emerging from collective attitudes. WP symbolizes the obstacles and limitations to achieving possible futures and moving forward. The PP explains current trends or driving forces influencing the direction of future change. Both WP and PP are informed by current information and documentation [34, 36]. As a

framework for depicting uncertain futures, the FT clarifies ambiguous and emerging conditions of change from the past, present, and future, enabling the discovery of insightful and feasible futures [46]. Each dimension of the triangle can not only be interpreted in various states and scenarios from other dimensions [47] but can also serve as a component of a unified picture or a spectrum of coherent potential scenarios [34, 36].

For a better understanding of potential futures in the FT, different scenario planning approaches, such as the 2×2 Intuitive Logic Scenario Planning approach, can be utilized [36]. Other scenario-planning approaches include sketching a spectrum of acceptable scenarios to prepare for uncertain futures [48, 49] and considering optimistic and pessimistic scenarios as the range's endpoints [50]. Inayatullah and Milojevic in their work link the FT to the Change Progression Scenario Method. This consists of four scenarios based on the distance from the PF and the WP. The 'radical scenario' is closest to the top vertex, followed by the 'adaptive scenario', then the 'marginal scenario', concluding with the 'no change scenario' (developed from the WP vertex). The main point is that FT is a useful approach as a foundational tool prior to applying other scenario techniques [51, 52]. These frameworks are depicted in Fig. 1.

Additionally, the "Health Systems Governance" (HSG) model is incorporated into each dimension of the FT to fulfill the study's objective of considering key stakeholders of Iran's PHC. This framework (Fig. 2) is an adaptation of the governance triangle put forward in the World Development Report 2004 [53], further adapted by Brinkerhoff and Bossert in 2008 [54]. This triangle reflects the set of arrangements that form the core of governance in practice by exploring key relationships between and within three categories of stakeholders: Health Governance (HG), Health Providers (HP), and Health Recipients (HR) or people [55].

By integrating both the FT and HSG models, we have developed a conceptual model that serves as the foundation for this research (See Fig. 3). Within this framework, the dimension of PF, as delineated in the FT model, emphasizes the significance of understanding the perceptions held by various stakeholders—specifically HG, HP, and HR—regarding the future of AI in PHC and how these perceptions should evolve. The dimension WP, another facet of the FT model, addresses the challenges that these three categories of stakeholders may confront in the adoption and application of AI within PHC. In relation to the dimension PP, also part of the FT model, our inquiry focuses on how AI emerging trends will impact these stakeholders. By aligning the FT with the Change Progression Scenario Model, we will evaluate two distinct scenarios: the optimistic scenario, representing a radical approach; and the pessimistic scenario, which illustrates a regression to a less desirable past. This framework facilitates a comprehensive exploration of future expectations, challenges, and the existing implications of AI within PHC for all stakeholders. Ultimately, it aims to clarify a significant pathway for the future of this system and to equip stakeholders with awareness and preparation on the necessary insights for their planning, strategic development, and practical responses to this emerging change.

The conceptual framework serves as a foundation for research, guiding the choice of methodology, data collection, and analysis techniques [56]. Data related to each dimension of the FT regarding the potential future of Iran's PHC system were collected and analyzed as follows:

- The **"Weights of the Past" (WP)** includes the obstacles and problems of Iran's PHC in facing AI, as identified through a literature review of relevant related publications.

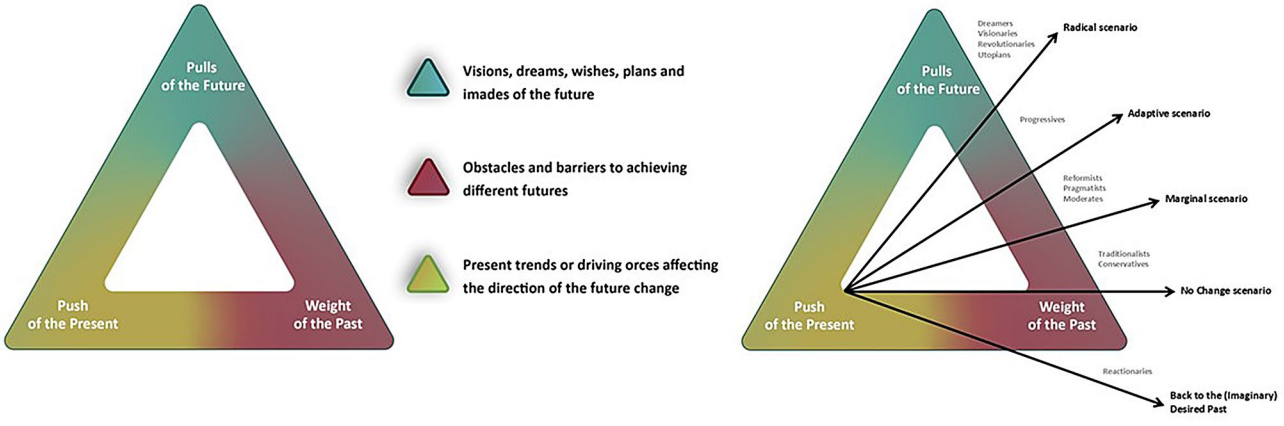

Fig. 1 Future triangle (FT) model and its link to the "Change Progression Scenario Model"

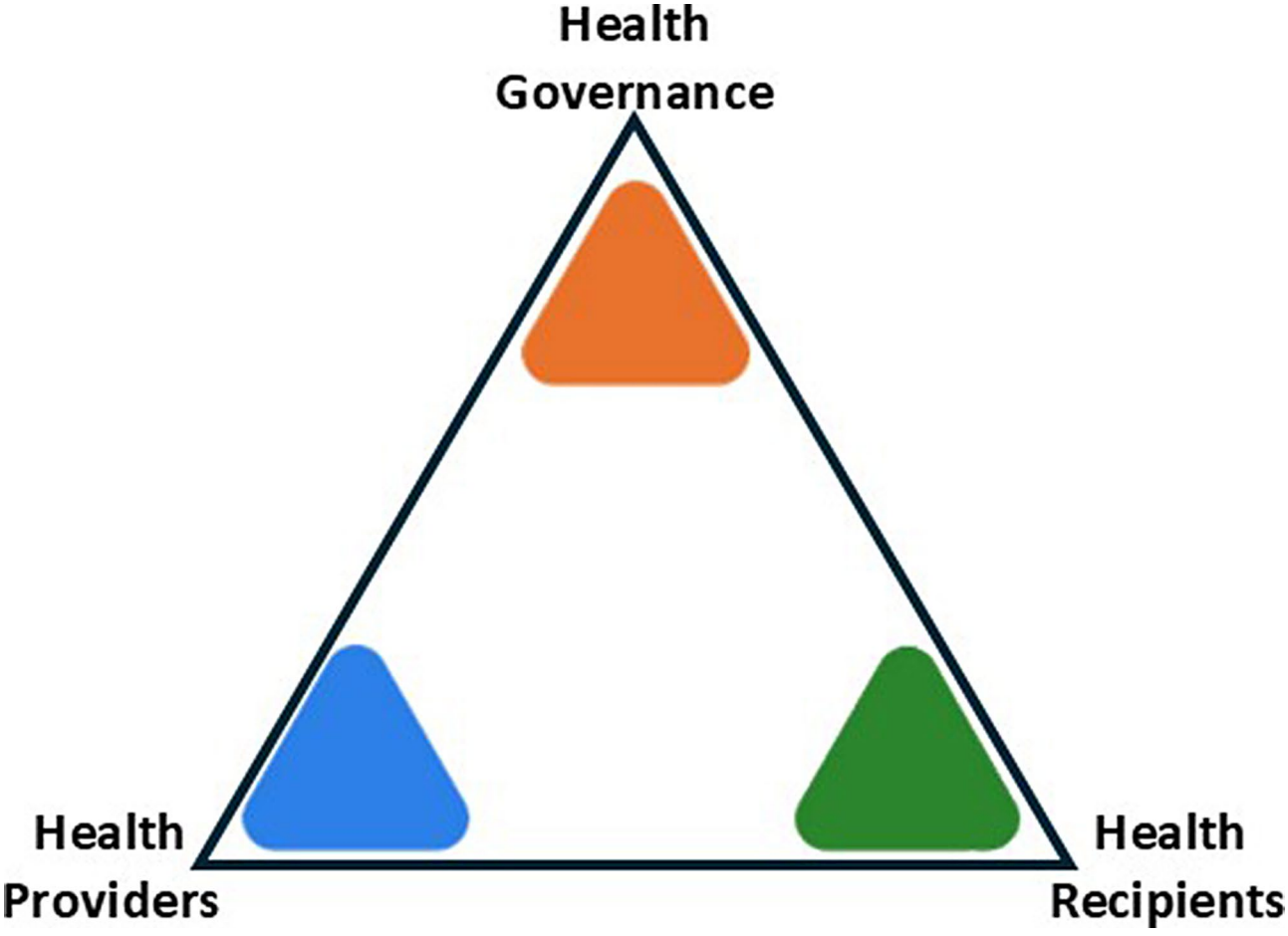

Fig. 2 "Health Systems Governance" (HSG) model

Documents, studies, and articles were searched using the keywords ((Iran) AND ("Challenge" OR "Problem*" OR "Obstacle") AND ("Primary Healthcare" OR "Primary Care")). This search was conducted across various international databases such as PubMed, Embase, and Google Scholar, as well as Persian-language databases including MagIran, Noormags, and the Scientific Information Database (SID).*

- The **"Push of the Present" (PP)** refers to the effects of AI implementation in the PHC systems,

as revealed through a literature review of relevant related publications.
Documents, studies, and articles were retrieved by searching keywords (("Primary health care" OR "Primary Care") AND ("Artificial intelligence" OR "Machine Learning" OR "Deep Learning")) on international databases like PubMed, Embase, and Google Scholar.

Throughout the entire review process for both aspects, from developing questions, searching the literature, extracting and analyzing data, and interpreting and writing results, the research team was involved. We exported all citations to EndNote where duplicates were removed by the automated function. Two reviewers (FY, MN), working in pairs, performed an independent assessment of titles and abstracts, and then full texts, according to the inclusion and exclusion criteria. A single reviewer extracted data, which was then confirmed by a senior reviewer (RD).

After applying the inclusion and exclusion criteria, a total of 21 publications were incorporated into the WP category, while 27 publications were included in the PP category. We synthesized the extracted data from the included studies and conducted a thematic analysis using an inductive approach. For this analysis, challenges associated with the WP dimension and the current impacts of AI on PHC within the PP aspect were initially categorized based on the HSG model, which includes the components of HG, HP, and HR. Subsequently, these categories were organized into appropriate sub-groups.

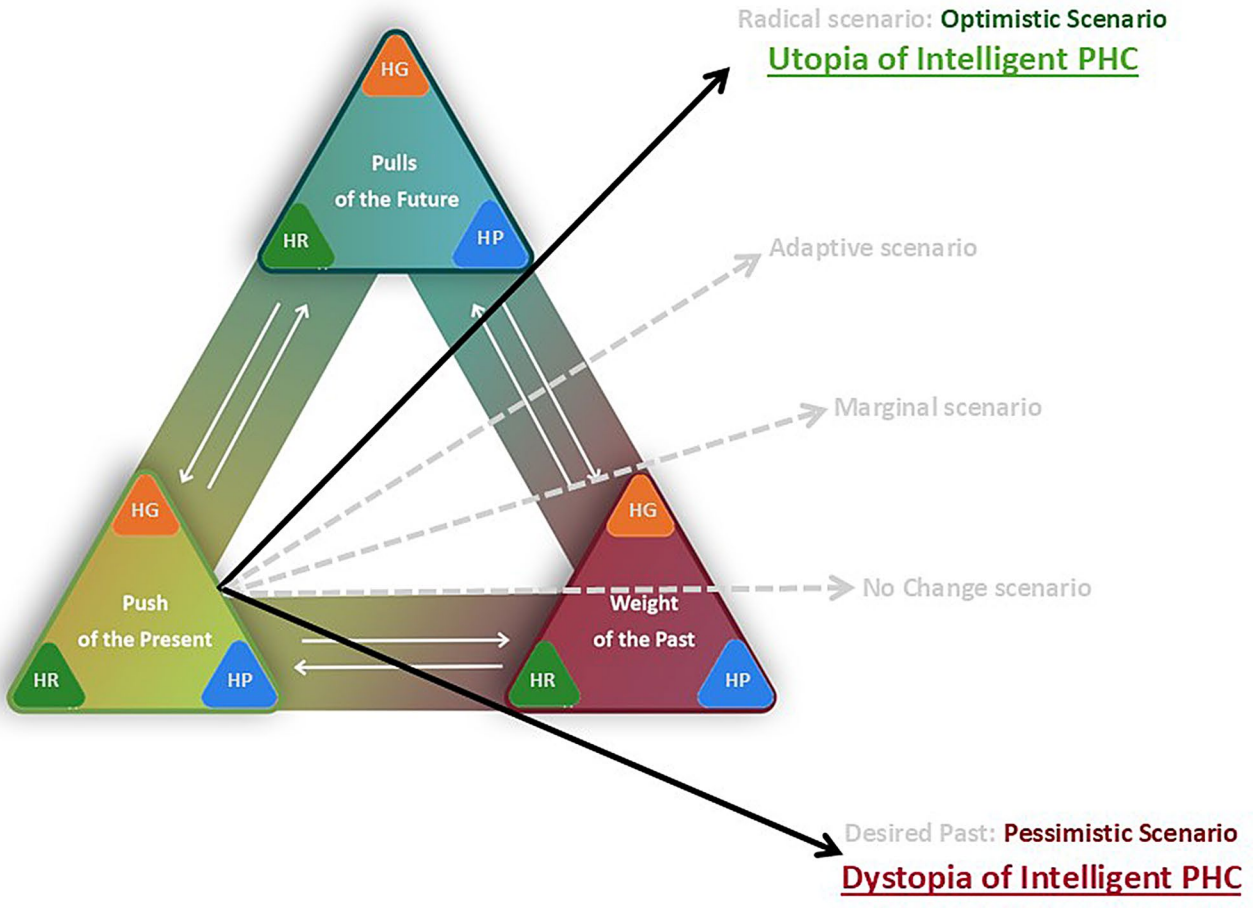

Fig. 3 Conceptual framework of the study

- The **"Pulls of the Future" (PF)** refers to the desired features of an intelligent PHC system. An intelligent PHC system is one that effectively leverages the opportunities presented by AI implementation while managing its associated challenges. This system is designed to consider the needs of all key stakeholders and utilize AI-driven solutions to enhance service delivery, improve patient outcomes, and promote efficiency within primary healthcare.

These insights were gathered through a survey sent to specialists, reflecting their expectations, wishes, and visions for the future. An open-ended question was posed to a selection of experts and futurists in health and AI within the healthcare system:
What characteristics should the PHC system have to leverage the opportunities of AI implementation and better manage past system challenges, and why?

The experts selected for this study were identified through purposive sampling, taking into account their specialized knowledge and academic qualifications. They were invited to participate via telephone and email communications. Upon providing their consent by completing the consent form, they submitted their responses electronically. The participant group included four females and five males, with a mean age of 56 years. Within this group, five experts specialized in futures studies related to health and primary care, while four experts focused on AI applications within the same domains, collectively contributing their insights to the study. After collecting all responses, a single reviewer (FY) analyzed data, which was then confirmed by a senior reviewer (RD). Through content analysis of the results obtained in this segment, the key characteristics of the future of AI-based PHC, and the underlying rationale, were discerned.

Findings

Push of the present (PP): impacts of AI on PHC systems

AI is a significant and rapidly evolving topic within PHC systems worldwide [57]. Research in this domain has demonstrated that this technology profoundly transforms the structure, functions, and processes of these systems, impacting prevention, diagnosis, and treatment, with the overarching goal of enhancing community

health [23, 58, 59]. One study revealed a segment of the population was willing to adopt AI applications in primary care during the coronavirus pandemic [60]. Despite this positive momentum, there is a notable lack of comprehensive economic analyses to justify investment in AI [61]. Furthermore, several concerns persist, including issues of readiness, acceptance and trust, unequal access, increased risk of bias, skepticism regarding AI utilization [62], misinterpretation of results without understanding the PHC context, over-reliance on technology [63], data quality issues, and ongoing legal and privacy challenges [64]. Nevertheless, despite these obstacles, the potential benefits of AI appear sufficiently compelling to warrant its increased adoption [65]. The opportunities arising from AI implementation in global primary care systems have been classified based on the HSG model and illustrated in Fig. 4.

In summary, the application of AI in PHC presents significant opportunities for each stakeholder. These benefits for HG are categorized into 3 main groups such as "cost-effectiveness", "services delivery", and "evidence-based policymaking", which are further divided into 12 subcategories. Also, opportunities for HPs are identified in 5 main categories: "health expert provider", "service and care provision", "patient follow-up", and "facilitating workflow", encompassing 16 subcategories. For HRs, the advantages of this technology are classified into 3 main groups: "boosting patient experience", "patient be a priority", and "patient commitment", divided into 10 subcategories. These impacts are detailed in Table 1 in the appendix.

Based on this table, it is evident that HPs stand to benefit the most from the integration of AI in primary care. It is essential to acknowledge that these positive implications will be reflected across all stakeholders, particularly HG. These benefits represent a significant step toward achieving the primary goal of the health system, which is to enhance the overall health of society. While the mentioned benefits offer considerable opportunities for the system, especially in developing countries like Iran, serious challenges persist. Therefore, the adoption of practical strategies and operational plans is crucial to avoid creating a skewed future with disproportionate elements.

Weights of the past (WP): challenges of iran's PHC system

Regarding Iran's commitment, since 1984, Iran's PHC system has been established in the form of local healthcare networks in cities with the aim of providing healthcare, increasing access to optimal health services [1], and reducing inequalities in rural and underprivileged urban areas [66]. The development of this network in Iran has undergone many challenging reforms. Although the establishment of this network has seen annual progress in health indicators [67, 68], rural population coverage, increased access, healthcare efficiency, reduction of rural inequalities, providing health services by local forces [5, 6], and provision of free PHC services [67, 69], it still suffers from numerous challenges [63]. The challenges

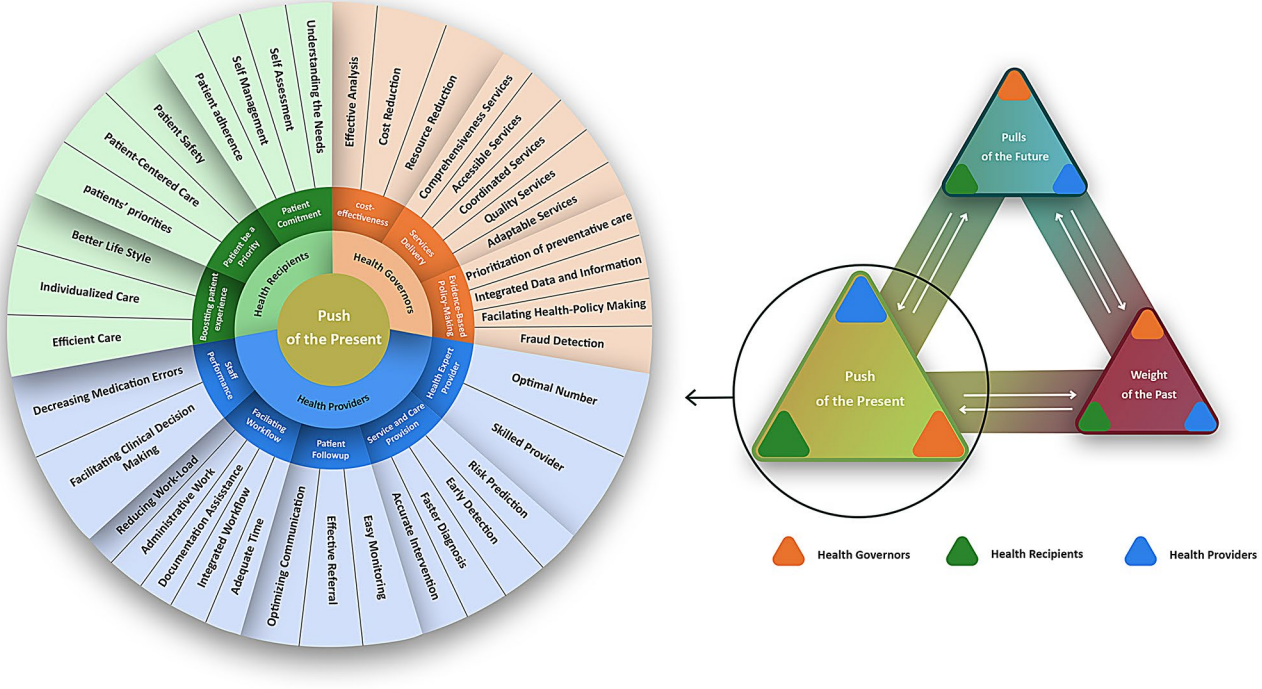

Fig. 4 Push of the Present (PP): Impacts of AI on PHC Systems

affecting the use of AI in this system were identified through a literature review and categorized based on the HSG, shown in Fig. 5.

Different dimensions of the HSG face various challenges across different fields. The challenges related to HG were classified into 4 main categories "health policymaking", "health planning", "monitoring & evaluation system" and "health service providing" encompassing a total of 13 sub-headings. The challenges affecting HPs are organized into 3 main categories: "human resources", "unsteady cooperation among staff", and "staff's performance" with 10 associated sub-headings. Similarly, issues related to HRs have been identified in 2 main categories: "inapproachable health services" and "lack of patient commitment" with 5 subcategories. These challenges are detailed in Table 2 in the appendix.

Based on this table, it is evident that HG and HP face the most significant challenges within Iran's PHC. However, it is important to note that the impact of these challenges is multifaceted, with each issue potentially generating challenges across various dimensions for other stakeholders, particularly HRs. Patients are the focal point of primary care services, and the principal objective of the health system is to meet their needs. While the number of challenges directly impacting patients is limited as depicted in the table, it can be posited that they are profoundly affected by the challenges encountered by other stakeholders. Overall, these challenges, while reflecting the current state of Iran's PHC, can directly or indirectly influence the use of AI in this setting.

Pulls of the future (PF): Features of the future image of intelligent PHC system

Given the uncertainties about the future of the intelligent PHC, it is crucial to define expectations, images, characteristics, and visions for this. In this regard, experts mentioned key points for why the future image should possess certain characteristics. (see Fig. 6)

These characteristics indicate that the desirable image of the interaction between technologies and the PHC system in the future should encompass 15 defined attributes. In this ideal image, the intelligent PHC system is forward-looking, resilient, agile, adaptable, change-embracing, participatory, cohesive, etc. Within this context, each of the three stakeholders in the HSG model should play an appropriate role regarding each of these characteristics. For example, in benefiting from AI technology, Iran's intelligent PHC system is receptive to change in such a way that HG embraces new technologies, HPs strive to acquire the necessary skills to use this technology, and HRs move towards accepting changes with trust and confidence in technology safety. Each of the stated features plays a significant role in reconstructing the desirable image of this system's future and requires comprehensive attention from HG, HPs, and HRs. It should be noted that the future image of Iran's PHC system is currently

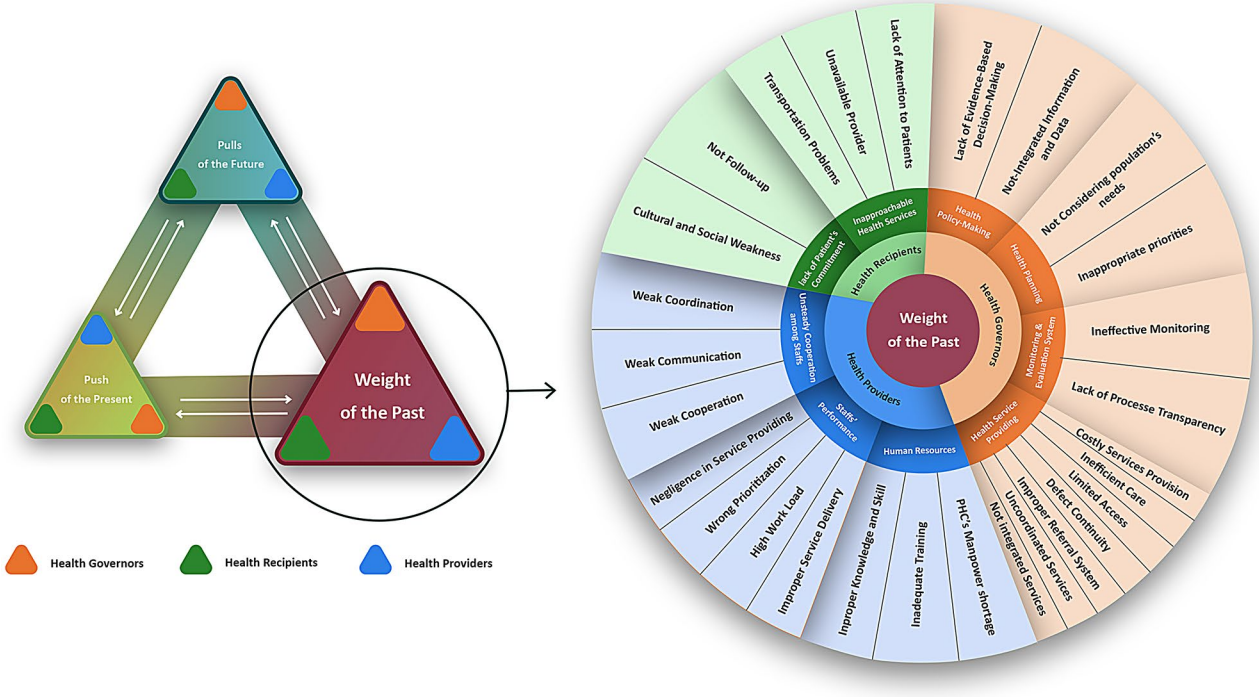

Fig. 5 Weights of the Past (WP): Challenges of Iran's PHC system

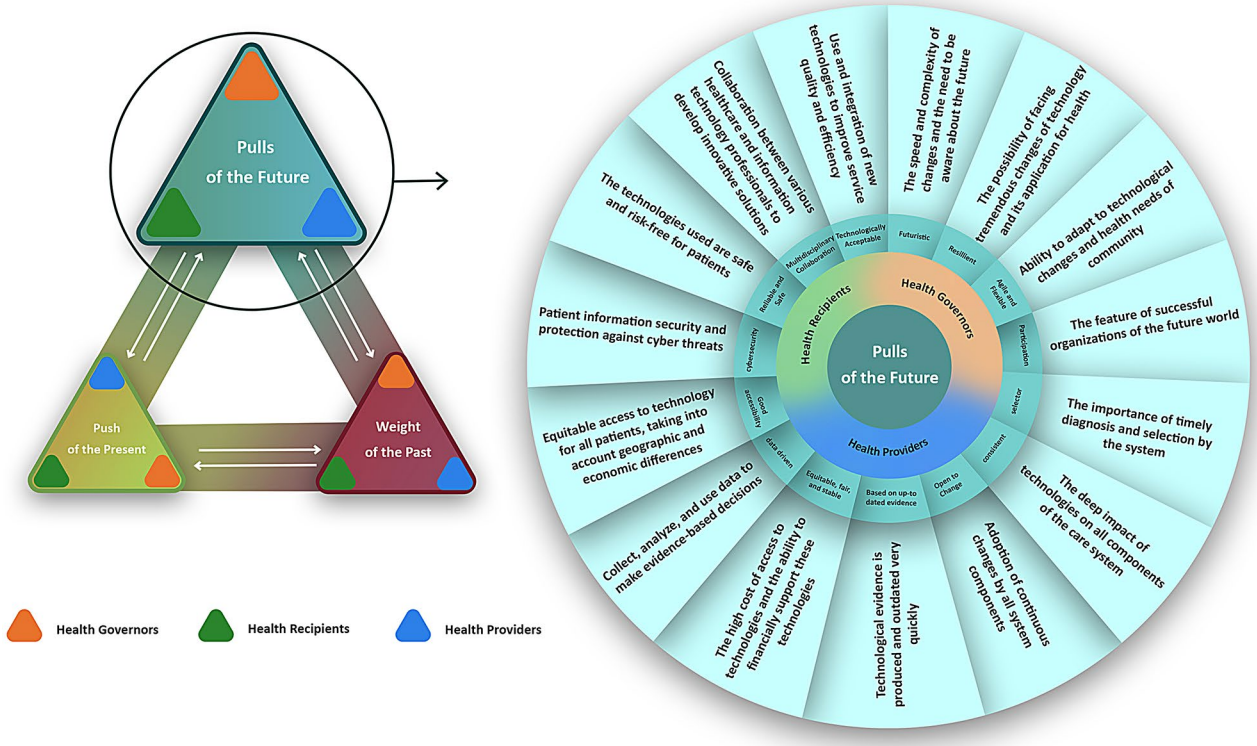

Fig. 6 Pulls of the Future (PF): Features of the future image of an intelligent PHC system

unclear, and there is no consensus on its characteristics [1, 70].

Discussion

AI is rapidly shaping an ambiguous future of the Primary Health Care (PHC) system, characterized by both promising and challenging possibilities for all stakeholders involved. In line with the primary aim of this study, it endeavored to demonstrate potential future scenarios while underscoring the pivotal roles of the three main stakeholders, health governor (HG), health providers (HPs), and health recipients (HRs). By developing a conceptual framework based on the future triangle (FT) and health systems governance (HSG), it has been possible to envision a future filled with possibilities, shaped by the interactions among the three dimensions of the FT. To enhance sensitivity among stakeholder groups, optimistic and pessimistic scenario approaches were employed to articulate these divergent states. One can imagine a future in which Iran's PHC system evolves toward either the "Utopia of Intelligent PHC" or the "Dystopia of Intelligent PHC," situated at opposite ends of a spectrum of possibilities. The interactions and impacts of the dimensions of a desirable future image, coupled with how past challenges are addressed and current trends are managed, will ultimately determine the trajectory of this system toward one of these scenarios.

Pessimistic scenario: dystopia of intelligent PHC

In this scenario, each component of the FT experiences misalignment and unbalanced development across the roles of HG, HPs, and HRs. Stakeholders within the PHC lack a clear vision of future goals and perspectives, resulting in obscured future projections. The absence of a common language for envisioning the future exacerbates discoordination, redundancy, and even conflict among system stakeholders. Under these conditions, activities tend to be sporadic, routine, and scattered, lacking a long-term perspective. Governors and managers engage superficially and temporarily in addressing past challenges, without implementing systematic improvements or exercising effective control. This scenario perpetuates several issues, including weaknesses in the referral and family doctor systems, a lack of evidence-based decision-making, neglect of essential community health needs, uncoordinated health service delivery, poor intersectoral collaboration, excessive workloads for providers, inadequate follow-up on the health status of service recipients, and a disregard for community needs. As news of AI applications in PHC systems and the benefits they can offer becomes more frequent, the absence

of a thorough analysis of these effects and a preparedness plan for adapting to new conditions fosters anxiety, stress, and fear regarding the future. In this context, there is no clear strategy for assessing, confronting, utilizing, and monitoring AI in PHC. Related technologies are employed disproportionately and inconsistently, often driven by the notion that "newer is better," which leads to further challenges within the PHC system. Consequently, the weight of the past hinders the positive development of AI for the benefit of all stakeholders, while the pull of the future fails to provide sufficient motivation to alleviate this burden.

Optimistic scenario: utopia of intelligent PHC

In this scenario, balanced growth is observed across each dimension of the FT, fostering harmony among all stakeholders. HGs, HPs, and HRs possess a clear and comprehensible vision of the future along with its associated goals and perspectives. This shared vision among stakeholders reflects specific the distinctive characteristics of an AI-enabled PHC system and establishes a consensus on the pathway to achieve these objectives. Consequently, this path is navigated through collaboration, coordination, and support from all parties involved. Under these conditions, activities are organized, cohesive, and directed toward long-term goals. News regarding the impacts of AI stimulates curiosity and promotes the deliberate application of AI in alignment with the functions of the PHC system. HG, while considering the role and needs of the system, HPs and HRs, adopt development strategies that leverage AI capabilities to continuously enhance the system, effectively managing and addressing deep-rooted challenges. In this scenario, all stakeholders reap the benefit of AI, including comprehensive and high-quality services, that are coordinated and tailored to meet needs, along with systematic and integrated monitoring and control. Additionally, this approach facilitates early prevention, timely and accurate disease diagnosis, and effective care and treatment. A specific mechanism is established for the timely identification, monitoring, assessment, and integration of new AI-related technologies into the PHC system. AI technologies are utilized based on necessity and with the philosophy that "more effective is better". Past challenges are largely mitigated through a deep and layered approach, along with the conscious and intelligent application of AI, moving the system towards health promotion with the most advanced technologies.

Between these pessimistic and optimistic scenarios lies a spectrum of potential futures, including marginal and adaptive changes. However, these scenarios, with their critical insights, serve as important warnings. The PHC system will progress toward the optimistic scenario if specific key requirements are addressed, whereas neglecting these requirements will drive it toward the pessimistic scenario. It is crucial to adopt a realistic perspective regarding the current state of Iran's PHC. The analysis of Iran's technological readiness for AI reveals significant technological, financial, and infrastructural barriers. These challenges include financial difficulties, a lack of sustainable financing models, inequitable resource distribution, insufficient national consensus on AI, inadequate information systems, macro-executive infrastructure deficiencies, organizational culture barriers, and ineffective motivational mechanisms, all of which hinder effective functioning [71–73]. Therefore, it is essential to implement measures that promote advancement toward the optimistic scenario. These measures include:

- Developing a deep and layered understanding of PHC challenges among policymakers to provide tailored solutions leveraging AI capabilities.
- Prioritizing innovative preventive and health promotion initiatives by policymakers, engaging the private sector and non-governmental organizations in these investments.
- Establishing health policy adjustments, including regulatory frameworks and ethics committees, to facilitate AI adaptation in PHC.
- Formulating integrated long-term and short-term plans for AI utilization to effectively manage PHC challenges and achieve a desirable future.
- Implementing legal mechanisms and guidelines to support AI technology adoption and accessibility in PHC settings.
- Building a repository of early case studies or real-world examples on the application of AI in PHC, in each country, highlighting the barriers encountered, and the successful implementation practices.
- Identifying and monitoring advancements in AI for necessary integration within the PHC system to enhance health service delivery.
- Introducing innovative mechanisms to raise awareness among system stakeholders, preparing them for future technological changes.
- Empowering managers and employees with training programs on AI opportunities and application mechanisms in PHC.
- Educating the public on the benefits of AI-based care to reduce resistance and improve access to these services.
- Addressing justice, accountability, and service quality concerns in developing AI-based service provision models.
- Developing sustainable financing mechanisms for AI-driven care and introducing appropriate payment mechanisms in the new PHC system.

- Strengthening information systems to maximize AI opportunities within the PHC system.
- Promoting cultural and social interventions to prepare the public for the integration of AI in PHC.

This study provides a roadmap for the future of the AI-based PHC system in Iran, incorporating a three-dimensional perspective that considers the future, present, and past for HG, HPs, and HRs. Despite this approach, numerous challenges associated with the application of AI must be addressed. It is essential to recognize that AI serves as a tool that can enhance service provision, though its implementation is accompanied by several challenges. Specifically, ethical and social concerns may arise, including bias and inequality in AI models, ethical and privacy issues, and data quality and integration challenges [57, 74–76]. These issues can undermine public trust in AI [77, 78] and hinder its feasibility in PHC. Addressing these challenges requires a multidimensional approach involving stakeholders [76, 79] to develop robust cybersecurity measures, ethical guidelines, and legal frameworks for responsible AI implementation in PHC systems [80, 81]. Several international organizations, including the WHO, the European Commission, and the OECD, have outlined ethical principles, practical advice, and clear guidance for AI in health systems [82–85]. These resources support AI technology developers, health ministries, and providers in mapping AI's benefits and challenges, enabling them to keep pace with rapid changes in this field.

To the best of our knowledge, this study is the first to provide a comprehensive vision of Iran's PHC future in AI implementation, considering perspectives from three main stakeholders. Prior studies have highlighted the powerful role of technology in reshaping Iran's health system [1, 86], consistent with Kueper's research emphasizing AI's potential in addressing PHC challenges [87]. Raising awareness and preparing for AI's benefits while minimizing adverse effects is critical [88] considering past, present, and future conditions. In this regard, Fergnani visualized four future scenarios of medical operations based on the FT and the "2 × 2 Intuitive Logic Scenario Planning" [36], while Fan et al. analyzed the Singapore Emergency Medical Association's future using the FT [89].

This study addresses an essential and timely topic in health by synthesizing the future expectations, past challenges, and present AI impacts in Iran's PHC system for three main stakeholders. Presenting an innovative model for integration and analysis, this research offers optimistic and pessimistic scenarios for Iran's primary care. However, this study has limitations. Primarily focused on Iran's PHC, the findings may have limited generalizability to other countries with different healthcare systems, regulations, and cultural contexts. Nonetheless, we have drawn future PHC expectations in alignment with global health objectives [90, 91]. Noting that many challenges in Iran's system are shared globally [90, 92], and AI impacts are relevant across various PHC systems [26, 57]. The proposed framework can serve as a methodological tool for future studies in diverse settings. Still, the specific context of each country influences its effective application. Secondly, the rapid evolution of AI technologies may render findings outdated as innovations emerge, altering the primary care landscape. Ongoing research is essential to keep the framework and scenarios updated based on AI advancements in PHC. The limited literature search expedited the research process but may have excluded relevant studies. Future studies should conduct more comprehensive reviews. The reliance on qualitative data limits the generalizability of the findings; future studies could measure AI adoption rates and conduct economic analyses for cost-effectiveness. Lastly, input from disciplines beyond healthcare, such as ethics, law, and technology, is crucial for understanding AI's implications fully. Future studies should engage interdisciplinary teams to address AI's multifaceted challenges in primary care and develop holistic solutions.

Conclusion

This study contributes to clarifying the future roadmap of AI integration in Iran's PHC system and raises stakeholder awareness of this emerging technology. By developing a conceptual framework for integrating and analyzing the collected evidence, we formulated optimistic and pessimistic scenarios based on future expectations, past challenges, and present impacts of AI within Iran's PHC system, considering three primary stakeholders. From our perspective, the critical question now is how to best shape and direct the efforts to optimize the current performance of PHC systems in the development and application of AI technologies. In this regard, we recommend establishing legal frameworks and guidelines, implementing targeted training for stakeholders—particularly HPs—, engaging interdisciplinary teams to address the AI's multifaceted challenges, and developing long-term and short-term implementation strategies aligned with the future vision and roadmap.

Abbreviations

AI	Artificial Intelligence
PHC	Primary Health Care
HSG	Health Systems Governance
FT	Future Triangle
WP	Weights of the Past
PP	Push of the Present
PF	Pulls of the Future
HG	Health Governor
HP	Health Provider
HR	Health Recipient

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions
RD, as the supervisor of the study, managed meetings with experts and futurists, contributing to the gathering, analysis, categorization, and interpretation of information related to the first dimension of the model (PF). Additionally, he conceptualized and interpreted the two scenarios presented in the study, overseeing the writing and revision of the manuscript. SI, the developer of the "Future Triangle" model and its associated scenario planning, played an advisory role in guiding the development of the conceptual framework and the design of the scenarios. FY, as the corresponding author, was responsible for the overall study and framework design, including the conceptualization of the model. She also prepared and revised the main manuscript, contributing to the searching, gathering, analyzing, categorizing, and interpreting of information related to the study's two dimensions (PF, WP, and PP). MN contributed by searching, gathering, analyzing, categorizing, and interpreting information relevant to the WP and PP dimensions, as well as providing the tables and figures for the study. All authors were involved in the editing and revision of the manuscript.

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Data availability
Generated and analyzed data related to the interviews (PF) are not publicly available due to confidentiality agreements and the privacy of interview participants but are available from the corresponding author on reasonable request. Additionally, the data related to reviewing the documents and the literature review (WP and PP) are available within the published article.

Declarations

Ethics approval and consent to participate
The study design was approved by the Research Ethics Committees of Kerman University of Medical Sciences (Approval ID: IR.KMU.REC.1402.182). The study only focused on the experts' professional views, not including sensitive personal data. The participants were informed before filling out the questionnaire both in writing and verbally on the following topics: the purpose of the project and why they were asked to participate, that their participation was voluntary and could be ended at any time without having to state any reason, that when the results were made publicly available it would not be possible to identify individuals, that no unauthorized persons would be able to access the questionnaire data. The participants were given time to ask questions and were then asked to provide informed consent concerning their participation before any data collection. We confirm that no experiments were conducted on humans or human tissue samples, and all data used in this study were collected in accordance with the relevant ethical guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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