

A comprehensive review of artificial intelligence application in medical diagnosis and patient care

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Abstract: This study employs a systematic mapping study technique to categorize the literature on the application of machine learning in healthcare. We conducted a Google Scholar search for prestigious journals, articles, and conference papers for our review using the keywords "use of machine learning in healthcare," and 1400 items were found. One element in the categorization procedure was analyzing the purpose, methodology, issue type, and sickness emphasis of each study. Five study areas were identified as a result of our work: interpretable machine learning (ML), medical image assessment, security/privacy frameworks, electronic health record (EHR) processing, and transfer learning.

Interestingly, research on cancer was found to be the primary emphasis of this study, whilst epilepsy was shown to be one of the least studied disorders in this regard. The category with the greatest research was the evaluation of medical pictures, while Interpretable ML/Explainable AI, a relatively new topic, showed signs of growth. The goal of this study is to provide upcoming scholars with a thorough grasp of the state of the subject now and suggest future lines of inquiry.

I. INTRODUCTION

The healthcare sector has changed significantly in recent years, moving away from the old hospital-centric paradigm and towards a more patient-centric one. The integration of new technologies, including big data, aided fog and edge networks, artificial intelligence (AI), and the Internet of Things (IoT), is facilitating this change.[1] The idea of Healthcare 4.0, which centres on giving individuals more choice over their health care, is essential to this transition.

Digital health under the Healthcare 4.0 paradigm is defined by the use of smart sensors that can provide real-time prediction models and enable business analytics. This analytical viewpoint, which is sensor-driven and patient-centric, represents a substantial shift from traditional healthcare methods. [2]It makes it possible to provide patients with improved insights into their health and well-being and to provide smart and connected care.

However, expectations indicate that another revolutionary paradigm change is imminent when the healthcare sector harmonises its operations with the tenets of Healthcare 4.0.[3] The next phase of this development, known as

Healthcare 5.0, is about to bring in cutting-edge technologies including augmented and virtual reality, smart control, and interpretable healthcare analytics. [4] Essentially, Healthcare 5.0 sees a highly personalised, dynamic, and reason-based analytics-driven healthcare environment.

The predicted transition to Healthcare 5.0 represents a quantum leap, whereby healthcare services will be profoundly networked, cognitively sensitive to individual requirements, and technologically advanced. The combination of smart control mechanisms, three-dimensional view models, and augmented and virtual reality has the potential to completely transform the healthcare experience.[7] It is anticipated that this revolutionary path would spur creative commercial solutions in the healthcare industry, eventually raising the standard and effectiveness of healthcare delivery. The healthcare industry is poised to usher in a new age of unprecedented advancements in the provision of healthcare services, heralding in Healthcare 5.0.

The significant concerns over the impact of AI technologies on social and individual elements have arisen from the pervasiveness of these technologies on a worldwide scale. The concept of Responsible AI emerged as a result of a paradigm shift towards assuring transparency and accountability in AI applications, acknowledging the necessity for their responsible and ethical use. Explainable Artificial Intelligence (EXAI) is a key technique in this framework that is specifically used for AI-enabled diagnosis and analysis in order to maintain ethical standards.[8]

II. EXAI AND PDP IN HEALTHCARE

A. EXAI

EXAI is a useful tool that helps with model improvement and result tracing in the healthcare industry. Based on feature extraction, it improves AI models' interpretability and explainability, which helps with ethical issues. When combined with design principles, EXAI's self-explanatory framework allows for a thorough comprehension and prediction of the behavioural elements of Deep Learning (DL) and Machine Learning (ML) models. A reassessment

of duties and responsibilities is required as a result of the complex issues that the deployment of Medical AI presents to legislators, healthcare practitioners, and technology designers.[7]

Beyond the healthcare industry, EXAI's adaptability finds uses in a wide range of industries, including sales, transportation, finance, human resources, and more.[8] Its uses in the healthcare industry include medical picture segmentation, drug distribution, disease detection, categorization, clinical support systems, and the advancement of healthcare technologies, such as robotic-assisted surgery.[9] In order to provide open and accountable operations between patients and healthcare practitioners, it is imperative that the notion of explainability takes into account the various viewpoints of technology, legality, medicine, and patient considerations. This is especially true for clinical support systems.[10]

Reliable analytics are successfully met by the strategic implementation of EXAI in various clinical decision models within healthcare operations. Applications encompass data management, clinical diagnosis, data segmentation, illness categorization, and healthcare sensor bias reduction. In essence, the use of EXAI promotes ethical AI practices in the medical domain and contributes to the greater discussion on the open, accountable, and responsible use of AI technology across a range of domains.

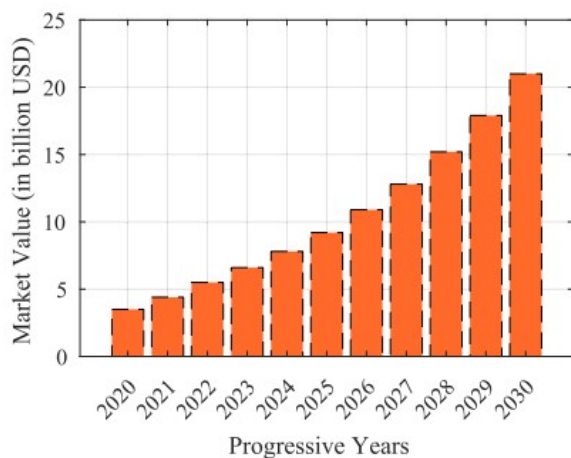


Fig 1[11]

Explainable Artificial Intelligence (EXAI), which integrates a module explaining the decision-making process, is essential to improving the effectiveness of trained models. This feature makes debugging easier and helps the model perform better. EXAI brings transparency to AI algorithms by providing concise justifications for the output decisions, hence providing explicit insights behind model predictions.[12] It guarantees adherence to predetermined guidelines, giving end users clear explanations and enabling them to comprehend and have faith in the decision-making process.

EXAI's capacity to optimise algorithms, lowering bias and permitting overrides to improve system decisions, is a key

feature. This translates to enhanced safety and equity in healthcare models, promoting trust in the decision-making process. EXAI is flexible and may be used with several machine learning methods, including decision trees, random forests, and artificial neural networks. There are two categories for the explanation scope: local explanations concentrate on specific predictions, whereas global explanations cover the entire model.

Aligning EXAI with particular factors and individualised health situations within the healthcare 5.0 ecosystem guarantees that the algorithm's alignment with patient use-cases is justified. This maintains the aspects of personalisation that are essential to healthcare 5.0. The global EXAI forecast is shown in Figure 1, which shows a compound annual growth rate (CAGR) of 18.4% from 2020 to 2030. A detailed list of all the abbreviations used in the article, together with descriptions of each one.

B Preliminary diagnosis and prediction(PDP)

Clinical trial participation (CTP) is an essential component of medical research that involves subjects receiving particular treatments as specified in a protocol or research plan created by researchers or investigators. These interventions could include medical devices, treatments, or behavioural adjustments like diet adjustments made by individuals. Three models are commonly used in clinical trials: comparing a novel medical strategy to the current gold standard, comparing it to a placebo that contains no active ingredients, or comparing it to a method that does not include any intervention.

A new drug's development and commercialization are expensive and time-consuming processes that take between 1.5 and 2.0 billion US dollars and ten to fifteen years. Notably, the clinical trial phases take up around half of this time and budget. Clinical trial participation rates can be low, despite their value. For instance, despite up to 20% of cancer patients being eligible, only 3-5% of patients actually participated in clinical trials, according to a Mayo Clinic research. Artificial intelligence (AI) is crucial in addressing the demand for more thorough clinical studies. By automatically extracting significant patterns from massive, unstructured datasets, such as audio, text, or image data, artificial intelligence (AI) helps with clinical trial design. A crucial element is natural language processing (NLP), which makes it possible to comprehend and correlate information in written or spoken language, enabling information sharing between computers and people. To improve patient-trial matching and recruitment, this capacity is used to correlate various datasets, including databases, electronic health records (EHRs), and medical literature. AI is still useful in clinical studies because it makes patient monitoring automatic and ongoing. Its use improves control and dependability, guarantees effective endpoint assessment, and

improves adherence. High-volume screening is effective, as evidenced by IBM's research employing the Watson AI platform, which led to an 80% increase in cancer clinical trial enrollment at the Mayo Clinic. To find patients who could be eligible, Mendel.ai, a member of the research network, has created a pre-screening tool for clinical trial participation. Mendel.ai's pre-screening improved the accuracy of identifying eligible individuals by 24-50% when compared to current techniques in studies on lung and breast cancer. With Mendel.ai, the time between patient eligibility and identification was drastically shortened—it only took minutes as opposed to days with traditional pre-screening procedures. These developments highlight how AI can revolutionise clinical trial participation rates and accelerate the drug development process.

Through the development of an AI application that combines automated Natural Language Processing (NLP) and Machine Learning (ML), researchers at Columbia University's New York State Psychiatric Institute, in partnership with the IBM Watson Research Centre, have made noteworthy advancements in the field of psychiatric diagnosis. This novel application achieves an astounding 100% accuracy rate in identifying the onset of psychosis in vulnerable patients, outperforming the 79% accuracy rate attained by conventional diagnosis techniques.

The AI system analyses speech patterns using natural language processing (NLP), a method similar to that used by psychologists to diagnose patients at risk for psychosis. However, by removing human error, the AI application shows a clear advantage. Psychologists' traditional method of diagnosis depends on their capacity to recognise minute clues in speech patterns. IBM researchers realised that human error, even a little diversion from the interviewer's thoughts, could cause them to overlook important cues that are essential for spotting the onset of psychosis. On the other hand, the AI diagnostic system never lets up, spotting symptoms that human observers would miss.

This AI diagnostic system's primary strength is its unmatched capacity to recognise patterns and indicators of the onset of psychosis. The system's ability to automate the diagnostic process allows it to outperform humans in terms of consistency and attention to detail, which significantly improves diagnostic accuracy. This innovative study shows how artificial intelligence can transform mental diagnosis by providing a more accurate and dependable way to detect people who are at danger of going into psychosis.

III. APPLICATION OF AI IN HEALTHCARE

A. Diabetes Prediction and AI applications:

Diabetes prediction is a broad category of AI applications, each with a specific function. Retinal screening, clinical decision support, risk classification for the predictive population, and patient self-management tools are some of these uses. AI uses retinal scans to identify anomalies such as exudates, maculopathy, diabetic retinopathy, and other conditions.[13] Clinical decision support systems keep an eye on wounds, neuropathy, and nephropathy in addition to diabetes. Finding high-risk diabetic subpopulations for complications, hospitalisation, and readmissions is the main goal of predictive population risk stratification. Artificial intelligence-enhanced glucose metres, dietary/activity trackers, and pancreas replacements are examples of patient self-management aids.[13]

Medtronic's Guardian Connect diabetes tracking system is a prime example. It is the first continuous glucose monitoring (CGM) device with AI capability to receive FDA approval. Guardian Connect forecasts major changes in blood glucose levels up to 60 minutes ahead of time using predictive machine learning algorithms. The belly-mounted sensor of the device tracks blood sugar levels every five minutes and notifies users of around 98.50% of hypoglycemia incidents. Patients are empowered to take prompt action to achieve blood sugar normalisation thanks to this proactive alert system.[14]

B. Cancer Prediction with NLP:

A NLP-based tool for evaluating mammography data was created by Houston Methodist researchers utilising free-text radiology and pathology information from 543 patients. The application saves a great deal of time, achieving an astonishing 99% accuracy when compared to manual physician evaluation. It took 50–70 hours to manually validate the accuracy of a subset of 54 cases, demonstrating the efficiency that AI provides. This technology has great potential to speed up the diagnostic process and improve the accuracy of cancer prognosis.[14]

C. Tuberculosis Diagnosis using AI:

Two distinct Deep Convolutional Neural Networks (DCNNs), AlexNet and GoogLeNet, were used to learn positive and negative X-rays for tuberculosis in order to diagnose the disease. The result of testing 150 examples for accuracy was 96% accuracy for the combined AlexNet and GoogLeNet model[14]. In 13 cases, there were disparities between the two DCNN models; however, radiologists' diagnosis accuracy in these circumstances was 100%. This demonstrates the accuracy advances made possible by deep learning and underscores the critical role artificial

intelligence (AI) can play in the near-term battle against tuberculosis.[14]

D. Using AI to Find New Drugs:

In the healthcare industry, artificial intelligence (AI) technology is significantly advancing drug discovery by, among other things, speeding up and improving the efficiency of pharmaceutical procedures. Automating target identification is a key use of AI in drug discovery, which helps to expedite the early phases of the drug development process. Furthermore, AI is essential for analysing off-target molecules, which makes medication repurposing easier. In the fields of artificial intelligence and healthcare, this dual functionality serves to streamline the drug discovery process, cut down on redundancy, and improve overall productivity.[15]

Prominent biopharmaceutical firms are proactively utilising artificial intelligence (AI) technologies to propel their drug research endeavours. To help with the development of immuno-oncology drugs, Pfizer, for example, has integrated IBM Watson, a machine learning-based system. Sanofi has also teamed up with Exscientia's AI technology to investigate drugs for metabolic disorders. Additionally, to improve its hunt for cutting-edge cancer medicines, the Cambridge, Massachusetts-based AI system Genentech, a division of Roche, works with GNS Healthcare.[15] These alliances, which result from joint ventures or internal AI initiatives at significant biopharmaceutical firms, are prime examples of the pharmaceutical industry's broad adoption of AI.[15]

Proponents of artificial intelligence (AI) and machine learning in drug discovery see a new era marked by more rapid, economical, and successful medication development. The partnerships between Pfizer, Sanofi, and Genentech demonstrate the industry's hope for the advantages of artificial intelligence in transforming drug research procedures. Experts generally agree that AI and machine learning techniques will play a bigger role in drug development projects in the future, despite some scepticism.[15]

Scientists confront both opportunities and challenges as the incorporation of AI transforms the pharmaceutical industry. New methods for drug discovery are introduced by automation combined with AI tactics. Even though these developments are very promising, more work needs to be done to overcome any roadblocks before researchers can fully realise how AI may revolutionise the drug development process. The field's current development marks a paradigm change towards a more technologically advanced, effective, and significant era of drug discovery in the healthcare

industry.[15] ****Smart Clinical Studies: Revolutionising the Biopharma Value Chain****

The gold standard for assessing the safety and effectiveness of novel medications has long been sequential, linear clinical studies. These studies, which are frequently carried out as discrete and well-defined stages of randomised controlled trials (RCTs), were primarily created to evaluate mass-market medications and haven't changed much in the last several years. But the emergence of artificial intelligence (AI) has the potential to completely transform clinical trials by providing chances to reduce cycle times, boost efficiency, and enhance clinical development results.[15] This is a paradigm change that the impact of AI on the biopharma value chain has been the subject of several papers (Lee, 2021; Angus, 2020).[15]

Real-world data (RWD), or scientific and research information, has become more readily available to biopharmaceutical companies. Despite this abundance of data, there are still obstacles in using it successfully because of a lack of knowledge and resources. Predictive AI models combined with advanced analytics offer a game-changing approach that allows researchers to better understand diseases, find relevant patient populations, locate important investigators, and support creative clinical study designs.[15]

Biopharmaceutical businesses now have easier access to scientific and research information, often known as real-world data (RWD). Even with so much data available, there are still barriers to effective data utilisation due to a lack of resources and expertise. Researchers may now uncover significant investigators, find relevant patient populations, better understand diseases, and support innovative clinical study designs with the help of predictive AI models and advanced analytics.[16]

AI's use in clinical trials marks a significant change towards a more perceptive and data-driven methodology. Researchers can find trends and insights that may have gone unnoticed in the past by using AI to analyse real-world data. Furthermore, data efficiency, accuracy, and integrity are guaranteed by the incorporation of AI algorithms into data management procedures. Beyond just the practical concerns of clinical trials, this revolutionary effect affects the whole biopharma value chain and heralds in a new age of innovative drug discovery. The continued investigation and application of AI in clinical trials highlight the technology's potential to completely change the game and improve the efficacy, agility, and knowledge of the drug development process.[16]

E. Continuous Patient Health Monitoring (PHM) with AI:

With the potential to shorten hospital stays for patients, speed up their recuperation, and lower death rates, continuous patient-centered pain management has come to light as a game-changing strategy. In addition to hospital settings, PHM is essential in giving patients and medical staff in-home reminders, instructions, and information about preventive care. The research in question focuses on PHM as a full suite of services and solutions that leverage AI techniques for tools for evaluation, symptom-checking, and continuous healthcare monitoring.[16]

These AI-driven PHM services provide patients with either ongoing or sporadic monitoring and are intended for usage in hospitals and at home. According to a study on user acceptability of these services, out of 15 healthcare technologies, AI-based health condition monitoring solutions were deemed the most important. In addition, out of 15 services that healthcare professionals indicated they would be willing to utilise, these solutions were regarded as the second-best option.[16]

F. Heart failure monitoring in Italy:

A prototype of an artificial intelligence-based computer-aided diagnosis system for heart disease diagnosis has been created by Italian researchers. This method is intended to support nurses and general practitioners, especially those without a cardiac speciality, in making clinical decisions. The system delivers diagnoses and prognoses based on the patient's present state of health by integrating anamnestic and instrumental data. Crucially, it takes into account the patient's prior clinical background, enhancing thorough evaluations. Additionally, the technology creates a useful database of heart failure patient data for later use. Notably, neural networks performed better than other AI techniques, correctly categorising 31 out of 36 patients in the test group and 98 out of 100 patients in the training population. The test population's overall accuracy was 86.10%, surpassing that of other methods.[16]

G. Health Monitoring after surgery:

In a different study, in-hospital mortality for patients having abdominal aortic aneurysm repair was predicted using Artificial Neural Networks (ANNs) and Machine Learning (ML) methods. ANNs and ML algorithms were trained with clinical variables such blood pressure, medication history, patient history, and duration of stay. High levels of sensitivity (87%), specificity (96.10%), and accuracy (95.40%) were demonstrated by the resulting prediction method. This illustrates how AI may be used to forecast surgical site health outcomes, offering insightful

information that enhances patient care and decision-making.[17]

These illustrations highlight how AI-driven PHM may revolutionise a range of healthcare settings by encouraging proactive action, ongoing monitoring, and enhanced clinical decision-making.[17]

H. Data Exchange for Artificial intelligence Users:

Artificial intelligence applications require data, and at the moment, there are several global, national, and local data-sharing programmes in operation. These projects deal with a wide range of data, such as genetic sequences, genomic analyses, protein structures, patient clinical information, medical images, event data, epidemiological data, movement data, remarks on social media, news articles, and scholarly publications. The hyper-fragmentation of these data-sharing initiatives presents a problem, too, as it can restrict progress to particular organisations and communities. The development of scalable methods for code, models, and data sharing is crucial to boosting the production and adoption of new AI applications. Connecting and fostering collaboration across many communities and geographic areas requires global, open, comprehensive, comparable, and verified data-sharing initiatives (Lip et al., 2020). (Luengo-Oroz & al., 2020).[17]

I. Open Science and Multi-Stakeholder AI Collaborations:

Open research is critical to increasing the rate of information diffusion and strengthening the capacities of national health systems, and it is facilitated by cross-border multi-stakeholder AI partnerships (Shaheen, 2021b). Initiatives like the Epidemic Intelligence from Open Sources (EIOS) network use open-source data to help identify, validate, and assess public health risks and hazards early on. Governments, international organizations, and academic institutions cooperate together in this network to detect early diseases rather than competing with one another. Particularly in the field of epidemiology, coordinated actions and decision-making at the local, national, and worldwide levels depend on global standards and database interoperability. It will be vital to consider public health campaigns, environmental variables, the capability of the health system's resources, and the socioeconomic effects of COVID-19 in order to comprehend the epidemiological traits and risk factors across various demographics (Sucharitha & Chary, 2021).[18]

J. AI assistance in diagnostics:

Effective illness diagnosis is still seen as a difficulty globally, despite all the advancements in medical science. Because the different disease processes and underlying symptoms are complicated, developing early diagnostic techniques is a continuous challenge. AI has the potential to change several facets of healthcare, including diagnosis. Machine learning (ML) is a branch of artificial intelligence (AI) that employs data as an input resource. Its accuracy depends heavily on the quantity and quality of the data input, and it can overcome some of the difficulties and complexity of diagnosis [19].

In summary, machine learning (ML) may help with decision-making, manage workflow, and automate jobs in a timely and economical way. Additionally, layers were added via deep learning using data mining and Convolutional Neural Networks (CNN) to assist find patterns in the data. These are quite useful for finding important patterns in large datasets that indicate the presence of illness. When it comes to identifying, forecasting, or categorizing illnesses, these instruments are quite useful in healthcare systems [20].

We're still a long way from completely utilizing AI for medical diagnostics. Nonetheless, more information is becoming available for the use of AI in the diagnosis of many illnesses, including cancer. An AI system for the diagnosis of breast cancer was trained with a sizable dataset of mammograms in a UK study that was published. According to this study, there was an absolute decrease in false positives and false negatives of 5.7% and 9.4%, respectively, when using an AI system to interpret mammograms [21]. In a different research, investigators compared radiologists' and AI's diagnosis of breast cancer in South Korea.

Compared to radiologists, the AI-utilized diagnosis had a 90% sensitivity rate vs. 78% for breast cancer with mass. Furthermore, AI detected early breast cancer 91% more accurately than radiologists 74% of the time [22]. Additionally, a deep learning study on skin cancer detection revealed that, in comparison to dermatologists, an AI utilizing CNN could correctly diagnose melanoma patients and suggest treatments [23, 24].

AI technology has been used by researchers to many additional disease states, including the detection of diabetic retinopathy [25], abnormalities in the electrocardiogram, and the prediction of risk factors for cardiovascular illnesses [26, 27]. Additionally, compared to radiologists' 50% and 73%, respectively, deep learning algorithms' 96% and 64% sensitivity and specificity for pneumonia from chest radiography [28]. The random forest algorithm performed the best, correctly predicting appendicitis in 83.75% of cases, with a precision of 84.11%, sensitivity of 81.08%, and specificity of 81.01%. This study was conducted on a dataset of 625 cases in order to diagnose acute appendicitis early and predict the need for appendix surgery.

The enhanced approach assists medical professionals in making well-informed choices regarding the diagnosis and treatment of appendicitis. Moreover, the authors propose that comparable methods could be applied to assess images of individuals with appendicitis or to identify infections like COVID-19 using either blood samples or images.[29]

K. Challenges and Opportunities in Model Sharing:

Even if a lot of data is shared, there aren't many projects at the moment that trade trained AI models for recommended applications. Difficulties include the need for specialised computing, design, and infrastructure; a deficiency of documentation; problems with verification and interpretability; and legal challenges pertaining to intellectual property and secrecy. It is essential to get past these challenges in order to share models effectively. Sharing already-trained and verified AI models may make it possible for solutions to adjust to a variety of circumstances more quickly. Algorithms that are commonly used include those that are used to diagnose diseases from pictures, forecast patient outcomes, removing false material from social media and gathering information from enormous databases of academic publications (Luengo-Oroz et al., 2020; Shaheen, 2021a; Harrer et al., 2019). Working together to share models and data is essential to improving the use of AI in the battle against COVID-19 and other global health issues.[18]

IV. CONCLUSION

Artificial intelligence (AI) is quickly taking the healthcare industry by storm, transforming both administrative and patient care. Even while AI has a lot of potential to help healthcare practitioners with a variety of activities, it's crucial to remember that the healthcare business is still in its infancy when it comes to AI. While some argue that AI can do certain things, including diagnosing illnesses, just as well as or even better than humans, a complete replacement of human functions in healthcare is still a ways off.

The application of AI in healthcare is always changing despite continual gains, as new research continues to expand and improve the technology. The healthcare industry, which is presently experiencing a rapid digital transition, stands to benefit greatly from the application of AI and machine learning. There is a significant chance that patients' quality of life will be improved.

When introducing new AI applications, safety and quality are of utmost importance, particularly in the healthcare sector. To preserve and improve the quality of AI techniques, compliance with rules, laws, and legal requirements is essential. The proposed regulatory framework for AI and ML-based technologies by the US

Food and Drug Administration is a step in the right direction towards tackling the latest difficulties in using AI to healthcare.

Developers of healthcare AI services are urged to join interest groups and evaluation frameworks in order to promote collaboration and assessment in the field. In order to advance the application of artificial intelligence in health through the creation of an evaluation framework, initiatives like the World Health Organisation and the International Telecommunications Union's Focus Group on Artificial Intelligence for Health bring together stakeholders from academia, industry, and government.

In the future, the project aims to create a model for a new AI platform that IT developers and healthcare practitioners alike may use. Using both open access and proprietary health data repositories, national health databases, hospital information systems, and imaging databases, the platform seeks to offer a cloud-based, open-access, readily integrated solution. The use of pre-trained models and AI techniques for quick, automatic, and precise diagnosis and prognosis will be made easier by this platform.

Explainable AI (EXAI) is becoming increasingly important as healthcare ecosystems move towards digital wellness and real-time prediction. For interpretability and model debugging, EXAI decision modules are preferred in Healthcare 5.0, where decision models are analytics-driven. By reducing bias, EXAI improves performance and fosters confidence in clinical procedures. The suggested survey presents models, structures, and approaches while outlining the application of EXAI in Healthcare 5.0. It presents a solution taxonomy backed by a case study that combines EXAI and Federated Learning (FL) for decentralised healthcare setups. Performance assessments confirm the advantages of EXAI in healthcare setups. In the end, the survey's lessons learned, research obstacles, and outstanding topics are discussed, with a focus on how AI is still influencing healthcare today.

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