Open Access

Review Article

Transforming Healthcare with Artificial Intelligence in Pakistan: A Comprehensive Overview

Laraib Umer, Muhammad Hashim Khan*, Yasar Ayaz**

National Center of Artificial Intelligence, Islamabad, Pakistan, *School of Mechanical and Manufacturing Engineering, Islamabad, Pakistan, **National University of Sciences and Technology Islamabad, Pakistan

ABSTRACT

Artificial Intelligence (AI) is transforming healthcare globally, including in Pakistan. This research journal paper provides an overview of the role and significance of AI in healthcare, ethical considerations, regulatory frameworks, challenges faced by AI healthcare startups, and the current landscape of AI adoption in Pakistan's healthcare system. AI has the potential to revolutionize disease prevention, diagnosis, and treatment by leveraging large healthcare datasets, advanced computational power, and machine learning algorithms. It improves patient outcomes, enhances clinical decision-making, and optimizes healthcare delivery. Globally, AI applications in healthcare encompass medical imaging, clinical decision support, drug discovery, genomics, and remote patient monitoring. AI algorithms accurately diagnose various medical conditions, predict treatment responses, and identify therapeutic targets. Successful AI implementations include combating antimicrobial resistance and improving pediatric healthcare. Ethical considerations in AI healthcare involve bias mitigation, privacy, transparency, and the role of healthcare professionals in shared decision-making. Regulatory frameworks and guidelines are being developed worldwide to ensure safe and responsible AI implementation. Quality criteria for AI-based prediction models focus on performance, interpretability, generalizability, and robustness. Legal and ethical considerations encompass liability, accountability, and the principles of beneficence, autonomy, and justice. In Pakistan, the integration of AI in healthcare can address challenges like limited resources and uneven distribution of healthcare facilities. AI technologies can analyze medical data, diagnose disease outcomes, and personalize treatment plans. The National Center of Artificial Intelligence (NCAI) in Pakistan is crucial in incorporating AI solutions in healthcare through research, innovation, training, and collaboration with healthcare institutions. The prospects of AI in healthcare in Pakistan are promising, with advancements in technology and data availability. Collaboration among stakeholders is essential for research, innovation, and the establishment of ethical frameworks and guidelines. The potential of AI in healthcare can be fully realized by addressing specific healthcare challenges, developing robust AI models, and prioritizing patient safety, privacy, and trust.

Keywords: Artificial intelligence, AI ethics, ChatGPT, Healthcare, NCAI.

How to Cite This Article: *Umer L, Khan MH, Ayaz Y. Transforming Healthcare with Artificial Intelligence in Pakistan: A Comprehensive Overview. Pak Armed Forces Med J 2023; 73(4): 955-963. DOI: https://doi.org/10.51253/pafmj.v73i4.10852*

INTRODUCTION

A. Background of AI in Healthcare

Artificial Intelligence (AI) has emerged as a transformative technology in various domains, including healthcare. AI refers to the simulation of human intelligence in machines that can analyze data, make decisions, and perform tasks without explicit programming. In healthcare, AI has the potential to revolutionize the way we prevent, diagnose, and treat diseases.[1,2]

The use of AI in healthcare is driven by the increasing availability of large healthcare datasets, advancements in computational power, and breakthroughs in machine learning algorithms. AI techniques, such as machine learning, natural language processing, and computer vision, enable healthcare systems to extract valuable insights from massive amounts of data, including electronic health records, medical imaging, genomics, and biomedical literature.[3,4]

B. Significance of AI in improving healthcare outcomes

The integration of AI into healthcare holds immense promise for improving patient outcomes, enhancing clinical decision-making, and optimizing healthcare delivery. AI can assist healthcare professionals in diagnosing diseases at an early stage, predicting treatment responses, and personalizing patient care plans. By analyzing complex data patterns, AI algorithms can identify subtle signs and patterns that may not be evident to human observers, thereby enabling early detection of diseases and improving prognostic accuracy.

Furthermore, AI can facilitate the discovery of new therapeutic targets, the development of precision medicine approaches, and the optimization of drug discovery processes. By analyzing genomic and proteomic data, AI algorithms can identify potential

Correspondence: Dr Laraib Umer, National Center of Artificial Intelligence, Islamabad, Pakistan

biomarkers for specific diseases, allowing for targeted interventions and more effective treatment strategies.[5]

This paper provides a comprehensive overview of AI's role in healthcare globally and specifically in Pakistan. It addresses the transformative potential of AI in improving healthcare outcomes, ethical considerations, regulatory frameworks, challenges faced by AI healthcare startups, and the current landscape of AI adoption in the Pakistani healthcare system. By exploring these areas, it aims to contribute to discussions on leveraging AI to transform healthcare and enhance patient outcomes.

Global Perspective on AI in Healthcare:

A. Overview of AI Applications in Healthcare Worldwide

The integration of Artificial Intelligence (AI) in healthcare has gained significant momentum worldwide. AI applications in healthcare encompass a wide range of areas, including medical imaging, clinical decision support, drug discovery, genomics, and remote patient monitoring. AI algorithms have demonstrated their potential to improve diagnostic accuracy, enhance treatment planning, and optimize healthcare delivery processes.[1]

AI-driven medical imaging technologies, such as computer-aided diagnosis systems, have shown promising results in assisting radiologists with the interpretation of medical images. These systems can detect subtle abnormalities, assist in early cancer detection, and provide quantitative analysis for improved decision-making. Additionally, AI algorithms have been applied to analyze electronic health records (HER s) and extract relevant clinical information to support clinical decision-making and patient management.[1]

B. Impact of AI on Diagnosis and Treatment

The impact of AI on diagnosis and treatment has been remarkable. AI algorithms have shown high accuracy and efficiency in diagnosing various medical conditions, including cancer, cardiovascular diseases, and neurological disorders. For example, deep learning algorithms have demonstrated their ability to detect skin cancer from dermoscopic images with performance comparable to dermatologists. Similarly, AI algorithms have been used to predict treatment responses and disease progression based on patient data, enabling personalized treatment approaches.[6]

Furthermore, AI has facilitated advancements in precision medicine by identifying genomic and proteomic biomarkers associated with specific diseases. By analyzing large-scale genomic datasets, AI algorithms can identify potential therapeutic targets and predict drug responses, leading to the development of targeted therapies and improved treatment outcomes.[7]

C. Examples of Successful AI Implementations in Healthcare

Several successful AI implementations in healthcare have showcased the transformative potential of this technology. One notable example is the application of AI in combating antimicrobial resistance (AMR). AI algorithms can analyze large-scale genomic data to identify AMR genes and predict antibiotic resistance patterns, enabling timely interventions and optimized antibiotic prescribing practices.[7]

AI has also made significant contributions to pediatric healthcare. Machine learning algorithms have been utilized to develop predictive models for children with cleft lip and palate, aiding in early diagnosis, treatment planning, and surgical outcomes.[8] Additionally, AI-driven telemedicine platforms have shown promise in improving access to healthcare services, especially in underserved areas.[9]

Ethical Considerations in AI Healthcare:

A. Ethical Challenges Associated with AI in Healthcare

The integration of Artificial Intelligence (AI) in healthcare brings forth several ethical challenges that need to be addressed. One of the key concerns is the potential bias in AI algorithms, which can lead to discriminatory outcomes in healthcare. Biased algorithms may disproportionately impact certain patient populations, exacerbating existing health disparities. It is crucial to ensure that AI algorithms are trained on diverse and representative datasets to mitigate bias and promote fairness in healthcare.[3]

Another ethical challenge is the issue of privacy and data security. AI algorithms require access to vast amounts of patient data, including sensitive health information. Protecting patient privacy and ensuring the secure storage and transmission of data are essential to maintain patient trust and comply with regulatory requirements.[10]

B. Importance of Transparency and Interpret-Ability in AI Algorithms

Transparency and interpretability are vital aspects of ethical AI implementation in healthcare. AI algorithms should be designed in a way that allows healthcare professionals and patients to understand how decisions are made. Transparent algorithms provide insights into the reasoning behind AI-generated

recommendations or predictions, enabling clinicians to evaluate their validity and make informed decisions.

Explainable AI also plays a significant role in gaining patient trust. When patients can comprehend the logic and processes involved in AI-driven healthcare interventions, they are more likely to feel confident and comfortable with the proposed treatment plans or diagnostic outcomes.[11]

C. Role of Healthcare Professionals in Ethical AI Implementation

Healthcare professionals play a pivotal role in ensuring the ethical implementation of AI in healthcare. They have the responsibility to critically evaluate and validate AI algorithms before integrating them into clinical practice. This includes examining the algorithm's performance, accuracy, and potential biases.

Moreover, healthcare professionals must advocate for patient-centered care and actively engage patients in shared decision-making processes when AI technologies are involved. This collaborative approach helps address ethical concerns related to patient autonomy, consent, and privacy.[12]

Regulatory Frameworks and Guidelines for AI in Healthcare:

A. Overview of Existing Regulations and Guidelines for AI in Healthcare

As the integration of Artificial Intelligence (AI) in healthcare continues to advance, regulatory frameworks and guidelines are being developed to ensure safe and responsible implementation. These regulations aim to address various aspects, including data privacy, algorithm transparency, and patient safety.[13,14] In different regions, such as the United States and Europe, regulatory bodies have issued guidelines to govern the use of AI in healthcare settings. These guidelines provide a framework for developers, healthcare providers, and policymakers to navigate the ethical and legal challenges associated with AI technologies.[13,15,16]

B. Quality Criteria for AI-based Prediction Models

To ensure the reliability and accuracy of AI-based prediction models in healthcare, quality criteria have been proposed. These criteria encompass factors such as model performance, interpretability, generalizability, and robustness. Healthcare organizations and researchers have recognized the importance of continual monitoring and updating of AI algorithms to maintain their clinical effectiveness and safety.[17,18] Compliance with quality criteria helps to improve the trustworthiness and utility of AI models in healthcare decision-making.[18]

C. Legal and Ethical Considerations in AI Implementation

The implementation of AI in healthcare raises various legal and ethical considerations. From a legal standpoint, issues such as liability, accountability, and responsibility come into play. Determining who is responsible for the outcomes of AI algorithms and potential errors or adverse events can be challenging.[16] Clear guidelines and policies are necessary to establish legal frameworks that govern AI usage in healthcare, promoting patient safety and protecting healthcare professionals.[19]

Ethical considerations revolve around the principles of beneficence, autonomy, and justice. The ethical use of AI in healthcare requires transparency in algorithm design, data collection, and decision-making processes. It is crucial to address biases, privacy concerns, and potential unintended consequences that may arise from AI implementation.[20]

Adoption and Significance of AI in Pakistan's Healthcare System

The healthcare system in Pakistan faces numerous challenges, including limited resources, uneven distribution of healthcare facilities, and a shortage of skilled healthcare professionals. The integration of AI in healthcare presents an opportunity to overcome these challenges and improve healthcare outcomes. AI technologies, such as machine learning and natural language processing, can be used to analyze large volumes of medical data, assist in diagnosis, predict disease outcomes, and personalize treatment plans. By automating repetitive tasks, AI can also reduce the burden on healthcare professionals and improve efficiency in healthcare delivery.[8,21]

Table-I: Ethical Considerations in AI Healthcare

Concern	Description
Bias in AI algorithms	AI algorithms may exhibit bias, leading to discriminatory outcomes. Mitigating bias through diverse and representative datasets is crucial for fairness in healthcare.[3]
Privacy and data security	AI algorithms require access to sensitive patient data. Ensuring privacy and data security are essential to maintain patient trust and comply with regulations.[10]
Transparency and interpretability	Transparent AI algorithms enable healthcare professionals and patients to understand decision-making processes. Explainable AI builds patient trust and facilitates informed decision-making.[11]
Role of healthcare professionals	Healthcare professionals are responsible for evaluating AI algorithms and engaging in shared decision-making. Addressing ethical concerns related to patient autonomy, consent, and privacy is essential.[12]

Table-II: Key References on Regulatory Frameworks and Guidelines for AI in Healthcare

Title	Authors/Journal	Year	Summary
European Commission. White Paper on Artificial Intelligence - A European Approach to Excellence and Trust. Brussels: European Commission; 2020.	European Commission	2020	Provides a European perspective on AI in healthcare, emphasizing excellence and trust in AI implementation.
The "inconvenient truth" about AI in healthcare	Panch, T., Mattie, H., Celi, L.A. / npj Digit. Med.	2019	Highlights the challenges and complexities associated with AI in healthcare, including ethical considerations and potential limitations.
Ethics and governance of artificial intelligence for health	World Health Organization	2021	Focuses on the ethics and governance aspects of AI in healthcare, providing guidelines for responsible AI implementation.
Legal and Ethical Consideration in Artificial Intelligence in Healthcare: Who Takes Responsibility?	Naik N, Hameed BMZ, Shetty DK, Swain D, Shah M, Paul R, Aggarwal K, Ibrahim S, Patil V, Smriti K, Shetty S, Rai BP, Chlosta P, Somani BK / Front. Surg.	2022	Explores the legal and ethical considerations surrounding AI in healthcare, particularly addressing the question of responsibility for AI outcomes.
Guidelines and quality criteria for artificial intelligence-based prediction models in healthcare: a scoping review	de Hond, A.A.H., Leeuwenberg, A.M., Hooft, L., et al. / npj Digit. Med.	2022	Provides an overview of guidelines and quality criteria for AI-based prediction models in healthcare, emphasizing model performance, interpretability, and generalizability.
Clinical artificial intelligence quality improvement: towards continual monitoring and updating of AI algorithms in healthcare	Feng, J., Phillips, R.V., Malenica, I., et al. / npj Digit. Med.	2022	Discusses the importance of continual monitoring and updating of AI algorithms in healthcare to ensure clinical effectiveness and safety.
A systematic review of trustworthy and explainable artificial intelligence in healthcare: Assessment of quality, bias risk, and data fusion	A.S. Albahri, Ali M. Duhaim, Mohammed A. Fadhel, Alhamzah Alnoor, Noor S. Baqer, Laith Alzubaidi, O.S. Albahri, A.H. Alamoodi, Jinshuai Bai, Asma Salhi, Jose Santamaría, Chun Ouyang, Ashish Gupta, Yuantong Gu, Muhammet Deveci / Information Fusion	2023	Presents a systematic review of trustworthy and explainable AI in healthcare, assessing quality, bias risk, and data fusion aspects.
The ethics of algorithms: Mapping the debate	Mittelstadt, B.D., Allo, P., Taddeo, M., et al. / Big Data Soc.	2016	Maps the ethical considerations and debates surrounding algorithms, providing insights into the broader ethics of AI in healthcare.

A. Achievements and Benefits of AI in Healthcare in Pakistan

Research studies conducted in Pakistan have highlighted the achievements and benefits of AI in healthcare. A cross-sectional online survey conducted among doctors and medical students revealed that there is a positive attitude towards AI, with participants recognizing its potential to improve diagnosis, treatment, and patient monitoring.[22] Another systematic review focusing on healthcare students showed that AI education and training programs can enhance knowledge, attitudes, and skills related to AI in healthcare.[23] Moreover, a systematic review on telemedicine in Pakistan highlighted its potential to bridge the gap between healthcare providers and patients, particularly in remote areas, leading to increased access to healthcare services.[24]

B. National Center of Artificial Intelligence in Pakistan:

NCAI in Pakistan, headquartered at the NUST is a leading hub for AI innovation, research, and training. NCAI plays a crucial role in incorporating AI solutions in healthcare by fostering collaboration between academia, industry, and healthcare institutions. Through partnerships with healthcare organizations, NCAI facilitates the development and implementation of AI-based solutions that address healthcare challenges specific to Pakistan. These solutions may include AI-powered diagnostics, remote monitoring systems, and personalized treatment recommendation systems.

Moreover, the NCAI focuses on providing training and capacity-building programs to healthcare professionals. By conducting workshops, seminars, and certification courses, the center equips healthcare

Table-III: Innovative Projects in AI Healthcare under the National Center of Artificial Intelligence (NCAI) in Pakistan

AI Healthcare Projects of NCAI	Project Name	Description
Pulmonology Diagnostics	Tuberculosis Detection System	Achieves 98.18% accuracy in classifying tuberculosis images and identifies regions of interest
	Lungs Injury Predictor	Utilizes deep learning and computer-aided diagnosis to detect abnormalities in chest X-ray images
Breast Cancer Diagnosis	Tashkees Breast Cancer Module	Accurately classifies mammograms into malignant, benign, and normal categories with over 80% accuracy
Brain Tumor Diagnosis	BrainViz module	Enables multi-modal viewing of brain MRI scans and accurately diagnoses brain tumor subtypes with 91% accuracy
AI-Enhanced Diagnostics	AI-Based DICOM Viewer	Transformative advancement in medical imaging diagnosis, empowering healthcare professionals with efficient and accurate diagnostic capabilities
Cardiac Monitoring and Diagnosis	Vascular Arterial Surgical Planning System (VASP)	AI-powered solution for accurate disease prediction and decision support in medical procedures
	Artificial Intelligence-Based Cardiac Monitoring System with Biotelemetry	Groundbreaking healthcare solution for fast and reliable ECG and PPG detection, intelligent auto-diagnosis capabilities, and portable digital stethoscope
Neuropathy Diagnostic System	On-chip Epilepsy Predictor	Utilizes AI technology for chronic neurological disorders, specifically epilepsy, for accurate seizure prediction
Cancer Diagnosis and Detection	AMAL	Utilizes AI and machine learning for faster and more accurate cancer diagnosis, reducing turnaround time by 95%
Other Healthcare Domains	ThalaScreen	AI-enabled point-of-care device for early detection of Thalassemia
	Robo-Chotu	Low-cost assistive robot designed for differently abled children and general use
	MindFoster	Mobile health device targeting mental health management and productivity enhancement
	RoboDoc	Support system for healthcare professionals dealing with contagious diseases
	Wearable EEG device	Records EEG, heart rate, and body motion simultaneously for assisting neurologists
	EBioSensors4Life	Focuses on early disease detection with smart healthcare electronic devices

professionals with the necessary knowledge and skills to utilize AI effectively in their practice. This enables healthcare professionals to leverage AI technologies for accurate diagnosis, efficient treatment planning, and improved patient care.[25]

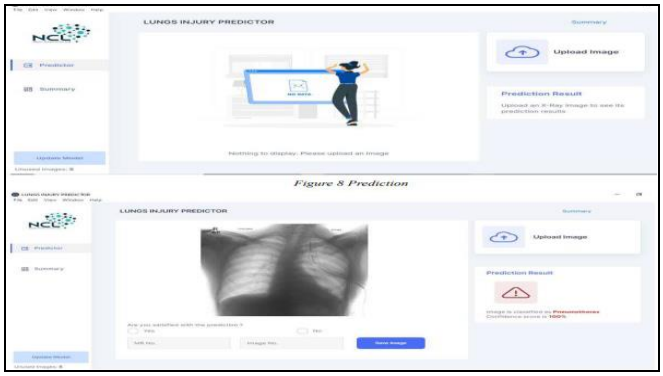

Figure-1: Lungs Injury Predictor by NCL, NCAI

C. National Center for Artificial Intelligence Revolutionizing Healthcare with AI Innovations in Pakistan. The National Center of Artificial Intelligence (NCAI) has developed 221 AI products benefiting sectors like healthcare, smart cities, agriculture, and more. In the healthcare domain, NCAI's core labs, including the Medical Imaging and Diagnostics Lab (MIDL), the Intelligent Information Processing Lab (IIPL) and the Neurocomputation Lab (NCL) are pioneering AI-driven advancements. The systems developed by these labs have shown remarkable accuracy in detecting diseases and are being commercialized and deployed in various healthcare facilities. NCAI's transformative use of AI in healthcare is revolutionizing patient care and empowering professionals. The center aims to establish Pakistan as a global AI leader, contributing to sustainable growth in the country.[25]

D. Revolutionizing Healthcare: AI Projects by National Center of Artificial Intelligence

The following are descriptions of several innovative projects/products in different domains:

Pulmonology Diagnostics Systems

Tuberculosis Detection System (TDS) achieves 98.18% accuracy in classifying tuberculosis images and

identifies the regions of interest. Another system based in pulmonology is the Lungs Injury Predictor, introducing the state-of-the-art solution for detecting abnormalities in chest X-ray images utilizing deep learning and computer-aided diagnosis to identify lung diseases and other conditions swiftly and accurately. By extracting key information and recognizing patterns, our system provides precise and efficient diagnosis. With the power of artificial intelligence and machine learning, it continuously improves its ability to detect abnormalities and offers real-time analysis as an invaluable tool for healthcare professionals.[26-38]

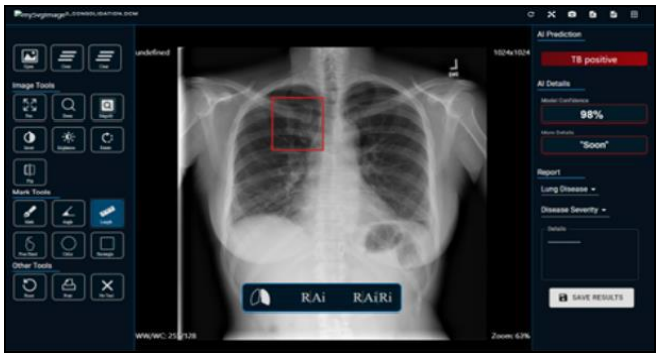

Figure-1: Tuberculosis Detection System (TDS)

Tashkees Breast Cancer module accurately classifies mammograms into malignant, benign, and normal categories with over 80% accuracy and marks lesion regions.[39-40]

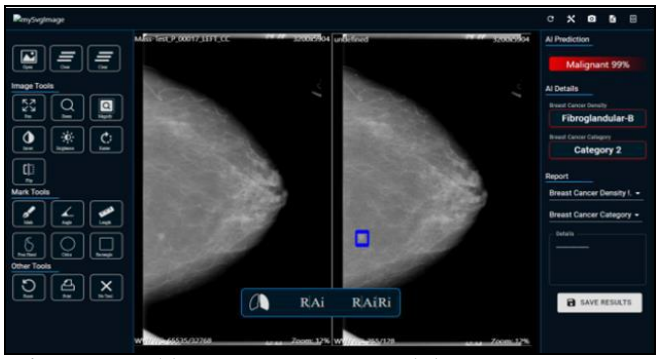

Figure-2 : Tashkees Breast Cancer Module

BrainViz module enables multi-modal viewing of brain MRI scans and accurately diagnoses brain tumor subtypes with 91% accuracy.[41] AI-Based DICOM Viewer represents a transfor-mative advancement in medical imaging diagnosis, empowering healthcare professionals with efficient and accurate diagnostic capabilities like image viewing capabilities, customizable reporting templates, and suggestion features for radiologists and doctors.[26-40]

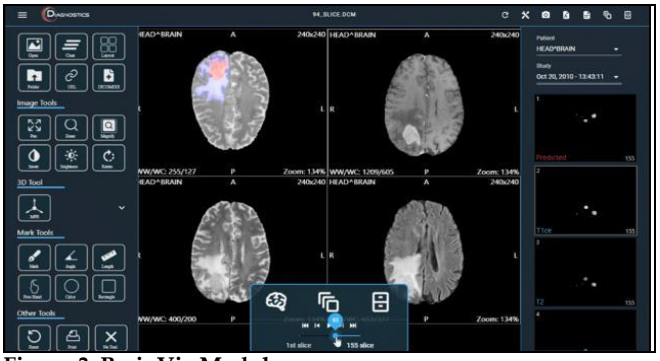

Figure-3: BrainViz Module

Vascular Arterial Surgical Planning System (VASP) - is our AI-powered solution for accurate disease prediction and decision support in medical procedures. VASP efficiently handles real-world labelled medical data, providing valuable feedback to surgeons and medical professionals. This medical system is a comprehensive AI model that combines clinical, biological, and imaging characteristics of CTA scans for disease prediction. With VASP, decision support to surgeons is provided using detection of diseased vessels and the prediction of the area and percentage of vessel involvement.

Figure-4 and Figure-5: The AI-Based DICOM Viewer - integrates three powerful systems including TDS, Tashkees and BrainViz

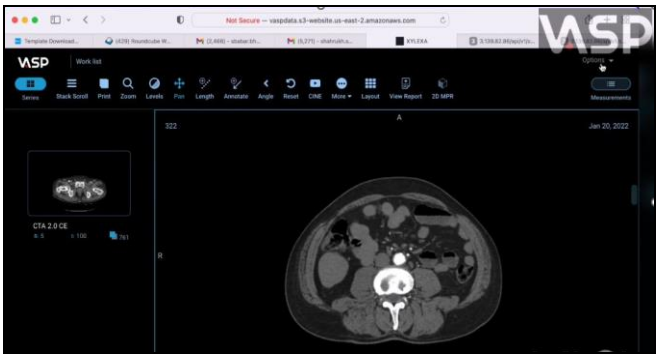

Figure-6: VASP - AI-powered solution for accurate disease prediction and decision support in medical procedures

On-chip Epilepsy Predictor using AI for Chronic Neurological Disorders - NCAI Research Fund Lab has developed the on-chip Epilepsy Predictor, an advanced product that utilizes AI technology for chronic neurological disorders, specifically epilepsy. This innovative solution integrates an ultra-low-power AI seizure prediction processor with an in-house developed EEG front-end at the integrated circuit design level. It accurately predicts seizures by analyzing real-time EEG data, empowering healthcare professionals and patients to take proactive measures. With its energy-efficient design and optimized performance, the On-chip Epilepsy Predictor demonstrates NCAI's commitment to advancing healthcare technology and improving the lives of individuals with epilepsy.

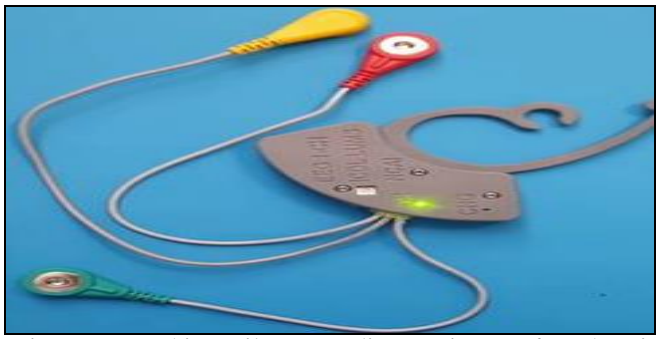

Figure-7: On-chip Epilepsy Predictor using AI for Chronic Neurological Disorders

The Artificial Intelligence-Based Cardiac Monitoring System with Biotelemetry is a groundbreaking healthcare solution for clinics, OPD facilities, remote areas, and medical support staff in Pakistan. This system incorporates advanced technologies to deliver fast and reliable ECG and PPG detection, along with intelligent auto-diagnosis capabilities. It also includes a portable and digital stethoscope for enhanced heart sound amplification. The single-channel ECG device offers a sustainable and intelligent alternative to 12-lead ECGs, facilitating accurate rate/rhythm management and heart disease diagnosis. The portable PPG device utilizes non-invasive and cost-effective optical signals to detect pulse rate. With its compact design, the digital electronic stethoscope provides superior sound quality for precise heart sound analysis. By introducing this innovative medical device, we aim to revolutionize cardiac monitoring in Pakistan and contribute to the development of intelligent and portable healthcare solutions.

AMAL–is a groundbreaking Cancer Diagnosis Assistant solution that utilizes Artificial Intelligence and Machine Learning to revolutionize cancer detection. With faster and more accurate diagnoses, AMAL saves lives by enabling timely intervention. Its remote accessibility and continuous learning capabilities ensure efficiency and excellence in cancer diagnosis. Amal delivers accelerated results, reducing turnaround time by 95%, and offers affordability with an 85% cost reduction. AMAL has already signed an agreement with PIMS, Islamabad over its commercialization potential.

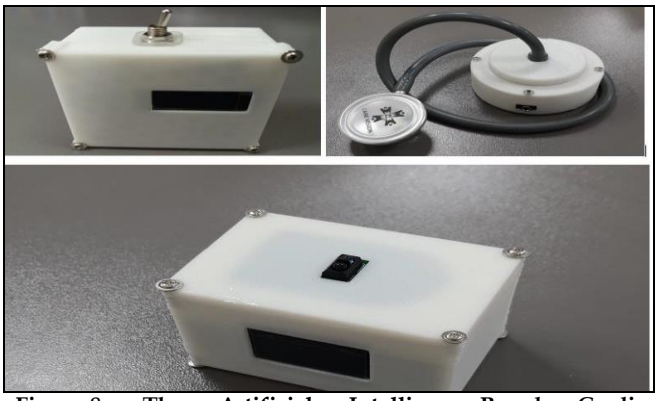

Figure-8: The Artificial Intelligence-Based Cardiac Monitoring System with Biotelemetry

Figure-9: AMAL - A groundbreaking Cancer Diagnosis Assistant

Thala Screen is an innovative AI-enabled point-of-care device for early detection of Thalassemia. This portable IoT-enabled testing device revolutionizes Thalassemia diagnosis and prevention by mapping blood samples against AI-trained algorithms, providing precise results. With its unique features, including AI-enabled decision support and cloud database integration, ThalaScreen simplifies and improves Thalassemia diagnostics. Made in collaboration with Rehman Medical Institute and Khyber Medical University, the device is being 3D printed locally with a completely indigenous algorithm helping transform Thalassemia detection and prevention.

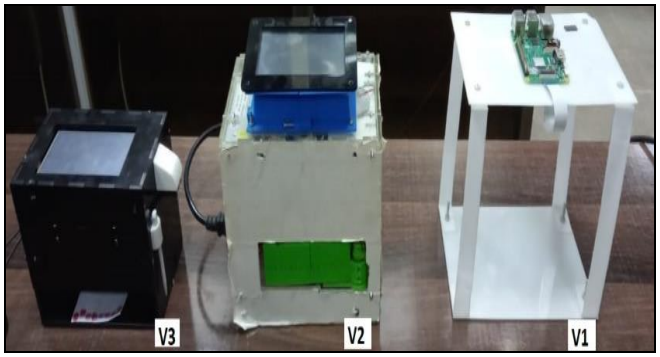

Figure-10: ThalaScreen - an innovative AI-enabled point-of-care device for early detection of Thalassemia

NCAI has produced various other healthcare systems including a lineup of groundbreaking innovations that are revolutionizing various fields and transforming lives.

Robo-Chotu: is a low-cost assistive robot designed for differently abled children and general use, incorporating AI cognitive models, interactive features, and smooth locomotion control.

Mind Foster: is a mobile health device targeting mental health management and productivity enhancement through neuromodulation techniques, personalized therapy, and easy operation.

RoboDoc: provides support to healthcare professionals dealing with contagious diseases, offering features like vital sign monitoring, haptic feedback, behavioral monitoring, user-friendly dashboards, and remote controlling capabilities.

Our *Wearable EEG Device* records EEG, heart rate, and body motion simultaneously, reducing neurologists' workload and assisting in detecting abnormalities.

EBioSensors4Life focuses on early disease detection with smart healthcare electronic devices, combining sensing technologies, readout electronics, and AI capabilities for accurate biomarker detection kits from blood, saliva, and sweat, ensuring affordability and accessibility. Experience the power of these innovations as we shape a brighter future in healthcare, assistive technology, mental well-being, and medical diagnostics.

Future Prospects of AI in Healthcare

The future prospects of AI in healthcare in Pakistan are promising. As technology advances and data availability improves, AI algorithms will become more sophisticated and accurate. The integration of AI with other emerging technologies, such as the Internet of Things (IoT), can further enhance healthcare delivery by enabling real-time monitoring and personalized care.

To fully leverage the potential of AI in healthcare, collaboration among policymakers, healthcare providers, technology experts, and researchers is crucial. Continuous research and innovation are needed to address specific healthcare challenges in the Pakistani context, develop robust AI models, and establish ethical frameworks and guidelines that prioritize patient safety, privacy, and trust.

REFERENCES

1. Rajpurkar P, Chen E, Banerjee O, Topol EJ. AI in health and medicine. Nat Med 2022; 28(1): 31-38. https://doi.org/ 10.1038/ s41591-021-01614-0.
2. Loh HW, Ooi CP, Seoni S, Barua PD, Molinari F, Acharya UR. Application of explainable artificial intelligence for healthcare: A systematic review of the last decade (2011-2022). Comput Methods Programs Biomed 2022; 226(1): 107161. https://doi.org/ 10.1016/j.cmpb.2022.107161
3. Siala H, Wang Y. SHIFTing artificial intelligence to be responsible in healthcare: A systematic review. Soc Sci Med 2022 ;296:114782. https://doi.org/ :10.1016/j.socscimed.2022.114782.
4. Lee D, Yoon SN. Application of Artificial Intelligence-Based Technologies in the Healthcare Industry: Opportunities and Challenges. Int J Environ Res Public Health 2021; 18(1):271. https://doi.org/10.3390/ijerph18010271
5. Dicuonzo R, Donofrio F, Fusco A, Shin M. Healthcare system: Moving forward with artificial intelligence. Technovation 2023; 120(1): 102510. https://doi.org/ 10.1016/j.technovation.2022.
6. He J, Baxter SL, Xu J, Xu J. The practical implementation of artificial intelligence technologies in medicine. Nat Med 2019; 25(1): 30-36. https://doi.org/10.1038/ s41591-018-0307-0.
7. Rabaan AA, Alhumaid S, Mutair AA, Garout M, Abulhamayel Y, Halwani MA. Application of Artificial Intelligence in Combating High Antimicrobial Resistance Rates. Antibiotics (Basel) 2022; 11(6): 784-788. https://doi.org/10.3390/antibiotics-11060784.
8. Huqh MZU, Abdullah JY, Wong LS, Jamayet NB, Alam MK, Rashid QF, et al. Clinical Applications of Artificial Intelligence and Machine Learning in Children with Cleft Lip and Palate-A Systematic Review. Int J Environ Res Public Health 2022 ;19(17):10860. https://doi.org/ 10.3390/ijerph191710860.
9. Mahdi SS, Allana R, Battineni G, Khalid T, Agha D. The promise of telemedicine in Pakistan: A systematic review. Health Sci Rep 2022; 5(1): e438. https://doi.org/ 10.1002/hsr2.438.
10. Wadden JJ. Defining the undefinable: the black box problem in healthcare artificial intelligence. J Med Ethics 2022;48:764-768.
11. Hindocha S, Badea C. Moral exemplars for the virtuous machine: the clinician's role in ethical artificial intelligence for healthcare. AI Ethics 2022; 2(1): 167–175. https://doi.org/10.1007/s43681-021-00089-6
12. Čartolovni A, Tomičić A, Lazić Mosler E. Ethical, legal, and social considerations of AI-based medical decision-support tools: A scoping review. Int J Med Inform 2022; 161(1): 104738. https://doi.org/10.1016/j.ijmedinf.2022.104738.
13. European Commission. White Paper on Artificial Intelligence - A European Approach to Excellence and Trust. Brussels: European Commission; 2020, Available at: https://commission.europa.eu/publications/white-paper-artificial-intelligence-exce-trust_en

14. Panch T, Mattie H, Celi LA. The "inconvenient truth" about AI in healthcare. NPJ Digit Med 2019; 2: 77. https://doi.org/10.1038/s41746-019-0155-4
15. World Health Organization. Ethics and governance of artificial intelligence for health. Geneva: World Health Organization; 2021, Available at: https://www.who.int/publications/i/item/9
16. Naik N, Hameed BMZ, Shetty DK, Swain D, Shah M, Paul R, et al. Legal and Ethical Consideration in Artificial Intelligence in Healthcare: Who Takes Responsibility? Front Surg 2022 ; 9(1): 862322. https://doi.org/10.3389/fsurg.2022.862322.
17. de Hond AAH, Leeuwenberg AM, Hooft L, Kant IMJ, Nijman SWJ, van Os HJA, et al. Guidelines and quality criteria for artificial intelligence-based prediction models in healthcare: a scoping review. NPJ Digit Med 2022; 5(1): 2-8. https://doi.org/10.1038/s41746-021-00549-7.
18. Feng J, Phillips RV, Malenica I, Bishara A, Hubbard AE, Celi LA, et al. Clinical artificial intelligence quality improvement: towards continual monitoring and updating of AI algorithms in health-care. NPJ Digit Med 2022; 5(1): 66-678 https://doi.org/10.1038/s41746-022-00611-y.
19. Bin Sawad A, Narayan B, Alnefaie A, Maqbool A, Mckie I, Smith J, et al. A systematic review on healthcare artificial intelligent conversational agents for chronic conditions. Sensors (Basel) 2022; 22(7): 2625. https://doi.org/ 10.3390/s22072625.
20. Mittelstadt BD, Allo P, Taddeo M, Wachter S, Floridi, L. The ethics of algorithms: Mapping the debate. Big Data Soc 2016; 3(2): 1-3. https://doi.org/10.1177/2053951716679679
21. Mousavi Baigi SF, Sarbaz M, Ghaddaripouri K, Ghaddaripouri M, Mousavi AS, Kimiafar K. Attitudes, knowledge, and skills towards artificial intelligence among healthcare students: A systematic review. Health Sci Rep 2023; 6(3): e1138. https://doi.org/10.1002/hsr2.1138.
22. Ahmed Z, Bhinder KK, Tariq A, Tahir MJ, Mehmood Q, Tabassum MS, et al. Knowledge, attitude, and practice of artificial intelligence among doctors and medical students in pakistan: a cross-sectional study. Frontiers in Public Health 2021; 9(1): 651108. https://doi.org/10.3389/fpubh.2021.651108
23. Baigi F, Tabassum S, Noor U. Attitude, knowledge, and skills of medical students regarding artificial intelligence in pakistan: a systematic review. J Med Educ Curr Dev 2021; 8(1): 23821205211012130.https://doi.org/10.1177/23821205211012130
24. Mahdi MS, Qureshi AM, Shakeel H, Munir N, Sheikh Z. (2021). telemedicine and COVID-19: a developing country perspective. Front Public Health 2021; 9(1): 635521. https://doi.org/10.3389/fpubh.2021.635521
25. Gong B, Nugent JP, Guest W, Parker W, Chang PJ, Khosa F, et al. Influence of artificial intelligence on canadian medical students' preference for radiology specialty: a national survey study. Acad Radiol 2019; 26(4): 566-577. https://doi.org/10.1016/j.acra.2018.10.007.
26. Mian A, Naeem M. "Multi-view convolutional recurrent neural networks for lung cancer nodule identification." Neurocomput 2021; 453(1): 299-311. https://doi.org/10.1016/j.neucom.2020
27. Fatima A, Shahid AR, Raza B, Madni TM, Janjua UI. State-of-the-Art Traditional to the Machine- and Deep-Learning-Based Skull Stripping Techniques, Models, and Algorithms. J Digit Imaging 2020; 33(6): 1443-1464. https://doi.org/10.1007/s10278-367-5.
28. Hira S, Shahid AR, Raza B. "Visual interpretability in 3D brain tumor segmentation network. Com Bio Med 2021; 133(1): 104410. https://doi.org/10.1016/j.compbiomed.2021.104410
29. Gao Y, Li J, Xu H, Wang M, Liu C, Cheng Y, et al. A multi-view pyramid network for skull stripping on neonatal T1-weighted MRI. Magn Reson Imag 2019; 63(1): 70-79. https://doi.org/1010.1016/j.mri.2019.08.025.
30. Fatima A, Madni TM, Anwar F, Janjua UI, Sultana N. Automated 2D Slice-Based Skull Stripping Multi-View Ensemble Model on NFBS and IBSR Datasets. J Digit Imaging 2022; 35(2): 374-384. https://doi.org/10.1007/s10278-021-00560-0.
31. Shaukat Z, Farooq QUA, Tu S, Xiao C, Ali S. A state-of-the-art technique to perform cloud-based semantic segmentation using deep learning 3D U-Net architecture. BMC Bioinformatics 2022; 23(1): 251-254. https://doi.org/10.1186/s12859-022-04794-9.
32. Usman M, Zia T, Tariq, A. Analyzing Transfer Learning of Vision Transformers for Interpreting Chest Radiography. J Digit Imaging 2022; 35(1): 1445–1462. https://doi.org/10.1007/s10278-022-00666-z
33. Aitazaz T, Tubaishat A. Transfer learning for histopathology images: an empirical study. Neural Comput Applic 2023; 35(1): 7963–7974 . https://doi.org/10.1007/s00521-022-07516-7
34. Nawaz M, Al-Obeidat F, Tubaishat A. MDVA-GAN: multi-domain visual attribution generative adversarial networks. Neural Comput Applic 2023; 35(2): 8035–8050. https://doi.org/10.1007/s00521-022-06969-0
35. Ul Abideen Z, Ghafoor M, Munir K, Saqib M, Ullah A, Zia T, et al. Uncertainty Assisted Robust Tuberculosis Identification With Bayesian Convolutional Neural Networks. IEEE Access 2020; 8(1): 22812-22825. https://doi.org/10.1109/ACCESS.2020.297.
36. Fiaz K, Madni M. Brain tumor segmentation and multiview multiscale-based radiomic model for patient's overall survival prediction. Int J Imag System Technol 2022; 32(1): 982-999. https://doi.org/10.1002/ima.22678
37. Latif U, Shahid AR. An end-to-end brain tumor segmentation system using multi-inception-UNET." Int J Imag System Technol 2021; 31(1): 1803-1816. https://doi.org 10.1002/ima.22585
38. Rafi A. Multi-level dilated convolutional neural network for brain tumour segmentation and multi-view-based radiomics for overall survival prediction. Int J Imag System Technol 2021: 1(2): 1519-1535. https://doi.org 10.1002/ima.22549
39. Hina I, Raza SA, Basit R, Hasan K. Multi-View Attention-based Late Fusion (MVALF) CADx system for breast cancer using deep learning. Mach Graph Vis 2020; 29(1/4): 55–78. https://doi.org 10.22630/MGV.2020.29.1.4.
40. Ali MJ. Enhancing breast pectoral muscle segmentation performance by using skip connections in fully convolutional network. Int J Imag System Technol 2020; 30: 1108-1118. https://doi.org 10.1002/ima.22410

.....