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REVIEW PAPER

HEALTH INFORMATION SCIENCE

Emerging Healthcare Systems with AI based Medicine, EHRs, VHAs, & Precision Healthcare: *A Scientific Study*

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ABSTRACT

Digital healthcare signifies a groundbreaking shift in the way we access and manage medical services. This exciting new phase marries healthcare with state-of-the-art digital technologies, creating a vibrant era of patient-centered, data-driven care. Imagine a world where mobile health apps, telemedicine, electronic health records (EHRs), artificial intelligence (AI), machine learning (ML), cloud computing, and the Internet of Medical Things (IoMT) come together to redefine our health journeys. At its core, precision healthcare thrives on the synergy of varied biological and clinical data. The power behind this movement is fueled by key advancements like genomic sequencing, molecular imaging, electronic health records (EHRs), and artificial intelligence (AI) algorithms. Healthcare 5.0 adopts a comprehensive view of health, recognizing the crucial connections between mental, physical, and emotional wellness. With the help of wearable sensors tracking vital signs and virtual health coaches guiding personal wellness journeys, patients enjoy continuous support tailored to their specific lifestyles and needs. This Paper is about Digital Healthcare systems and specially focused on applications of ICT in healthcare domain, paper highlighted some of the emerging aspects viz. AI based Healthcare, Precision Healthcare, Healthcare 5.0, Virtual Health Assistant, and so on.

Keywords: Digital Healthcare, Healthcare Informatics, ICT in Healthcare, EHRs, Precision Healthcare, Sustainable Healthcare, AI in Healthcare, VHAs

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In our increasingly digital environment, this innovative approach leads to swifter diagnoses, more timely treatments, and greater access to healthcare—an absolute game-changer for individuals in remote or underserved areas. The blend of digital technology with traditional healthcare practices not only promises to elevate the quality of care we receive but also empowers us as patients to take charge of our own health journeys[2],[22]. Core Components of the Digital Healthcare Ecosystem are include—

- ***Electronic Health Records (EHRs)-***EHRs play a pivotal role in streamlining data sharing among healthcare providers, making coordinated care smoother and minimizing administrative hiccups. With real-time access to vital information like medical histories, prescriptions, allergies, and lab results, clinicians can make informed and precise decisions for your care[3],[13].
- ***Telemedicine and Remote Consultations—***Telemedicine stands out as one of the most transformative innovations, breaking down barriers between doctors and patients through virtual consultations. This is especially crucial for those in rural or isolated regions, where access to medical facilities can be a significant challenge.
- ***Wearable Devices and the Internet of Medical Things (IoMT)—***Think of smartwatches, fitness trackers, and connected health monitors—they're not just gadgets; they continually gather crucial health metrics such as heart rates, blood oxygen levels, and sleep patterns. These devices form the backbone of the IoMT, relaying real-time health data to doctors, which allows for timely detection of potential issues and proactive intervention[5],[12],[26].
- ***Artificial Intelligence and Machine Learning—***AI and ML are revolutionizing the interpretation of complex medical data—from analyzing X-rays to predicting potential disease outbreaks. These groundbreaking technologies significantly enhance personalized medicine, facilitate early diagnoses, and accelerate drug development, improving both the speed and accuracy of medical decision-making.
- ***Patient Engagement Platforms—***With digital portals at our fingertips, managing appointments, accessing test results, receiving reminders, and even consulting with mental health professionals has never been easier! These platforms nurture a sense of ownership and engagement, which is vital for effective long-term health management and positive behavior change[10],[51].

Digital healthcare is here to transform our lives for the better and there are many beneficiaries as depicted in Fig. 1, making the journey towards wellness an exciting adventure!

OBJECTIVE

The Paper entitled 'Emerging Healthcare Systems with AI based Medicine, EHRs, VHAs, & Precision Healthcare: *A Scientific Study'* is carried with the following aim and objective—

1. To know about the basics of Emerging aspects of Healthcare Sciences in respect of Information and Communication Technology.
2. To learn about the existing works on Health Informatics leading to AI based Medicine, VHAs, EHRs & Precision Healthcare including sustainable healthcare systems.

3. To learn about the Artificial Intelligence applications in Healthcare and Medical Science domain and allied fields.
4. To know about the Electronic Health Record and Virtual Health Assistant in contemporary Healthcare Scenario.
5. To learn about the challenges and issues of Latest Healthcare Informatics practices specially above mentioned topics.

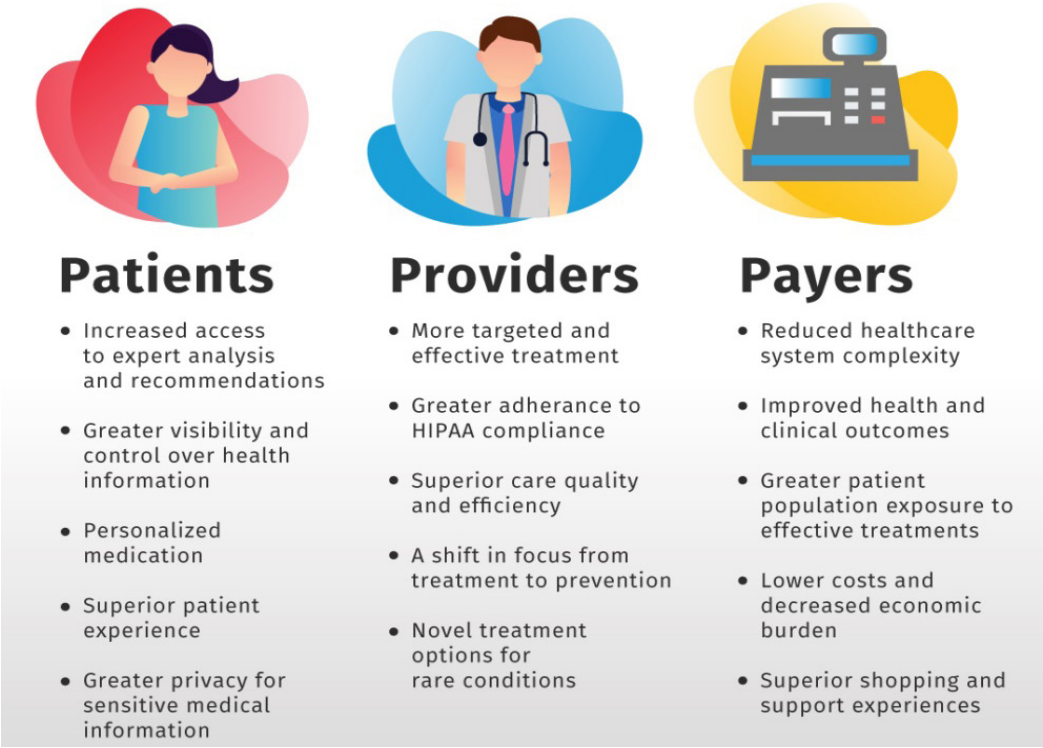

Fig. 1: Major benefeciaries of Digital Healthcare (**Source:** Hitachi Health)

METHODS

This study, 'Emerging Healthcare Systems with AI based Medicine, EHRs, VHAs, & Precision Healthcare: *A Scientific Study'* is conceptual and entirely theoretical in nature and thus entirely prepared based on existing works appeared in books, journals, edited volumes, conference proceedings, and so on. All the works scientifically analyzed and reported here in different sections.

EXISTING WORKS

There are several work related to the topic 'Emerging Healthcare Systems with AI based Medicine, EHRs, VHAs, & Precision Healthcare: *A Scientific Study'* already been conducted and here some of them are listed alphabetically as under:

Alami, H. *et al.* (2022),[6] The report advocates for legislative measures to rectify these gaps, highlighting

the necessity for inclusive digital health policies that emphasize underprivileged communities. The authors assert that virtual care must be integrated judiciously to prevent exacerbating social disparities in healthcare access.

Al-Assaf, K., Bahroun, Z., & Ahmed, V. (2024),[7] However, obstacles such as cybersecurity risks, data privacy concerns, and interoperability issues among different healthcare systems are highlighted. The report underlines the necessity for solid regulatory frameworks to ensure ethical and secure deployment. The authors conclude that while Healthcare 4.0 has enormous potential, its success depends on addressing technical, ethical, and policy-related hurdles.

Cambaza, E. (2023),[16] A significant focus is on how microfinance solutions help low-income populations afford healthcare services. Challenges such as legislative loopholes, cybersecurity threats, and digital literacy restrictions are mentioned. The study indicates that while FinTech offers considerable potential to improve healthcare accessibility and sustainability, coordinated policy initiatives are important to achieve equal adoption and long-term impact.

Chengoden, R. *et al.* (2023),[17] The paper suggests prospective research opportunities, including AI-driven avatars for individualized patient care and decentralized data management. The authors conclude that while the metaverse holds enormous promise for healthcare, important infrastructural and ethical problems must be addressed for widespread use.

Gagnon, R.J. (2022),[23] The author considers crucial issues such as financial management, personnel development, and technological adoption as critical to the success of home-based care models. The report identifies problems including staff shortages, regulatory compliance issues, and limited reimbursement methods for home healthcare services. Case studies highlight successful techniques, such as the incorporation of telemedicine to save costs and enhance patient outcomes. The study indicates that home healthcare sustainability depends on balancing cost effectiveness with high-quality patient-centered care, underlining the need for creative business models and regulatory assistance.

Hossain, Z. *et al.* (2024),[30] A important discussion is the change from fee-for-service models to outcome-based reimbursement systems, which promote quality over quantity. Challenges such as high implementation costs, data privacy concerns, and regulatory hurdles are addressed. The study indicates that sustainable healthcare expansion involves a balance between technology advancements and ethical issues, pushing for coordinated efforts among stakeholders.

Ibrahim, M. *et al.* (2025),[31] the report underlines the necessity of encryption, blockchain, and AI-driven threat detection in securing patient data. Challenges like as resistance to change, high implementation costs, and compatibility concerns are mentioned. The report indicates that a comprehensive cybersecurity framework is crucial for sustainable EHR adoption, arguing for continued developments in security technologies.

Krahe, M.A., Larkins, S.L. & Adams, N. (2024),[41] the study also underlines the impact of government policies in creating digital health strategy. The authors conclude that while Australia has achieved substantial progress in digital health adoption, continuous research and policy refinement are necessary to address accessibility and ethical concerns.

Malviya, R. *et al.* (2025),[44] Digital Blockchain: Big Data, Artificial Intelligence, and Virtual Reality in Healthcare Ecosystem. This book analyzes the convergence of blockchain, big data, AI, and virtual reality (VR) in healthcare, stressing their cumulative potential to boost security, efficiency, and patient

involvement. The authors explore blockchain's function in maintaining data integrity, AI's applications in predictive diagnostics, and VR's impact on medical training and remote patient care. The paper highlights important issues such as data interoperability, ethical considerations, and the high cost of deployment. The authors suggest that a well-integrated digital ecosystem can increase healthcare accessibility and efficiency, but underline the need for regulatory control and ethical frameworks to avoid dangers.

Mathura, P. *et al.* (2024),[46] The authors conclude that virtual home hospitals have the potential to change healthcare delivery, but require careful planning, investment, and policy alignment for successful deployment.

Mishra, P. & Singh, G. (2023),[50] Internet of Medical Things Healthcare for Sustainable Smart Cities: Current Status and Future Prospects. Key obstacles include data security hazards, interoperability issues, and regulatory concerns. The paper identifies various solutions, including blockchain for safe data exchange and AI for predictive healthcare analytics. The authors suggest that IoMT can considerably enhance urban healthcare systems but requires sufficient infrastructure and legal frameworks for widespread use.

Yenduri, G. *et al.* (2023),[73] Key concerns include high implementation costs, regulatory uncertainties, and cybersecurity threats. The survey highlights new research fields such as AI-powered virtual health assistants and blockchain-secured medical records. The authors conclude that while the metaverse has the potential to better healthcare delivery, its widespread acceptance depends on technology advancements, ethical considerations, and legislative development.

Zeng, Y. *et al.* (2024),[75] The paper highlights problems such as computer literacy among older persons, accessibility limitations, and ethical concerns with AI-driven healthcare. The authors propose legislative solutions, including government subsidies for digital health devices and tailored educational initiatives for senior folks. The study finds that digital healthcare technologies can considerably increase geriatric care but require a patient-centered strategy to achieve inclusivity and efficacy.

AI BASED PRACTICES IN HEALTHCARE SYSTEMS

AI is transforming both vaccine development and predictive analytics in healthcare, making processes faster, more efficient, and data-driven. And there are several health benefits of AI based Healthcare as depicted in Fig. 2 (Source: TechTarget).

AI-Driven Vaccine Development

- Accelerated Drug Discovery: AI models analyze vast datasets to identify potential vaccine candidates, significantly reducing development time.
- Optimized Clinical Trials: AI helps design smarter trials by predicting patient responses and optimizing participant selection[4],[25].
- Real-Time Monitoring: AI tracks clinical trial data, ensuring safety and efficacy while expediting regulatory approvals.
- Vaccine Distribution Strategies: AI-powered models optimize logistics, ensuring equitable vaccine distribution.

Predictive Analytics in Healthcare

- Early Disease Detection: AI analyzes electronic health records (EHRs), medical imaging, and wearable device data to predict diseases before symptoms appear.
- Personalized Treatment Plans: AI tailors treatments based on genetic profiles, improving patient outcomes.
- Hospital Resource Optimization: AI forecasts patient surges, helping hospitals allocate resources efficiently[9],[37].
- Epidemiological Surveillance: AI tracks infection patterns, predicts outbreak hotspots, and assists in vaccine planning.

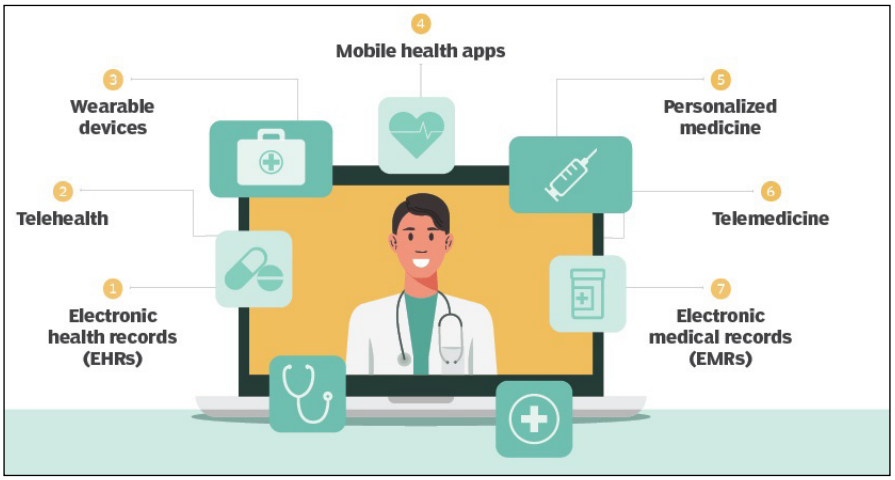

Fig. 2: Some of the application zones of AI based Healthcare

AI APPLICATIONS AREAS IN HEALTHCARE

AI is revolutionizing healthcare by making it more proactive and precise and there are other areas also opening up (as mentioned in Fig. 3, *source Datafalir*).

Breast Density Classification

Breast density classification is an important aspect of mammography, as it helps assess the amount of fibroglandular tissue relative to fat in the breast. The BI-RADS (Breast Imaging Reporting and Data System) classifies breast density into four categories:

- **Almost entirely fatty** – The breast consists mostly of fat, making abnormalities easier to detect.
- **Scattered areas of fibroglandular density** – Some dense tissue is present, but it does not significantly obscure mammographic findings.

- **Heterogeneously dense** – A considerable amount of dense tissue is present, which may obscure small masses.
- **Extremely dense** – The breast is predominantly dense, reducing the sensitivity of mammography and making cancer detection more challenging[11],[28].

Dense breast tissue is common and can be influenced by factors such as genetics, age, and hormone therapy. Women with dense breasts may require additional screening methods, such as ultrasound or MRI, to improve cancer detection. Breast density is a significant factor in breast cancer risk and screening effectiveness. Women with dense breasts have a higher proportion of fibroglandular tissue, which can make it harder to detect tumors on mammograms. Studies indicate that the denser the breast, the greater the risk of developing breast cancer[1],[7]. Impact on Cancer Risk is as follows—

- Increased Risk: Women with extremely dense breasts have a 1.83 times higher risk of developing breast cancer compared to those with low-density breasts.
- Challenges in Detection: Dense tissue can obscure tumors, making mammograms less effective in detecting early-stage cancer.

Screening Recommendations regarding AI based Healthcare Systems are as follows for effective healthcare systems—

- Mammography: Still the standard screening method, but its sensitivity decreases with increasing breast density[14],[29],[36].
- Supplemental Screening: Women with dense breasts may benefit from breast MRI or ultrasound, which can detect cancers missed by mammograms.
- Early Screening for High-Risk Groups: The American College of Radiology (ACR) recommends early screening for women with dense breasts and additional risk factors, such as genetic predisposition.

Given the complexities of breast density and cancer detection, personalized screening strategies are crucial. AI-driven breast cancer detection is transforming diagnostics by improving accuracy, efficiency, and accessibility[15],[21],[52]. Here are some emerging methods:

1. AI-Powered Mammography Analysis

AI models, such as those developed by ScreenPoint Medical, MIRAI, and iCAD, enhance mammogram interpretation by detecting calcifications, masses, and architectural distortions. These systems help radiologists identify subtle abnormalities that might be missed in traditional screenings.

2. Risk Assessment Models

AI integrates imaging data with genetic and lifestyle factors to predict long-term breast cancer risks. This enables personalized screening strategies, ensuring high-risk individuals receive early interventions[24],[27].

3. AI-Enhanced Imaging Technologies

Advancements in digital breast tomosynthesis (3D mammography) and deep learning algorithms have improved detection rates while reducing false positives. AI-assisted imaging is becoming a standard in modern breast cancer diagnostics.

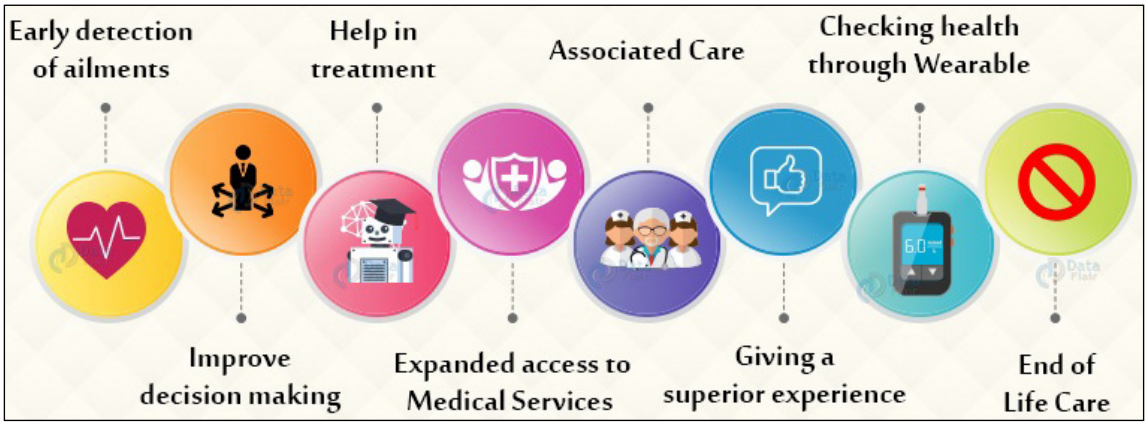

Fig. 3: AI based new age services in Healthcare

4. Chromosomal Analysis for Cancer Detection

Recent research suggests that chromosomal instability plays a role in breast cancer progression. AI-powered analysis of chromosome properties could refine early detection and treatment strategies. AI is revolutionizing breast cancer detection, making screenings more precise and accessible. India faces a growing breast cancer burden, and AI integration is being explored to improve early detection and patient outcomes. AI-driven screening tools could help address disparities in healthcare access[18],[19],[54].

Medical imaging in Healthcare

Medical imaging is a crucial field in healthcare that enables the visualization of internal body structures for diagnosis, treatment planning, and research. It encompasses various techniques, including. Key Medical Imaging Modalities

- X-ray Radiography – Uses X-rays to produce images of bones and tissues, commonly used for detecting fractures and infections.
- Computed Tomography (CT) – Combines X-rays with computer processing to generate detailed cross-sectional images of organs and tissues.
- Magnetic Resonance Imaging (MRI) – Utilizes strong magnetic fields and radio waves to create detailed images of soft tissues, such as the brain and muscles.
- Ultrasound Imaging – Employs high-frequency sound waves to visualize organs, commonly used in prenatal screenings and cardiac assessments[20],[33].

- Positron Emission Tomography (PET) – Uses radioactive tracers to assess metabolic activity, aiding in cancer detection and neurological studies.
- Fluoroscopy – Provides real-time moving images of internal structures, often used in procedures like angiography.
- Hybrid Imaging (PET-CT, PET-MRI) – Combines multiple imaging techniques to enhance diagnostic accuracy.

Medical imaging plays a vital role in early disease detection, treatment monitoring, and surgical planning. Advances in AI and machine learning are further improving image analysis and interpretation. AI-driven medical imaging is transforming diagnostics and treatment planning by enhancing accuracy, efficiency, and accessibility[32],[39],[43]. Here are some key advancements:

1. AI-Powered Image Analysis

AI models, particularly deep learning algorithms, improve medical image interpretation by detecting subtle abnormalities that might be missed by human radiologists. These systems enhance diagnostic precision in detecting conditions such as cancer, neurological disorders, and cardiovascular diseases.

2. Automated Image Segmentation

AI assists in segmenting medical images, identifying structures like tumors, blood vessels, and organs with high precision. This capability is crucial for surgical planning and targeted therapies. AI is integrated into various imaging techniques, including MRI, CT, PET, and ultrasound, to improve image clarity and resolution. AI-driven enhancements help reduce noise and artefacts, leading to more reliable diagnoses.

AI in Radiomics & AI for Workflow Optimization

Radiomics, an emerging field, uses AI to extract quantitative features from medical images, aiding in disease characterization and prognosis. AI-driven radiomics is particularly useful in oncology for predicting tumour behavior and treatment response. AI streamlines radiology workflows by automating routine tasks, reducing interpretation time, and minimizing errors. This efficiency allows radiologists to focus on complex cases and improves overall healthcare delivery[34],[38]. AI is revolutionizing medical imaging, making diagnostics more precise and accessible.

AI BASED ELECTRONIC HEALTH RECORD

An Electronic Health Record (EHR) is a digital version of a patient's medical history, designed to streamline healthcare delivery by storing and sharing health information electronically. EHRs contain demographics, medical history, medications, allergies, immunization records, lab results, radiology images, and billing information. Key Benefits of EHRs:

- Improved Accessibility – Healthcare providers can access patient records instantly, reducing paperwork and enhancing efficiency.

- Enhanced Coordination – EHRs facilitate seamless communication between different healthcare providers, improving patient care.
- Data Security & Privacy – Modern EHR systems incorporate encryption and access controls to protect sensitive patient data.
- Reduced Errors – Digital records minimize prescription errors and improve diagnostic accuracy[40],[42].
- Population Health Insights – EHRs enable data-driven healthcare decisions, helping identify disease trends and improve public health strategies.

Challenges in EHR Implementation

- Interoperability Issues – Different healthcare systems may struggle to exchange data efficiently.
- Data Privacy Concerns – Ensuring compliance with regulations like HIPAA and GDPR is critical.
- High Implementation Costs – Transitioning from paper records to EHRs requires significant investment.

EHRs are transforming healthcare by making patient data more accessible, secure, and actionable. AI-driven advancements in Electronic Health Records (EHRs) are transforming healthcare by improving efficiency, interoperability, and patient care[35],[55].

AI-Driven EHR Advancements

- Automated Data Entry & Documentation – AI-powered systems reduce administrative burdens by automatically transcribing physician notes and updating patient records.
- Predictive Analytics for Patient Care – AI analyzes EHR data to predict disease progression, enabling early interventions and personalized treatment plans.
- Interoperability Improvements – AI enhances data exchange between different healthcare systems, ensuring seamless access to patient records across institutions.
- Enhanced Security & Privacy – AI-driven cybersecurity measures protect sensitive patient data from breaches and unauthorized access[45],[56].
- Clinical Decision Support – AI integrates with EHRs to provide real-time recommendations, assisting physicians in making informed treatment decisions.

Regulatory Frameworks for AI in EHRs are include HIPAA (USA) – Ensures patient data privacy and security in AI-powered EHR systems, GDPR (EU) – Regulates AI-driven healthcare data processing to protect patient rights. FDA & EMA Guidelines i.e. Oversee AI-based medical applications are to ensure compliance and ethical use. AI is revolutionizing EHRs by making healthcare more efficient, secure, and data-driven.

PRECISION HEALTHCARE: EMBRACING PRECISION HEALTHCARE: A TRANSFORMATIVE LEAP IN MODERN MEDICINE

Precision healthcare, often known as precision medicine, marks an exciting new chapter in the world of clinical practice. This innovative approach aims to customize medical care based on the distinct genetic, environmental, and lifestyle factors specific to each patient. Moving away from the outdated "one-size-fits-all" approach that has long been prevalent, precision healthcare harnesses cutting-edge technologies to craft personalized preventive, diagnostic, and treatment strategies. This not only elevates clinical outcomes but also helps minimize potential side effects[18].

Core Principles and Technological Foundations

There are many reasons for the development of Precision Healthcare and these essential tools empower healthcare professionals to create comprehensive patient profiles. As a result, clinicians can better predict disease risk, tailor treatment plans, and closely monitor how effective those treatments are with unprecedented accuracy[10]. One of the most remarkable advancements can be seen in the oncology sector. With the advent of tumor genome profiling, cancer specialists can pinpoint specific genetic mutations and select targeted therapies that are more likely to lead to positive treatment outcomes[47],[58]. This personalized approach significantly reduces reliance on the traditional trial-and-error methods in cancer treatment, ultimately enhancing patient survival rates[24].

Emerging Applications: From Pharmacogenomics to Wearable Technologies

Pharmacogenomics plays a crucial role in precision healthcare by studying how genetic differences influence drug metabolism and effectiveness. This insight enables the development of medication plans that are not only safer but also more effective, thereby reducing harmful drug reactions and improving patient adherence to treatment[66]. Moreover, the rise of wearable biosensors and remote monitoring technologies has revolutionized health tracking in real-time[48],[62]. These advancements allow for timely interventions and foster an ongoing feedback mechanism that can adapt treatment paths dynamically[70]. AI-driven predictive models are also becoming a staple in routine healthcare. By sifting through vast amounts of data, these models can predict an individual's risk of developing chronic conditions such as diabetes or heart disease, often years before any clinical signs appear. This remarkable predictive power highlights the preventive potential of precision healthcare and emphasizes the shift towards proactive care methodologies[60]. By embracing these innovations, the healthcare landscape is on the cusp of a thrilling transformation—one that promises to enhance patient care and redefine how medical treatments are delivered in the future.

Challenges and Considerations

Precision healthcare holds immense promise for transforming the way we approach medicine, but it also brings with it a slew of practical and ethical hurdles that we must navigate carefully. The high costs linked to genetic testing and data analysis stand as a major obstacle to how widely we can implement these groundbreaking advancements, especially in areas with limited resources[49],[64],[65]. There are also pressing concerns about data privacy and the ethical implications of using genetic information that could

lead to discrimination based on genetic risk factors. These issues require immediate attention to ensure we move forward responsibly [38]. Additionally, the healthcare community needs to develop standardized protocols for interpreting and utilizing complex biological data. This is crucial to guarantee that our clinical applications are both consistent and reliable.

UNDERSTANDING HEALTHCARE 5.0 & VHAS: THE HUMAN-TECHNOLOGY SYMBIOSIS IN FUTURE HEALTHCARE

Healthcare 5.0 is ushering in an exciting era of change in the medical domain—an era where human compassion meets cutting-edge technology in a brilliant collaboration. Building on the foundations laid by Healthcare 4.0, which focused on digital transformation, automation, and harnessing vast amounts of data, Healthcare 5.0 takes a giant leap forward. It moves beyond mere efficiency to foster a healthcare system that is not only more personal and caring but also more resilient. At the heart of this groundbreaking shift is the spirit of Industry 5.0, which champions the synergy between human insight and technological prowess[59],[62].

Imagine a future where a smart healthcare ecosystem thrives, seamlessly integrating Artificial Intelligence (AI), the Internet of Things (IoT), 5G connectivity, robotics, blockchain technology, and immersive experiences through augmented and virtual reality (AR/VR). In this innovative landscape, healthcare professionals gain unparalleled access to real-time data and intelligent tools, empowering them to provide care that is finely tuned to the unique needs of each patient. This means patients will receive highly personalized care experiences that prioritize both their physical health and emotional well-being. Picture a hospital operating under the principles of Healthcare 5.0. Here, advanced predictive AI algorithms can anticipate the needs of the intensive care unit (ICU), robotic systems handle repetitive nursing tasks, and AR-enhanced surgeries improve precision in treatment—all of this allowing doctors to focus on what truly matters: engaging with their patients on a human level. With digital twin technologies simulating health trajectories, patients and clinicians can collaborate more effectively on treatment plans[61],[71]. One of the most remarkable aspects of Healthcare 5.0 is its emphasis on predictive and preventive care. AI-driven analytics can foresee disease outbreaks, assess individual health risks, and optimize resource distribution within healthcare networks. This proactive approach transforms healthcare from a reactive model into one that not only treats conditions but actively works to prevent them, leading to a healthier and more sustainable system. Moreover, this model is committed to increasing access to healthcare[63],[76]. Through sophisticated telemedicine platforms and AI support, individuals in remote or underserved areas can receive cutting-edge diagnostics and expert consultations, aligning perfectly with the global mission for equitable and inclusive healthcare for all.

Virtual Health Assistant: Basics with Applications

Virtual Health Assistant are applicable in wide range of activities and these areas are emerging (may also refer Fig. 4, *Source: Narola Infotech*) and this include as follows—

- Appointment Management: With the help of chatbots, patients can schedule an appointment, or even cancel and move dates, easily on chatbots.

- Symptom Checkers: They provide preliminary assessments based on symptoms and suggest further action.
- Chronic Disease Support: These chatbots remind patients to take their medication or schedule follow-up visits.
- Mental Health Support: Such chatbots listen to the emotional issues of a user to encourage that user to discuss more serious issues, such as depression or anxiety, without any fear of judgment[66],[74].
- Health Education: They give the user concise and exact information on diseases and preventive measures, helping them be empowered in the knowledge-making process.

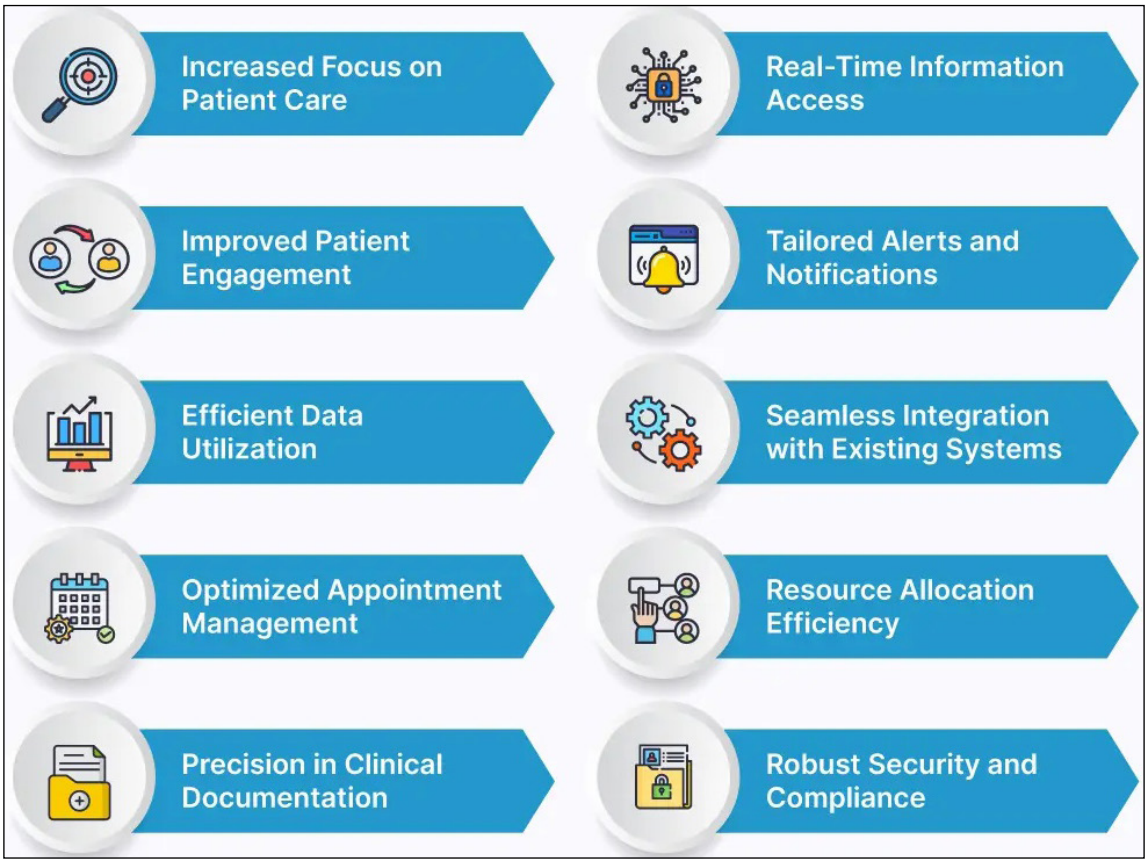

Fig. 4: Advantages of VHAs in Healthcare Systems

CHALLENGES AND LIMITATIONS OF DIGITAL AND EMERGING HEALTHCARE SYSTEMS

In times of global emergencies like the COVID-19 pandemic, we witnessed the remarkable value of digital healthcare tools. Telemedicine, AI-powered triage systems, and remote monitoring not only alleviated the pressure on hospitals but also ensured that patients continued to receive the care they needed. Additionally,

public health surveillance systems harnessed the power of big data analytics to track the spread of the virus, providing crucial insights that informed policy decisions. Despite their advantages, chatbots face several challenges[68],[70]:

- Limited Medical Expertise: Programming algorithms do not feature the fine-tuned judgment of a human specialist and, therefore, give inappropriate diagnoses and ill-fitted recommendations.
- Lack of Empathy: The arrangements made by chatbots imitate human interaction, but they cannot provide the type of emotional bond that is provided by a real person. This deficiency is amplified while dealing with sensitive and life-threatening health issues.
- Data Privacy Concerns: Handling sensitive patient information raises issues with security and compliance with relevant legislation such as HIPAA. Data security must be fully established as the cornerstone of winning consumer trust.
- Technological Constraints: Natural language processing (NLP) errors may cause failure in the understanding of medical queries thus restricting their applicability for chatbots in the most difficult situations[53],[57].

Future Trajectory and Global Outlook

As we look ahead, the horizon is brightly lit by innovations like single-cell sequencing, liquid biopsy diagnostics, and the fascinating integration of multi-omics—bringing together genomics, proteomics, metabolomics, and transcriptomics. These advancements are set to propel the accessibility and effectiveness of precision healthcare to new heights[28]. Moreover, the emergence of AI-driven diagnostic tools will undoubtedly simplify clinical decision-making processes and sharpen our early detection capabilities. As healthcare systems around the world begin to embrace more personalized, predictive, and participatory models, precision healthcare is not just an idea to aspire to; it is becoming a tangible reality woven into the fabric of modern medical practice. We are on the cusp of a transformative era—one characterized by individualized, data-driven care focused on achieving optimal outcomes for every patient. Let's embrace this new landscape with enthusiasm and commitment, ready to redefine healthcare as we know it!

CONCLUDING REMARKS

Deepening contextual understanding, better NLP models, and electronic health records (EHRs) integration to create newer personalized care applications will address a lot of limitations that future chatbots would face. Furthermore, ethical frameworks and regulatory guidelines will be primary for providing safe deployment. In conclusion, there is a lot of capacity for chatbots as virtual health assistants to transform how healthcare gets delivered in many dimensions, including access, efficiency, and patient engagement. Of course, limiting their capabilities should also be relevant to any planned maximization of their impact on the modern healthcare system. Digital healthcare is not merely a technological upgrade; it represents a transformational movement that redefines the dynamics between patients, providers, and data. By merging innovation with genuine empathy, this new healthcare paradigm has the potential to provide personalized, secure, and universally accessible health solutions. As we address challenges through thoughtful policy, education, and technology, digital healthcare is poised to become a vital foundation of global health progress for years to come.

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