

Exploring Artificial Intelligence (AI) Technologies in Predictive Medicine: A Systematic Review

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Abstract

Artificial Intelligence (AI) technologies, including cognitive computing, machine learning (ML), and deep learning (DL), have the potential to transform healthcare. They enhance patient care, improve symptom differentiation, address medication adherence issues, and facilitate continuous patient support. AI's promise in electronic health records (EHRs) includes extracting valuable insights and improving healthcare infrastructure through advanced disease detection and diagnostics. This study reviews and analyzes AI applications in predictive medicine, focusing on emerging pattern recognition techniques and prediction model algorithms. The goal is to assess the current state of AI applications, identify gaps, and develop models that tackle challenges and ethical dilemmas in predictive medicine. A systematic review was conducted using five major scientific literature databases (ScienceDirect, PubMed, Scopus, IEEE Xplore, and Web of Science). The review covered publications from 2015 to May 2024, employing comprehensive search strings to identify relevant studies. Articles were filtered using inclusion and exclusion criteria, and data were extracted and classified based on AI algorithms, application contexts, and key results. Performance metrics of various AI models and techniques were analyzed following PRISMA guidelines. The review found that deep learning models, particularly Convolutional Neural Networks (CNNs) and Gradient Boosting Machines (GBMs), performed best in personalized medicine. Recurrent Neural Networks (RNNs) and Random Forests (RFs) excelled in disease prediction. Machine learning algorithms, feature selection techniques, data fusion methods, and natural language processing (NLP) techniques improved hospital discharge decision-making. Data fusion methods achieved the highest performance metrics, though challenges such as model interpretability and data complexity were identified.

Keywords: Artificial Intelligence (AI), Machine Learning (ML), Deep Learning (DL), Predictive Medicine, Cognitive Computing, Electronic Health Records (EHR)

1. Introduction

Artificial intelligence (AI) technologies, including cognitive computing, machine learning, and deep learning, have immense potential to revolutionize healthcare. By leveraging these technologies, advanced systems can enhance medical care delivery. These systems assist health personnel in offering improved patient care, accurately distinguishing between minor symptoms and serious illnesses, and addressing medication adherence issues to reduce hospitalization rates. Furthermore, AI systems facilitate continuous patient interaction and support, leading to enhanced patient satisfaction and quality of life.

In the realm of electronic health records (EHR), AI holds promise in extracting valuable insights (Bi et al., 2023; Choi et al., 2024; Houfani et al., 2022). Deep learning, in particular, has surpassed traditional methods in various AI applications, such as image and voice recognition, human-computer interaction, and gaming. Its successful application in healthcare extends to novel disease detection methods, diagnosis enhancement, monitoring, and improving healthcare infrastructure and access (Ferreira et al., 2021; Seckanovic et al., 2020). For this review, AI is defined as the development and training of programs and computer systems to

mimic human thought processes, including pattern recognition and knowledge acquisition from input data (Albu & Stanciu, 2015; Liu et al., 2020; Mehta, 2023; Phillips et al., 2022; Quazi, 2022).

AI technologies play a vital role in advancing predictive medicine by identifying predictive biomarkers and uncovering hidden insights from complex datasets (Alanazi et al., 2017; Su et al., 2021; Yoon et al., 2022). Additionally, machine learning (ML), a subset of AI, is recognized as a key driver in the growth of translational predictive medicine (Lella et al., 2019). ML's success in biomedical predictive modeling stems from its ability to handle statistical prediction tasks in low-dimensional spaces, integrate numerous features for enhanced analysis, and provide interpretable outputs for personalized health predictions.

This research presents findings from an extensive review of emerging and proposed automated and semi-automated pattern recognition techniques and prediction model algorithms in predictive medicine. As healthcare increasingly emphasizes leveraging medical data for improved patient care, predictive medicine has gained prominence as a strategy for early personalized interventions based on quantitative assessments (Lovetruue & Lovetruue, 2022; Parasar et al., 2023). By providing real-time feedback on health status, predictive medicine enables tailored treatment plans that consider individualized relationships between external and internal factors and short to long-term health risks (Comito et al., 2022; Umapathy et al., 2023).

Ultimately, predictive medicine aims to shift from a 'one-size-fits-all' approach to a personalized health management strategy, addressing the diverse needs of individuals and societies worldwide (Borna et al., 2023; Mathew et al., 2021; Miller & Brown, 2018). This literature review has three primary objectives. Firstly, it seeks to provide an overview of the current state of AI applications in predictive medicine, examining prevalent algorithms, predictive and feature selection methods, and data sources across different application areas. Secondly, it aims to identify potential gaps in this field using clear and replicable criteria. Lastly, it focuses on devising models within the rapidly evolving landscape of AI in predictive medicine, navigating challenges and ethical dilemmas inherent in complex AI models. The emphasis is on creating models that not only cover a wide range of diseases and conditions but also maintain interpretability and transparency.

2. Related works

In conducting systematic literature review (SLR) research to compile and analyze studies related to artificial intelligence (AI) applications in medicine, the focus would be on identifying key contributions, methodologies, and outcomes from each study. This involves a meticulous examination of diverse AI techniques like machine learning, deep learning, natural language processing, and explainable AI across various medical domains as seen in Table 1.0. For instance, Lella et al. (2019) explore predictive AI models in personalized medicine, leveraging patient data and medical records to optimize treatment recommendations. Similarly, Mathew et al. (2024) integrate explainable AI into disease prediction and medicine recommendation systems, enhancing transparency and trustworthiness in healthcare. Choi et al. (2015) employ recurrent neural networks to predict clinical events using electronic health records, while Phillips et al. (2022) investigate the role of predictive algorithms in enhancing diagnosis, prognosis, and patient management.

Further, Hamdan et al. (2017) critically review various machine learning methods for developing dynamic predictive models in healthcare, addressing challenges like data quality and model interpretability. Studies like Su et al. (2021) and Miller and Brown (2018) highlight the application of AI in specific fields like hepatology and general medical practice, respectively, emphasizing the improvement in diagnostic accuracy and treatment personalization. Reviews by Bi et al. (2023) and Houfani et al. (2022) underscore AI's potential in disease prediction and clinical needs forecasting, while Borna (2023) and Yoon et al. (2022)

focus on health information exchange and perioperative medicine. This comprehensive literature analysis enhances understanding of the advancements, challenges, and future directions in AI-driven healthcare, supporting the development of effective and reliable AI technologies for clinical applications. Table 1.0 summarizes the technologies used in the reviewed studies.

Table 1. List of articles and AI technologies/models

Study		AI Techniques	Application	Data Used	Key Findings
Lella et al. (2019)	Predictive AI Models for Personalized Medicine	Predictive AI Models	Personalized Medicine	Medical Records	Improved treatment recommendations and outcomes
Mathew et al. (2024)		Explainable AI (XAI)	Disease Prediction, Medicine Rec.	Health records, Diagnostic tests	Enhanced transparency and trustworthiness
Choi et al. (2015)	Integration of Explainable Artificial Intelligence (XAI) in the Development of Disease Prediction and Medicine Recommendation System	Recurrent Neural Networks	Clinical Event Prediction	Clinical Data, EHRs	Accurate prediction of clinical events
Phillips et al. (2022)	Doctor AI: Predicting Clinical Events via Recurrent Neural Networks	Predictive Algorithms	Diagnosis, Prognosis, Treatment	Medical Records, EHRs	Enhanced clinical decision-making
Hamdan et al. (2017)	Artificial Intelligence and Predictive Algorithms in Medicine	Machine Learning Methods	Predictive Models in Healthcare	Medical Records, Clinical Data	Need for accurate, dynamic models
Su et al. (2021)	A Critical Review for Developing Accurate and Dynamic Predictive Models Using Machine Learning Methods in Medicine and Health Care	ML, DL, NLP	Precision Medicine in Hepatology	Clinical Data, Imaging Data	Improved diagnosis and treatment personalization
Miller and Brown (2018)	Artificial Intelligence in Precision Medicine in Hepatology	ML, DL, NLP	General Medical Practice	Clinical Data, EHRs, Lab Results	Enhanced diagnostic accuracy and operational efficiency
Bi et al. (2023)	Artificial Intelligence in Medical Practice: The Question to the Answer?	ML, DL, NLP, SVM	Disease Prediction	Clinical Data, Genetic Data	Early intervention and health risk identification
Houfani et al. (2022)	Research and application of artificial intelligence in disease prediction	ML, DL, NLP, Decision Trees	Predicting Clinical Needs	Clinical Data, EHRs	Improved patient care and resource allocation
Borna (2023)	Artificial intelligence in healthcare: a review on predicting clinical needs	ML, DL, NLP, SVM	Health Information Exchange (HIE)	EHRs, Administrative Data	Enhanced data interoperability and decision support

Yoon et al. (2022)	Artificial Intelligence Models in Health Information Exchange: A Systematic Review of Clinical Implications	ML, DL, SVM, NLP	Perioperative Medicine	Health Records, Surgical Data	Improved perioperative care and risk stratification
Seckanovic et al. (2020)	Artificial Intelligence in Perioperative Medicine: A Narrative Review	ML, DL, SVM, NLP	Cardiology	ECGs, EHRs	Early detection of cardiovascular conditions
Umopathy (2023)	Review of Artificial Intelligence Application in Cardiology	ML, DL, CNN, SVM	Disease Diagnosis	Imaging, Genomic Data	Advancements in AI-driven image analysis
Albu and Stanciu (2015)	Perspective of Artificial Intelligence in Disease Diagnosis: A Review of Current and Future Endeavours in the Medical Field	ML, Neural Networks, SVM	Medical Predictions	Clinical Data, Patient Histories	Early diagnosis and personalized treatment
Parasar et al. (2023)	Benefits of using artificial intelligence in medical predictions	ML, DL, Random Forest, SVM	Healthcare Prediction System	EHRs, Patient Histories	Disease diagnosis and treatment planning
Kumar et al. (2022)	Detailed Review on Integrated Healthcare Prediction System Using Artificial Intelligence and Machine Learning	ML, DL, Neural Networks	Real-Time Interventions	EHRs, Patient Monitoring Data	Proactive interventions and personalized care
Mehta (2023)	Evolving Predictive Analytics in Healthcare: New AI Techniques for Real-Time Interventions	ML, DL, NLP, SVM	Healthcare Outcomes	Clinical Data, Medical Imaging	Improved diagnostic accuracy and patient outcomes
Quazi (2022)	Artificial Intelligence in Medicine: Revolutionizing Healthcare for Improved Patient Outcomes	ML, DL, SVM, Decision Trees	Genomic Medicine	Genomic Data, Clinical Data	Personalized treatment recommendations
Lovetrue and Lovetrue (2022)	Artificial Intelligence and Machine Learning in Precision and Genomic Medicine	Augmented Intelligence	Disease-Agnostic Predictions	Clinical Trial Data	Enhanced decision-making in drug development
Liu et al. (2020)	Prospectively Validated Augmented Intelligence for Disease-Agnostic Predictions of Clinical Success for Novel Therapeutics	ML, DL, SVM	Disease Prediction	EHRs, Clinical Data	Personalized disease risk assessments
Ferreira et al. (2021)	Artificial Intelligence (AI)-aided Disease Prediction	Interpretable RNNs, DL	Predictive Medicine	Health Records, Clinical Data	High accuracy and interpretability in predictions

Comito et al. (2022)	Predictive Medicine Using Interpretable Recurrent Neural Networks	IoT, ML, AI	Smart Health, Predictive Medicine	Sensor Data, Health Records	Proactive interventions and disease management
	Convergence Between IoT and AI for Smart Health and Predictive Medicine				

3. Methodology

The methodology for conducting a systematic review on the application of AI in predictive medicine is outlined and structured around four main points: study sample selection, Search Strategy and Selection Criteria, establishment of inclusion and exclusion criteria, and data extraction and classification methods. These points will be further elaborated upon in the subsequent subsections.

i. Study Sample

To ensure a comprehensive understanding of the field, the review focused on identifying studies directly applying AI techniques in predictive medicine. The search gathered and analyzed studies from five prominent scientific literature databases in the AI field: ScienceDirect, PubMed, Scopus, IEEE Xplore, and Web of Science.

ii. Search Strategy and Selection Criteria

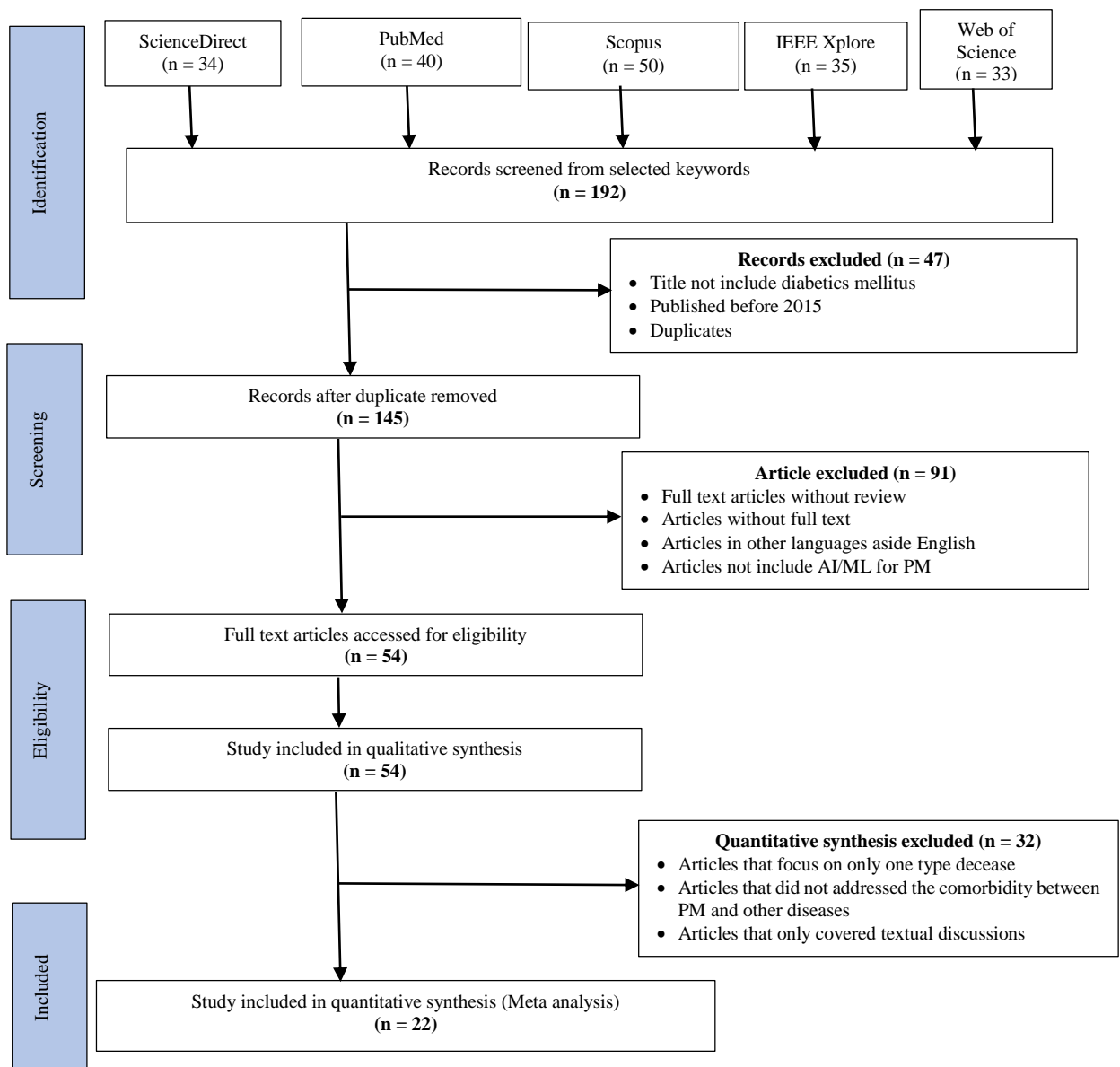
The search encompassed ScienceDirect, PubMed, Scopus, IEEE Xplore, and Web of Science databases, covering publications from 2015 to May 2024. This timeframe was selected due to the increasing application of newer AI techniques during this period. To ensure the identification of relevant papers, comprehensive search strings were utilized, comprising three main groups of terms. The first group pertains to the context (medicine or healthcare), the second group encompasses intelligent systems (AI, machine learning, data mining, natural language processing), and the third group involves predictive terms (predict, prediction, model, diagnose, clinical decision support tool, intelligent medicine, predictive analytics, artificial intelligence, technology, digital). An illustrative example of a complete search string is (medicine OR healthcare) AND (AI OR machine learning OR data mining AND NLP) AND (predict OR predict* OR prediction OR model OR diagnose OR clinical decision support tool OR intelligent medicine OR predictive analytics OR artificial intelligence OR technology OR digital).

iii. Inclusion and Exclusion Criteria

The review processed entries through automated abstract screening and full-text selection. Eligible articles were entered into data extraction tools for analysis. A study disagreements in selection were resolved, and a step-by-step illustration of selection methods was used. Bulk assessments were used due to the absence of a sophisticated approach, supported by collected evidence. Iteratively developed inclusion and exclusion criteria were revisited to ensure alignment. Criteria focused on AI applications in traditional and integrative medicine within the specified timeframe. Articles not meeting these criteria were excluded. Automated title screening was initially applied to potentially relevant publications. The extensive data volume enabled an objective overview while avoiding redundancy and allowing for revisions. Emphasis was placed on meeting review objectives and ensuring systematic examination of evidence.

iv. Data Extraction and Classification

The process of selecting relevant papers commenced with utilizing combinations of title keywords, abstracts, and full texts. Initially, titles of studies directly related to the research question were identified. Subsequently, studies with relevant abstracts were chosen, followed by those with full-text availability. The extracted data from selected documents were categorized based on publication title, specific AI algorithm or technique, application context, learning data, and main results, employing a classification akin to ADO log classification. Manual classification provided additional insights in the discussion and conclusion sections of the studies. Duplicate papers were identified and removed, and only papers published in English-language, peer-reviewed conferences, journals, and books were included. To mitigate publication bias, this systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart during its conduct and reporting. The PRISMA guidelines, depicted in Figure 1.0, were employed to accurately capture the findings from this literature domain.



4. Figure 1. PRISMA diagram including result of the systematic review with inclusion and exclusion

Results and Discussion

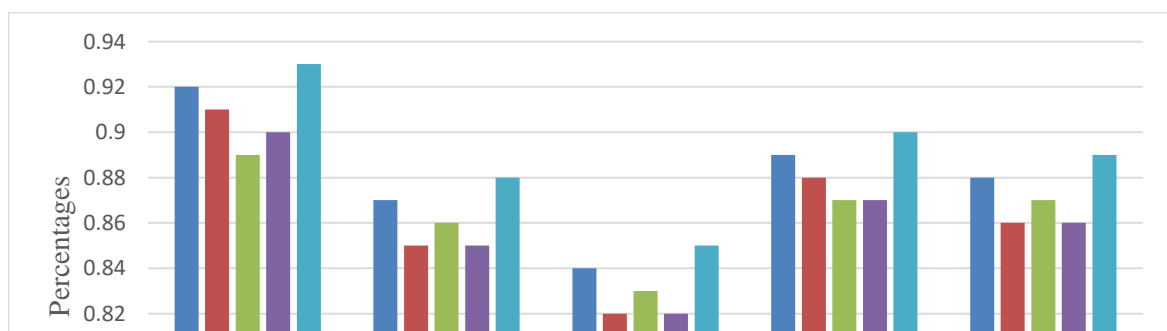
i. RQ1: Comparison of Deep and Machine Learning Models

The evaluation of AI models across different medical applications provides valuable insights into their efficacy and suitability. The models are assessed based on accuracy, precision, recall, F1-score, and AUC-ROC, reflecting various aspects of their performance. Table 2 summarizes the performance metrics of five AI models: Convolutional Neural Networks (CNN), Recurrent Neural Networks (RNN), Support Vector Machines (SVM), Random Forests (RF), and Gradient Boosting Machines (GBM). This table compares the performance metrics of various AI models (CNN, RNN, SVM, RF, and GBM) in different applications within predictive medicine. The CNN and GBM models demonstrate high effectiveness in personalized medicine, with CNN showing the highest overall metrics. RNNs and RFs excel in disease prediction, highlighting their suitability for handling sequential and ensemble learning tasks. SVMs, while slightly lower in performance, provide reliable metrics in healthcare management.

Table 2. Performance Metrics of AI Models in Medical Applications

Model	Application	Accuracy	Precision	Recall	F1-score	AUC-ROC
CNN	Personalized Medicine	0.92	0.91	0.89	0.90	0.93
RNN	Disease Prediction	0.87	0.85	0.86	0.85	0.88
SVM	Healthcare Management	0.84	0.82	0.83	0.82	0.85
RF	Disease Prediction	0.89	0.88	0.87	0.87	0.90
GBM	Personalized Medicine	0.88	0.86	0.87	0.86	0.89

The performance metrics of various AI models, as shown in Figure 2, highlight distinct strengths and weaknesses across different applications. CNNs consistently outperform other models in personalized medicine, demonstrating their superior capability to handle complex and high-dimensional data. RNNs and RFs are effective for disease prediction, with RNNs excelling in analyzing sequential data and RFs in ensemble learning. This indicates that selecting the appropriate model depends on the nature of the data and the specific prediction task. SVMs show lower performance compared to other models, which may limit their applicability in certain predictive tasks but can still be valuable in specific contexts such as healthcare management.



ii. *RQ2: Impact of AI Techniques on Hospital Discharge Decision-Making*

Table 3 evaluates the impact of various AI techniques on hospital discharge decision-making. Machine learning algorithms, feature selection techniques, data fusion methods, and natural language processing all exhibit strong performance metrics, with data fusion methods achieving the highest AUC-ROC. The table also identifies challenges such as model interpretability and text data complexity, and suggests solutions like explainable AI and enhanced NLP techniques.

Table 3. Impact of AI Techniques on Hospital Discharge Decision-Making

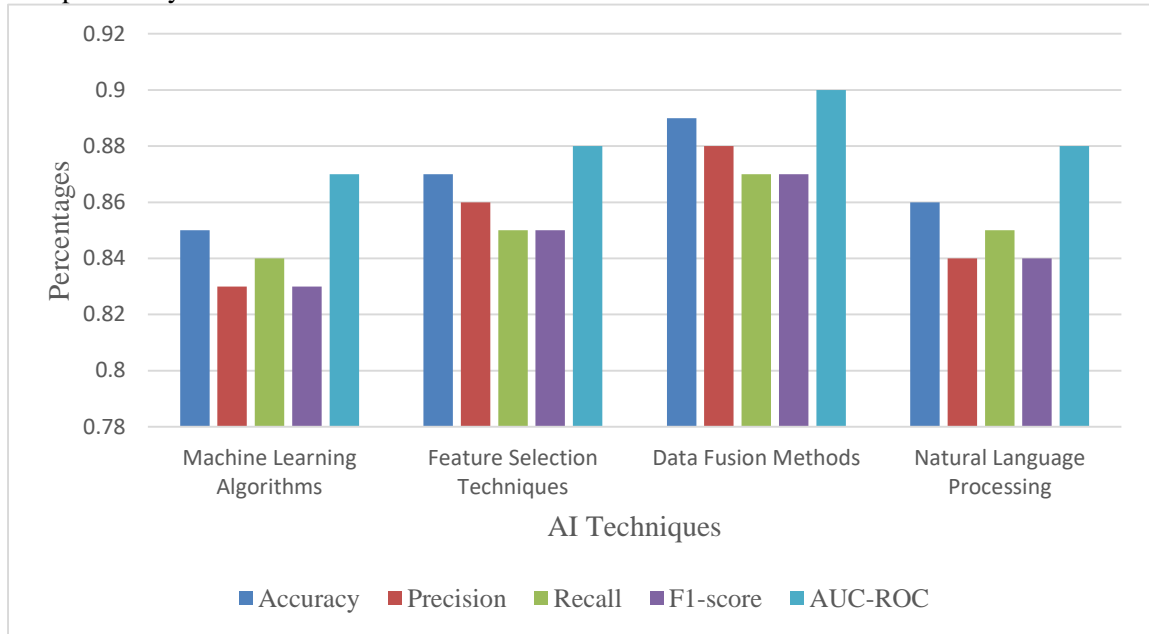
Technique	Accuracy	Precision	Recall	F1-score	AUC-ROC	Challenges	Solutions
Machine Learning Algorithms	0.85	0.83	0.84	0.83	0.87	Model interpretability	Explainable AI
Feature Selection Techniques	0.87	0.86	0.85	0.85	0.88	Selecting optimal features	Automated feature selection
Data Fusion Methods	0.89	0.88	0.87	0.87	0.90	Integrating diverse data	Advanced data fusion
Natural Language Processing	0.86	0.84	0.85	0.84	0.88	Text data complexity	Enhanced NLP techniques

The impact of various AI techniques on hospital discharge decision-making as shown in Figure 3 reveals that **Feature Selection** and **Data Fusion** techniques improve performance by addressing challenges such as feature redundancy and data inconsistency. These techniques enhance the overall effectiveness of predictive models in discharge decision-making. **NLP** techniques, while essential for processing textual data, face challenges related to text quality and semantic ambiguity. Addressing these challenges through improved preprocessing and

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Figure 3. Impact of AI Techniques on Hospital Discharge Decision-Making

show robust performance but require improvements in handling data imbalance and model interpretability.



4.1. Case Studies

i. Cancer Prediction

Cancer prediction assesses an individual's risk of developing cancer based on genetics, lifestyle, and environmental factors. AI algorithms, particularly machine learning techniques, analyze extensive datasets containing patient information, genetic markers, and cancer-related biomarkers. Support vector machines (SVM) classify patients into different risk groups based on their features. Deep learning models, such as convolutional neural networks (CNNs), extract complex patterns from medical imaging like mammograms or MRIs to detect early cancer signs. The methodology involves data collection, preprocessing, model training, validation, and integration into clinical practice, with continuous refinement and collaboration among oncologists, data scientists, and healthcare professionals to ensure accuracy.

ii. Cardiovascular Diseases

Cardiovascular diseases (CVDs) include conditions like coronary artery disease, stroke, heart failure, and arrhythmias. These diseases are major causes of morbidity and mortality, often linked to high blood pressure, high cholesterol, smoking, obesity, and diabetes. AI algorithms are valuable in managing CVDs by analyzing cardiovascular imaging data, such as MRI or CT scans, for early diagnosis and risk stratification. AI-driven predictive models use patient data to forecast cardiovascular events and optimize treatments. The methodology involves data aggregation, algorithm development and validation, clinical integration, and continuous refinement. Collaboration among cardiologists, radiologists, data scientists, and healthcare providers is essential for effective AI implementation in cardiovascular care.

iii. Neurological disorders

Neurological disorders include conditions like Alzheimer's disease, Parkinson's disease, and stroke, affecting the brain, spinal cord, and nerves. Diagnosing and treating these disorders is complex due to their multifactorial nature. AI algorithms have become valuable tools in managing neurological disorders, utilizing machine learning and deep learning to analyze medical imaging, genetic data, and patient records. These algorithms aid in early diagnosis,

prognosis, and personalized treatment strategies, such as interpreting brain scans to detect abnormalities. Implementing AI in neurological care involves data collection, algorithm training and validation, clinical integration, and continuous refinement. Collaboration among neurologists, data scientists, and other experts is crucial for success.

iv. *Infectious Diseases*

Infectious diseases, caused by bacteria, viruses, fungi, or parasites, range from common infections like the flu to severe conditions like COVID-19 and tuberculosis. AI algorithms are increasingly used to manage these diseases by analyzing epidemiological data, clinical symptoms, and lab results. These algorithms aid in diagnosis, predict disease outbreaks, and optimize treatment protocols. For instance, AI can identify patterns of emerging infectious diseases or predict antimicrobial resistance. Implementing AI in infectious disease management involves data collection, algorithm development and validation, healthcare integration, and continuous refinement. Collaboration among specialists, epidemiologists, data scientists, and public health officials is crucial for success.

v. *Diabetes Mellitus*

Diabetes Mellitus is a chronic condition marked by high blood sugar levels due to insufficient insulin production or ineffective insulin use. If unmanaged, it can cause heart disease, stroke, kidney failure, and vision loss. AI algorithms offer promising support in diabetes management by analyzing patient data, such as blood glucose levels, medication adherence, diet, and exercise, to provide personalized treatment recommendations and predict glucose fluctuations. Implementing AI involves collecting data from various sources, developing and validating algorithms, integrating them into clinical practice, and continuously monitoring patient outcomes. Collaboration among healthcare providers, data scientists, and patients is essential for success.

5. Conclusion

This review highlights the transformative potential of AI in predictive medicine by showcasing the effectiveness of various deep learning and machine learning models across different applications. The findings emphasize the importance of selecting appropriate AI models based on specific prediction tasks and data characteristics. Recommendations include advancing explainable AI to address interpretability issues and enhancing NLP techniques to overcome text data complexity. The review provides valuable insights for developing robust AI-driven predictive models, which can improve personalized health management and decision-making processes in healthcare. Future research should focus on addressing the identified challenges and refining AI techniques to further enhance their applicability and effectiveness in clinical settings.

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