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Review on AI-Driven Innovations in Stroke Care: Enhancing Diagnostic Accuracy, Treatment Efficacy, and Rehabilitation Outcomes

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Stroke remains one of the leading causes of both disability and mortality worldwide, requiring immediate intervention to limit brain damage and prevent complications. Integrating artificial intelligence (AI) into stroke management has revolutionized diagnostic, treatment, and rehabilitation processes, offering new opportunities for improving precision and outcomes. This study investigates the current tools, applications, and challenges associated with AI-assisted decision support systems in stroke management to enhance diagnostic accuracy, treatment efficacy, and personalized care. Through an extensive review, we analyzed how AI plays a pivotal role in stroke care, including diagnostic imaging, treatment decision-making, and rehabilitation. AI demonstrated remarkable accuracy in MRI and CT stroke detection, significantly improving diagnostic efficiency. AI-powered decision support systems optimized treatment plans, particularly in selecting candidates for thrombolysis and mechanical thrombectomy, thereby reducing mortality and improving outcomes. AI-driven rehabilitation programs provide personalized therapy, enhancing motor recovery and patient outcomes. Despite its potential, challenges such as data heterogeneity, privacy concerns, and the need for large, diverse datasets remain significant barriers. Overall, AI has proven to be transformative in stroke care, streamlining diagnostic, treatment, and rehabilitation processes. Its continued advancement may further refine predictive models and create more effective, tailored healthcare interventions globally.

Keywords: Stroke; AI-driven innovations; diagnostic accuracy; chronic disability.

1. INTRODUCTION

Stroke is one of the leading causes of chronic disability and death worldwide, representing an immense public health challenge [1]. Once clinical signs indicate a potential disruption in cerebral circulation, prompt medical intervention must occur immediately to mitigate brain damage and potential complications [1,2]. Stroke is the second-leading cause of death and disability worldwide, estimated to cost an estimated $721 billion [3,4]. While stroke rates tend to vary according to gender, males generally face higher age-adjusted rates - although women face their unique risks related to pregnancy [3,4]. Genes can increase specific individuals' risk through hereditary disorders or mutations that increase susceptibility to risk factors like hypertension and diabetes [4,5]. Common risk factors for stroke are HTN, smoking, DM, obesity, cardiovascular disease, and older age - as well as a family history of stroke [4,5]. Symptoms may include difficulty speaking, numbness or weakness on one side of the body, vision problems, severe headaches, or difficulty walking [6]. Diagnosis typically includes blood tests, CT scans, MRIs, or other specialized imaging tests [5,6]. Management of stroke depends on whether it is ischemic or hemorrhagic, with possible treatments including tissue plasminogen activators, blood-thinning medications, thrombectomy, and interventions such as angioplasty [5-7]. Prompt medical intervention and rehabilitation play an integral part in mitigating brain injury, with rehabilitation focused on rebuilding strength, speech, and functional abilities [7,8]. Integrating AI into decision support systems has revolutionized stroke management, allowing clinicians to diagnose, treat, and predict outcomes more precisely and rapidly than before [9]. AI systems use vast datasets to uncover patterns that elude human analysis, providing invaluable assistance with decision-making processes [9,10]. This is especially vital in stroke management, where factors like type, location, and extent all play an essential role in treatment plans [9,10]. AI's role extends into rehabilitation, where it can customize recovery plans, predict recovery trajectories, and adjust the rehabilitation process based on the patient's progress, enhancing rehabilitation effectiveness and patient outcomes [11-15]. Integrating AI into clinical settings presents multiple hurdles, including data privacy issues and the requirement of large, diverse datasets [16,17]. Despite these difficulties, AI holds great promise for stroke management, offering sophisticated predictive models and personalized treatment strategies and creating more effective healthcare interventions globally [18,19]. This article investigates current tools and challenges associated with AI-assisted decision support systems for stroke management, with particular attention paid to improving diagnosis precision, treatment efficacy, personalized care, and emphasizing timely and effective stroke care.

2. METHODOLOGY

This review followed PRISMA guidelines to examine the role of AI in stroke management, with specific emphasis placed on diagnostic accuracy, treatment efficacy, and rehabilitation outcomes. A comprehensive literature search was performed using PubMed, Scopus, and IEEE Xplore databases from January 2010 to December 2023 using keywords like Artificial Intelligence, Stroke Management, Diagnosis, Treatment, and Rehabilitation. Attracting articles regarding AI applications in stroke diagnosis, treatment, or rehabilitation was vital, while exclusion criteria consisted of non-peer-reviewed studies or those not related directly to stroke management. After screening 110 studies with two independent reviewers through title, abstract, and full-text reviews, only 62 met our eligibility criteria. Data extraction utilized a standard form to capture study design, AI techniques (such as machine learning (ML) algorithms, deep learning models, and neural networks), outcomes, and critical findings before synthesizing these qualitatively to provide an expansive overview. The quality evaluation utilized the Newcastle-Ottawa Scale and Cochrane Risk of Bias Tool to resolve discrepancies through reviewer consensus. It provided an in-depth examination of AI's effect on stroke management with insights into its potential and limitations.

Fig. 1 shows the screening and selection of the studies according to PRIMSA guidelines.

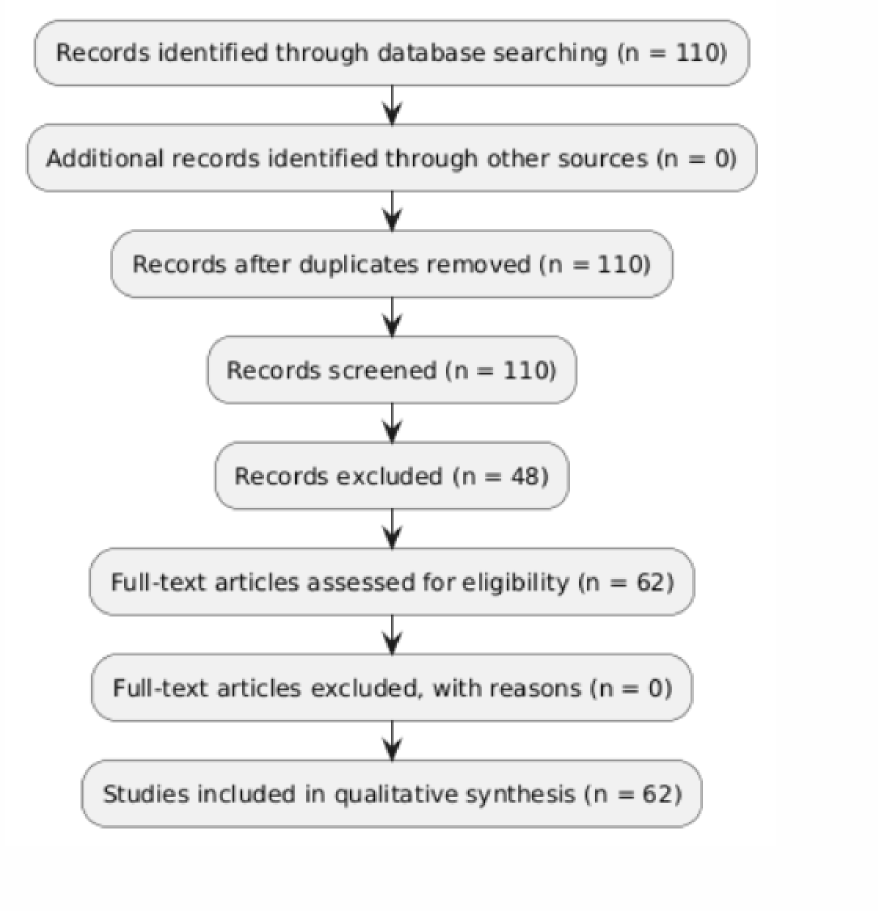

Fig. 1. PRISMA Flowsheet

3. RESULTS AND DISCUSSION

AI integration in stroke management has shown promising advances across diagnostic, treatment, and rehabilitation stages [15–18]. This discussion delves into the implication of these findings, emphasizing AI's transformative potential in improving clinical outcomes. By reviewing current applications and outlining possible challenges that AI presents to stroke care, we aim to present a complete picture of AI's place within stroke treatment. This review underscores the necessity of continued innovation and collaboration within this sector to overcome existing hurdles and fully realize AI-powered healthcare solutions. Integrating AI in stroke care provides a valuable comparison with traditional human intelligence methods [19–24]. Table 1 highlights differences and synergies between human Intelligence and AI when applied to various aspects of stroke care, ranging from feature identification and imaging interpretation to clinical assessment and treatment decision-making.

3.1 Artificial Intelligence (AI) in Diagnostic Imaging

AI has revolutionized diagnostic imaging, particularly in stroke management, by leveraging advanced algorithms and deep learning models to enhance the precision and usefulness of stroke diagnosis and treatment [9]. AI algorithms, especially convolutional neural networks (CNNs), have demonstrated significant capabilities

Table 1. Comparative Evaluation of Artificial and Human Intelligence Systems in Stroke Management

Aspect	Human Intelligence	Artificial Intelligence
Feature Identification	Non-contrast CT — ASPECTS scoring, hypodensity detection, CT angiography — clot detection and collateral assessment, CT perfusion — novel post-processing and quantification of lesion characteristics, Collection of clinical features (for example, age, NIHSS, demographics) to identify critical features associated with adverse events and treatment response	Multimodal, Non-contrast CT, CT angiography, CT perfusion, Age, NIHSS, risk factor identification, Frailty examination, Patient history
Imaging Interpretation	Severity grading, Identification of markers of adverse events, Tissue outcome prediction	Automated interpretation and quantification of imaging data, Pattern recognition to identify subtle changes undetectable by humans
Clinical Assessment	Collection and analysis of clinical features (age, NIHSS, demographics), Manual integration of patient history and risk factors	Integration of comprehensive clinical data and ML algorithms to identify key features associated with adverse events and treatment response
Patient Outcome Prediction	Prediction based on clinical and radiological features	Advanced predictive models analyzing vast datasets, High accuracy in predicting patient outcomes based on clinical and radiological features
Treatment Decision	Treatment recommendations based on clinical experience and guidelines, Prediction of adverse outcomes based on clinical judgment	Automated decision support systems offering treatment recommendations, Predictive analytics for adverse outcome prediction, and overall outcome prediction

CT: Computerized Tomography, NIHSS: National Institutes of Health Stroke Scale, ASPECTS: Alberta Stroke Program Early CT Score, Machine Learning: ML in interpreting neuroimaging, effectively distinguishing between ischemic and hemorrhagic strokes on CT and MRI scans [9,10]. A notable study published by Yousef Gheibi et al. highlighted that CNNs could accurately detect infarcts and hemorrhages, segment affected areas, and classify stroke types, substantially aiding in timely decision-making during acute stroke events [11]. Additionally, AI-based clinical decision support systems (CDSS) have been developed to assist clinicians by integrating various AI techniques to analyze imaging data, predict patient outcomes, and recommend treatment protocols [12]. However, challenges such as data heterogeneity, methodological robustness, and integration into clinical workflows remain [12]. Data heterogeneity, arising from different imaging modalities, patient demographics, and clinical settings, affects the performance and generalizability of AI models [11,12]. Ensuring methodological robustness through standardized protocols and rigorous validation is crucial for the clinical translation of these AI models [12]. Fig. 2 showcases brain MRI scans where artificial intelligence has highlighted stroke-affected regions in the lower slices with red markers, indicating areas of abnormal activity or damage for precise diagnosis and treatment planning.

Moreover, integrating AI tools into existing clinical workflows requires comprehensive training for clinicians to fully trust and understand AI recommendations [10-12]. Despite these challenges, AI applications in acute stroke imaging have shown promise

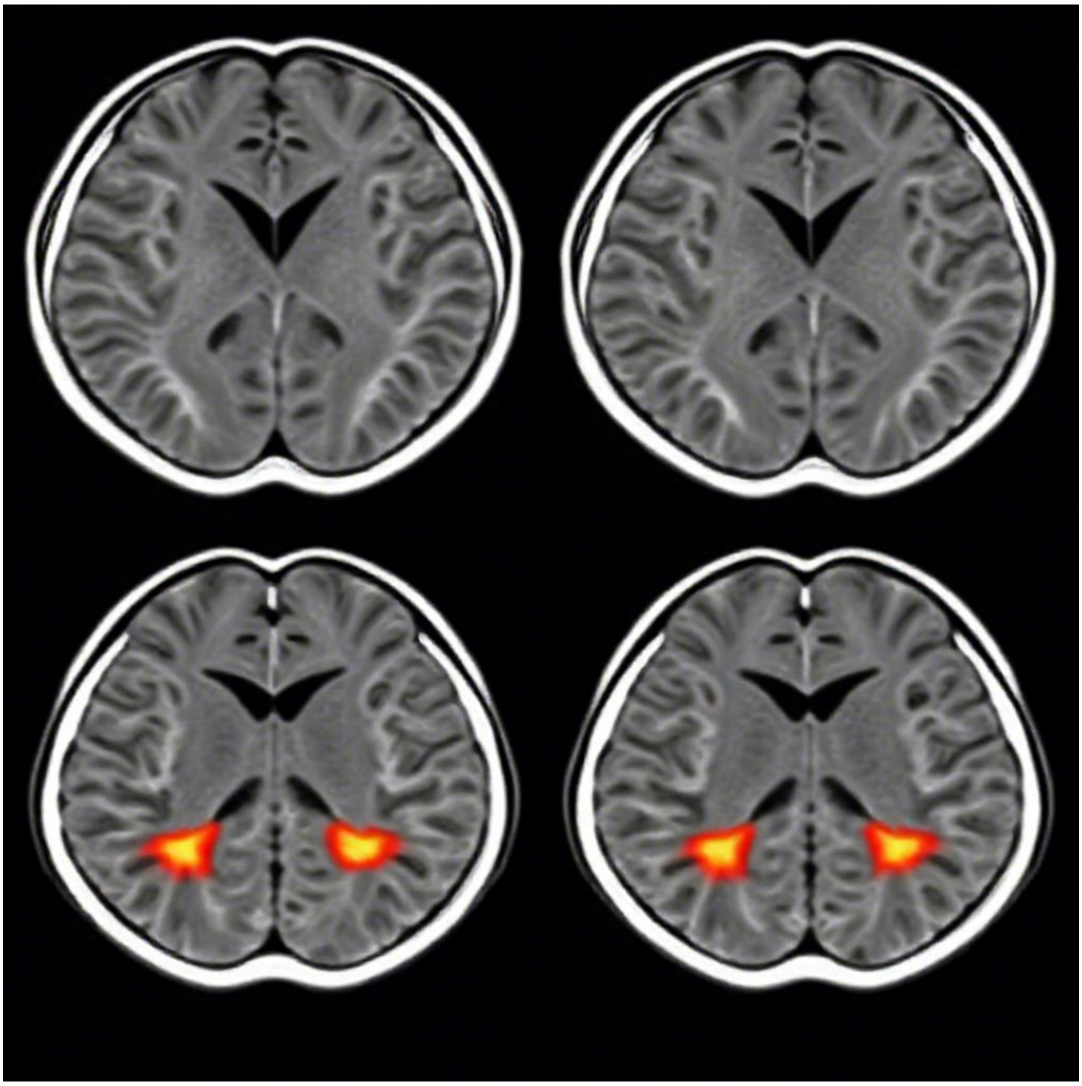

Fig. 2. AI-Assisted Stroke Detection in Brain MRI Scans
AI: Artificial Intelligence, MRI: Magnetic Resonance Imaging

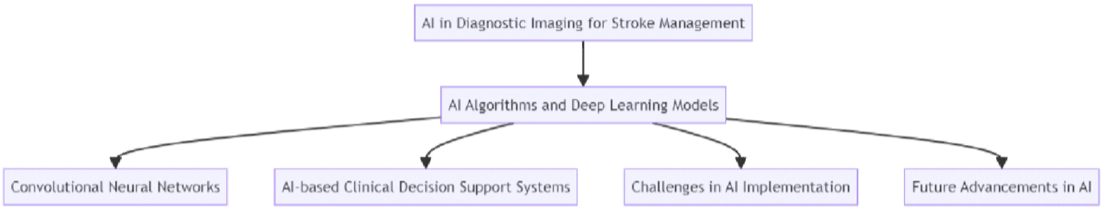

Fig. 3. AI Integration in Diagnostic Imaging for Stroke Management: Key Components and Future Directions
Artificial Intelligence: AI

in reducing diagnosis time and improving treatment outcomes [10-12]. AI's role in prognostication, using ML models to predict patient outcomes based on imaging and clinical data, allows for personalized treatment plans and better resource allocation [12,13]. Comparative studies indicate that deep learning models excel over traditional ML techniques regarding precision and efficiency, although they require large datasets and significant computational resources [13,14]. Future advancements in AI are expected to enhance imaging techniques further, improve real-time analysis capabilities, and integrate with other emerging technologies, such as telemedicine and wearable devices, providing comprehensive stroke management solutions [14,15]. This integration could facilitate remote monitoring and timely interventions, ultimately transforming clinical practice and improving patient outcomes [14,15]. Continued research and technological advancements persist in addressing existing challenges, making the future of AI in stroke imaging promising with the potential for significant improvements in diagnostic accuracy, treatment efficacy, and overall patient care. Fig. 3 shows the diagram depicting the role of AI in diagnostic imaging for the management of stroke.

3.2 Predictive Analytics in Stroke

Predictive analytics using ML has significantly advanced stroke management, particularly in forecasting stroke risk and outcomes, providing more accurate and personalized predictions [16]. This discussion delves into the latest clinical studies, comparing and contrasting different approaches and highlighting new predictions and advancements in AI for stroke management. ML models involving logistic regression, support vector machines (SVM), random forests, and deep learning models have been extensively used to predict stroke risk [17]. For instance, Matthew Chun et al. (2021) published a study comparing various ML models for stroke risk prediction in a cohort of 0.5 million Chinese adults [18]. The study found that gradient-boosted trees (GBT) provided the best discrimination and calibration for predicting 9-year stroke risk, with an area under the receiver operating characteristic (AUROC) of 0.833 in men and 0.836 in women [18]. Ensemble models, which combine multiple ML algorithms, have shown superior performance in stroke prediction [18,19]. The same study by Chun M. et al. also highlighted that an ensemble approach combining GBT and Cox regression models achieved higher accuracy and specificity compared to single-model approaches, with an accuracy of 76% in men and 80% in women and a specificity of 76% in men and 81% in women [18,19]. Researchers conducted different comparative studies by comparing the efficacy of traditional and ML models [18-20]. Chuan Hong et al. (2023) compared the performance of existing stroke-specific risk prediction models and novel ML techniques [20]. It found that while ML models did not significantly improve discriminative accuracy over traditional models like the CHA2DS2-VASc score, they offered better calibration and could potentially address racial disparities in stroke prediction [20]. The study's discrimination C indexes were similar for stroke-specific models (Framingham stroke: 0.72; REGARDS self-report: 0.73) and pooled cohort equations (0.72). Significant differences were observed by race, with lower discrimination in Black individuals (C indexes: 0.69 in Black women, 0.64-0.66 in Black men) compared to White individuals [21]. Deep learning models, particularly CNNs, have shown promise in stroke imaging and risk prediction [22]. Fig. 4 shows the role of CNNs in neuroimaging, enhancing the capability to manage stroke.

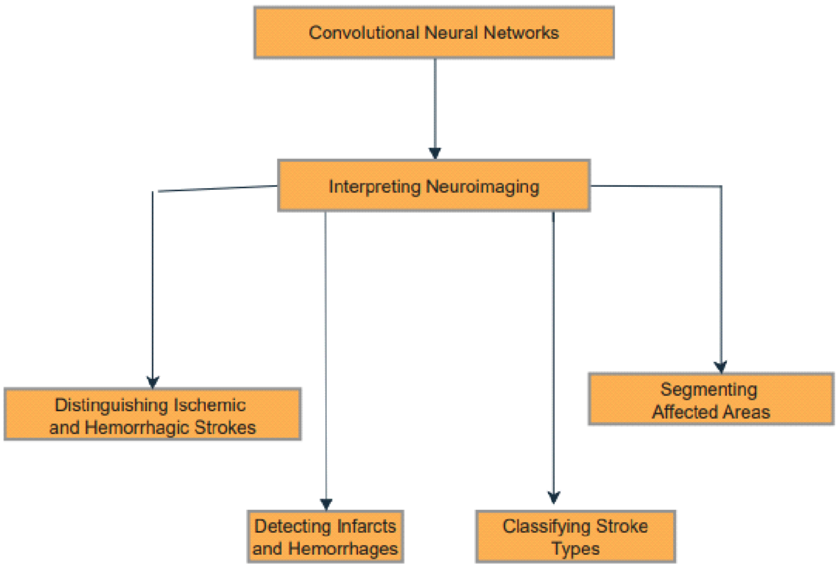

Fig. 4. Key Applications of CNNs in Neuroimaging for Stroke Management
Convolutional Neural Networks: CNNs

A systematic review by Mainali S. et al. (2021) in Frontiers in Neurology discussed the advancements in deep learning techniques for stroke diagnosis and outcome prediction, emphasizing their improved accuracy over traditional ML models [23]. This review highlighted the potential of ML for improving clinical decision-making, though it noted challenges such as small sample sizes and the need for data collation [23]. A systematic review by Meng Chen et al. (2024) included 41 studies using ML algorithms for predicting ischemic stroke outcomes [24]. It analyzed risk factors, data sources, model building, and validation [24]. Cardiovascular diseases, age, sex, NIHSS score, and diabetes were the top risk factors identified [24]. The review noted that many studies used single-center data and lacked external validation, highlighting the need for improved research practices [24]. Kyu Sung Choi et al. (2022) comprehensively reviewed AI applications in neuroimaging and the clinical applications of AI, including stroke detection, Prediction, and image quality improvement [25]. AI showed potential in improving detection and prediction accuracy in neuroimaging, though challenges such as standardization and data sharing were noted [25]. Real-time analysis of imaging data using AI could become standard practice, allowing for immediate decision-making during critical periods, such as the acute phase of a stroke [26]. This capability is significant for thrombectomy and thrombolysis decisions, where every minute counts [26]. AI is expected to integrate with other emerging techniques, such as wearable gadgets and telemedicine, to give comprehensive stroke management solutions [27]. This integration could facilitate remote monitoring and timely interventions, ultimately transforming clinical practice and improving patient outcomes [27]. For example, wearable devices could continuously monitor vital signs and detect early signs of stroke, triggering timely alerts and interventions [27]. AI advancements are expected to enhance imaging techniques further, improving the resolution and contrast of imaging modalities [28]. This will facilitate detecting subtle changes in brain tissue, aiding in early and accurate stroke diagnosis [27]. Enhanced imaging techniques are poised to improve the detection of ischemic and hemorrhagic strokes, thereby enabling timely intervention [28].

Additionally, large and diverse datasets are needed to train AI models for their generalizability and performance [32]. Collaborative efforts between healthcare institutions, researchers, and technology companies can facilitate the creation of comprehensive datasets [33]. Integrating AI tools into clinical workflows requires extensive training for clinicians to trust and fully understand AI recommendations [34]. This involves technical training and fostering a culture of collaboration between AI systems and healthcare professionals [35]. Developing user-friendly AI interfaces and continuous education programs can support this integration [36]. Despite these challenges, the future of AI in stroke management holds promise [36]. Developing sophisticated predictive models and personalized treatment strategies can pave the way for more effective healthcare interventions globally [37]. AI has the potential to revolutionize stroke management by enhancing diagnostic accuracy, optimizing treatment plans, and improving patient outcomes [38]. A growing body of evidence supports AI's ability to enhance diagnostic accuracy, optimize treatment plans, and improve patient outcomes [39]. Despite challenges like data privacy concerns and the need for large, diverse datasets, the future of AI in stroke management holds promise [39]. Developing sophisticated predictive models and personalized treatment strategies can pave the way for more effective healthcare interventions globally [40]. Ongoing research and technological advancements persistently aim to tackle existing challenges, making the future of AI in stroke management promising with the potential for significant improvements in diagnostic accuracy, treatment efficacy, and overall patient care.

3.3 AI in Personalized Rehabilitation

AI-driven platforms are being developed to provide personalized rehabilitation programs [33]. These platforms use ML algorithms to analyze patient data and predict recovery trajectories [33]. A systematic review by Campagnini et al. (2022) analyzed various ML methods for predicting functional recovery in post-stroke rehabilitation [34]. The review highlighted the effectiveness of linear and logistic regression algorithms in predicting motor functional recovery while pointing out limitations such as small sample sizes and high heterogeneity among input and output variables [34]. Robotic systems integrated with AI are increasingly used to assist in physical therapy [35]. These systems can adapt to the patient's progress and provide real-time feedback [35]. A study by Lee et al. (2022) focused on designing and evaluating AI and robotic coaches for rehabilitation exercises [36]. Through iterative design and feedback from therapists and patients, the study emphasized the benefits of such systems in managing therapy and enhancing patient motivation, despite some concerns about usability for patients with cognitive impairments [36]. White et al. (2023) evaluated deep learning and multimodal data for predicting recovery following stroke [37]. The researchers used CNNs trained on MRI and tabular data to predict post-stroke recovery outcomes [38]. Results depicted the highest classification accuracy (0.854), area under the curve (0.899), and F1 score (0.901) when combining regions of interest from MRI scans with lesion size, initial severity, and recovery time in a 2D Residual Neural Network [38]. AI in personalized rehabilitation for post-stroke patients holds immense potential to transform clinical practice. The future of AI in rehabilitation appears promising, with innovations in imaging techniques, real-time data analysis, and the incorporation of various technologies to significantly enhance patient outcomes.

3.4 Challenges and Future Directions in AI for Diagnostic Imaging

Ensuring patient data privacy is a significant challenge in AI-driven diagnostic imaging. AI systems require large datasets to train effectively, but these datasets often contain sensitive patient information [39]. Protecting this data from breaches is paramount [39]. According to a study by Santini et al. (2023), data privacy concerns are exacerbated by the need for data sharing across institutions to improve model robustness, raising the risk of unauthorized access [39]. The secure storage and transmission of data are crucial for preventing breaches and ensuring compliance with regulations such as GDPR and HIPAA [40]. Encryption and secure access protocols are essential measures highlighted by de Aguiar EJ et al. (2023) to safeguard patient data in AI applications [41]. Clinicians often find it challenging to interpret AI-generated recommendations, especially when the AI's decision-making process is not transparent [42]. This lack of transparency, or "black box" nature of AI, can hinder clinical integration and trust [42]. According to a study by Weina Jin et al. (2022), enhancing the interpretability of AI models through explainable AI techniques is crucial for gaining clinician trust [43]. Building confidence in AI systems among healthcare professionals is essential, and clinicians must be confident that AI recommendations are reliable and accurate [43]. This sentiment is echoed in a Jana Fehr et al. (2023) survey, which found that transparency and reliability influence clinician acceptance of AI tools [44]. Deep learning models could improve lung cancer detection accuracy compared to traditional methods [45]. The survey by Ardila et al. (2019) showed that AI could identify lung cancer with a high degree of accuracy, potentially outperforming radiologists in some cases [45]. Another study by Amy Yuan et al. showed that AI could predict the development of diabetic retinopathy, aiding in personalized treatment plans [46]. The survey by Gunasekeran et al. (2019) found that AI models could effectively stratify patients based on their risk of developing retinopathy, enabling timely interventions [47]. A systematic review by Zhao Q found that AI models had high sensitivity and specificity in diagnosing fatty liver disease using imaging techniques like MRI and ultrasound [48]. They highlighted the potential of AI to accurately identify fatty liver, which is critical for early intervention [47,48]. This study confirmed the effectiveness of AI in detecting fatty liver, emphasizing the need for further high-quality studies to validate these findings [47,48]. The meta-analysis by Miriam Cobo et al. (2023) pointed out the importance of standardizing imaging protocols to enhance the generalizability of AI models [49]. Research published in BMC Medical Imaging showed that AI algorithms could accurately detect intracranial aneurysms, reducing missed detections and false positives [49]. They demonstrated the potential of AI to improve diagnostic accuracy and reduce the burden on radiologists [49]. Comparative analyses indicated that AI could provide quantitative data on aneurysm attributes, aiding in long-term monitoring and risk assessment [50]. The research by Zhongjian Wen et al. (2024) highlighted the role of AI in providing detailed aneurysm characterization, which is crucial for personalized treatment planning [50]. Future research aims to develop comprehensive predictive models based on individual pathophysiology [51]. These models will enable standardized assessments and personalized treatment plans [51]. They discussed integrating genetic, phenotypic, and clinical data to create predictive models to tailor treatment to individual patients [52]. AI systems will increasingly integrate with electronic health records (EHRs) to provide real-time decision support and improve patient outcomes [52]. This integration is a crucial driver for the widespread adoption of AI in clinical practice [52]. Continued advancements in deep learning techniques will enhance the accuracy and efficiency of AI in diagnostic imaging [53]. A review by Litjens et al. (2023) emphasized the role of CNNs and other deep-learning architectures in improving diagnostic performance [53,54]. A study by Obermeyer et al. (2019) highlighted the potential for AI to perpetuate existing biases in healthcare if not carefully managed [55]. Developing robust regulatory frameworks to ensure AI's safe and effective use in clinical practice will be essential [55]. Regulatory bodies must establish guidelines for developing, validating, and deploying AI tools in healthcare [56,57,66]. Integrating AI into diagnostic imaging can revolutionize healthcare by improving accuracy, efficiency, and personalized care. However, addressing challenges related to data privacy, dataset diversity, and clinical integration is crucial. Future research and advancements in AI algorithms, predictive models, and ethical considerations will pave the way for more effective and reliable AI-driven diagnostic tools. Fig. 5 shows the future predictions for AI-integrated management of stroke.

3.5 AI-Assisted Decision Support Systems (AI-DSS) Overview

AI-Assisted Decision Support Systems (AI-DSS) have been developed to aid clinicians in making timely and accurate decisions across various fields, including healthcare, finance, and operations research [28, 58]. These systems integrate AI techniques to analyze data, predict outcomes, and recommend protocols, significantly transforming decision-making processes [28,58]. AI-DSS assists in diagnosis, treatment planning, and predicting patient

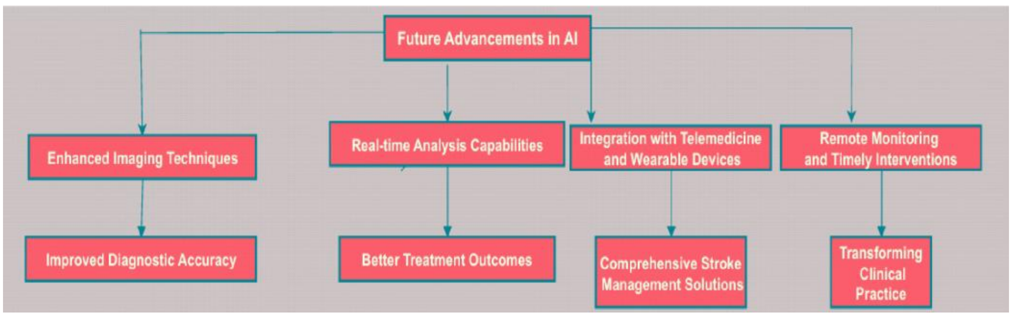

Fig. 5. Future Advancements in AI and Their Impact on Stroke Management
Artificial Intelligence: AI

outcomes [58]. For instance, a systematic review by Akay et al. (2022) included 121 studies on AI-DSS for acute ischemic stroke, highlighting the heterogeneity in data sources, methods, and reporting practices [29]. AI tools have been instrumental in selecting candidates for thrombolysis and mechanical thrombectomy [28]. A study by Ben Alaya et al. (2023) reviewed AI methods that utilize multiple MRI features to recognize patients who benefit from acute reperfusion therapies, showing improved sensitivity and specificity compared to traditional mismatch assessments [30,31]. A clinical trial across four comprehensive stroke centers demonstrated that AI-driven software significantly speeds up the detection of large vessel occlusion (LVO) in stroke patients, reducing treatment time and potentially improving outcomes [31]. The automated system was linked to a 60% drop in mortality rates [31].

Additionally, a study presented at the American Stroke Association's International Stroke Conference 2024 showed that ischemic stroke survivors who received care recommendations from an AI-based system had fewer recurrent strokes, heart attacks, or cardiovascular deaths within three months compared to individuals whose treatment was not guided by AI tools [32]. AI models like Long Short-Term Memory (LSTM) networks have also been used to predict patient needs in holistic healthcare, significantly improving sensitivity and specificity compared to traditional rule-based systems [58]. These systems can analyze patient records, imaging data, and genetic information to provide comprehensive diagnostic support [58]. In finance, AI-DSS supports investment decisions and risk management by analyzing vast datasets to identify patterns and predict market trends [58]. AI algorithms can automate trading, enhance fraud detection, and improve customer service through personalized interactions [59]. By employing ML and natural language processing, these systems can analyze financial reports, news articles, and social media ideas to predict market movements and guide trading strategies. [59]. AI optimizes logistics and supply chain management in operations research by automating data collection, analysis, and decision-making processes [59]. This integration enhances efficiency and resource allocation [59]. AI-DSS can predict demand, optimize inventory levels, and streamline transportation routes, leading to cost savings and improved service levels [59]. AI-assisted DSS typically consists of data management, model management, a knowledge engine, and a user interface [59]. Data management involves collecting and storing relevant data from various sources, including structured data from databases and unstructured data from text documents and images [59]. Model management encompasses the algorithms and computational models that process data and make predictions [59]. ML models, encompassing deep learning and reinforcement learning, are commonly used to analyze complex datasets and generate actionable insights [60]. The knowledge engine uses AI to interpret the data and model outputs to provide recommendations [60]. This component integrates domain knowledge with ML models to ensure the recommendations are contextually relevant and accurate [59, 60]. The user interface permits users to interact and collaborate with the system, input data, and understand the recommendations provided [59, 60]. A user-friendly interface is crucial for effectively adopting AI-DSS in clinical and operational settings [60]. Research emphasizes the importance of balancing ethical considerations with the efficiency gains from AI, ensuring transparency and accountability in AI-assisted decision-making [60]. AI has made substantial advancements in diagnostic imaging, enhancing accuracy and efficiency [60]. AI tools like Automated Retinal Disease Assessment (ARDA) are being used to detect diabetic retinopathy, helping prevent blindness in patients with diabetes [60]. AI has also been used to detect anemia through non-invasive methods, such as analyzing eye photographs, which could simplify and improve screening processes [60]. AI enhances operational efficiency by automating data analysis and reducing the time required for diagnosis [61]. Table 2 identifies several recent studies on AI's role in stroke.

However, ethical considerations such as bias, transparency, and accountability are essential, underscoring the need for robust ethical frameworks to guide AI implementation in healthcare [61]. The future of AI in diagnostic imaging and treatment decision-making for stroke management looks promising, with several anticipated advancements [62]. AI is expected to play a crucial role in personalized medicine by tailoring diagnostic and treatment plans to individual patient profiles [61, 62]. AI-assisted decision-support systems are revolutionizing various fields by providing accurate, efficient, and ethical support [58-60]. Fig. 6 depicts the functions of AI-DSS in stroke management.

Table 2. Characterization of several latest studies related to AI in stroke management

First Author	Year	Type of Study	Results
Bojsen et al. [62]	2024	Systematic review and meta-analysis	Sensitivity: 93%, Specificity: 93%, Positive Likelihood Ratio: 12.6, Negative Likelihood Ratio: 0.079
Zhu et al. [63]	2023	Network meta-analysis of RCTs	SUCRA for RT + VR: 99.6% (ARAT), 84.8% (FMA-UE-Distal), 74.1% (FMA-UE-Proximal)
Ji W, et al. [63]	2023	Prospective cohort study	AUC: 0.925, Accuracy: 0.864, Sensitivity: 0.818, Specificity: 0.932
Colangelo et al. [64]	2023	Not specified	AUC: 0.77 (early), 0.61 (late), 0.71 (long-term)
Chen et al. [65]	2022	Prospective cohort study	AUC: 0.83 (ANN model), $p < 0.001$
Sung et al. [67]	2022	Retrospective cohort study	AUC: 0.825 (text + age model), comparable to the NIHSS model (AUC: 0.841)
Guo, Yutao, et al. [68]	2022	Review	Proposed a new paradigm for real-time stroke risk prediction using AI and machine learning.
Yeo, Melissa, et al. [69]	2021	Review	Examined AI in clinical decision support and outcome prediction for stroke, detailing various applications.
Soun, J. E., et al. [70]	2021	Review	Analyzed AI's role in acute stroke imaging, emphasizing advancements and challenges.
Rabinovich, Emily P., et al. [71]	2020	Review	Investigated telerobotics and AI in stroke care, highlighting innovations and practical applications.
Bivard, Andrew, et al. [72]	2020	Review	Explored AI for decision support in acute stroke, discussing current roles and future potential.
Mouridsen, Kim, et al.[73]	2020	Review	Reviewed AI applications in stroke, focusing on diagnostic and prognostic tools.
Gilotra K, et al. [74]	2023	Review	Examined AI in stroke care and research, highlighting diagnostic accuracy, treatment efficacy, and rehabilitation outcomes.
Liebeskind, David S., et al. [75]	2018	Commentary	Discussed the potential and limitations of AI in stroke care, questioning the depth of current AI applications.

AUC: Area Under the Curve, ANN: Artificial Neural Network, ARAT: Action Research Arm Test, FMA-UE: Fugl-Meyer Assessment for Upper Extremity, NIHSS: National Institutes of Health Stroke Scale, RCT: Randomized Controlled Trial, RT: Robotic Therapy, SUCRA: Surface Under the Cumulative Ranking Curve, VR: Virtual Reality.

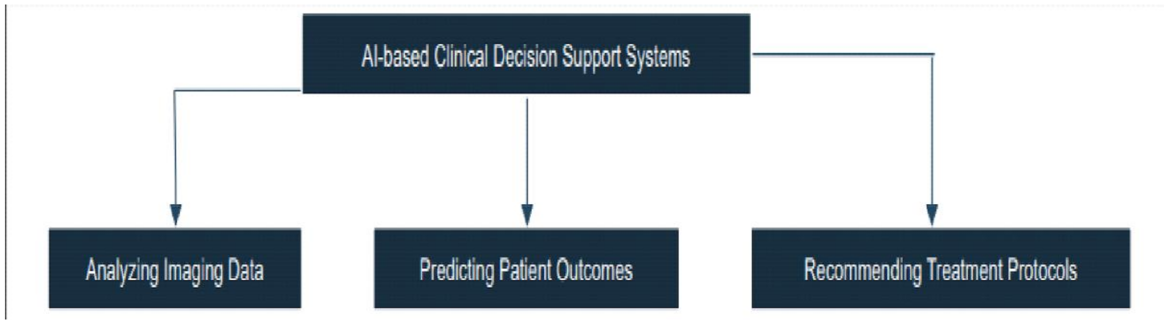

Fig. 6. Functions of AI-based CDSS in Stroke Management

AI-based Clinical Decision Support Systems: CDSS

3.6 AI in Stroke Management: Transformations, Current Impact, and Future Directions:

AI significantly transforms stroke management by optimizing diagnostic, treatment, and rehabilitation processes [50,51]. AI systems leverage extensive datasets and advanced algorithms to refine treatment strategies, enhance diagnostic accuracy, and personalize rehabilitation plans [50,51]. In treatment decision-making, AI improves the selection of interventions such as thrombolysis or mechanical thrombectomy by analyzing patient characteristics and historical outcomes [52,53]. Notable studies demonstrate AI's effectiveness in predicting the success of thrombolysis by evaluating variables such as clot location and patient health status [54]. Additionally, AI models support the optimal use of mechanical thrombectomy by combining it with intravenous thrombolysis, leading to better functional outcomes and reduced mortality [54]. AI-powered systems are at the forefront of generating personalized treatment plans by analyzing a comprehensive array of patient-specific data, including genetics, biomarkers, and comorbidities [40–42]. These systems compare data with treatment responses from similar patients to tailor interventions to individual needs, significantly improving treatment outcomes [40–42]. AI tools leverage ML algorithms to predict stroke risk and outcomes with high precision [47,48]. For example, a study published in Scientific Reports analyzed factors such as age, heart disease, and hypertension. It demonstrated that AI models achieved superior accuracy in stroke prediction compared to traditional risk-scoring systems [61]. This advanced predictive capability allows for more precise and personalized treatment planning [61]. Continued advancements in deep learning techniques will enhance the accuracy and efficiency of AI in diagnostic imaging [56]. Innovations in neural network architectures and training methods are critical for improving model performance in clinical applications [56]. Generative models like GANs and VAEs will be used for data augmentation, image synthesis, and improving diagnostic accuracy [56]. These models can generate high-quality synthetic data to supplement real-world datasets, addressing issues related to data scarcity and diversity [57]. Integrating AI into diagnostic imaging can revolutionize healthcare by improving accuracy, efficiency, and personalized care [57]. AI-driven programs tailor therapy to individual needs by predicting recovery trajectories and optimizing strategies [58]. Personalized rehabilitation leverages AI algorithms to analyze data such as injury type, pain levels, and muscle activation patterns, crafting customized exercise regimens based on real-time feedback and progress [59]. For instance, AI can optimize rehabilitation by tailoring exercises based on real-time feedback and progress data [57,58]. This ensures that each patient receives a therapy regimen that addresses their needs and recovery goals, significantly transforming stroke management through diagnosis, treatment, and rehabilitation advancements [57,58]. Studies in the American Journal of Neuroradiology have highlighted the efficacy of AI, particularly CNNs, in accurately detecting and classifying stroke types from imaging scans, facilitating timely interventions [9–11]. Clinical trials at the American Stroke Association International Stroke Conference demonstrated that AI-based systems enhance treatment decision-making, improving patient outcomes by reducing recurrent strokes and related complications [58–60]. In rehabilitation, AI-driven programs incorporating virtual reality (VR) and robotics have substantially enhanced motor function recovery by providing personalized therapy and real-time feedback [57,58]. Integrated with AI, virtual Reality (VR) and robotic systems create immersive environments that adjust to the patient's progress, offering challenging tasks to enhance motor skill recovery [59]. Continuous monitoring and follow-up are facilitated by AI systems, which use wearables and sensors to track patient movements and vital signs, enabling real-time feedback and therapy adjustments [55,56]. AI also supports remote patient monitoring, analyzing data from wearable devices to ensure adherence to rehabilitation plans and allowing for timely interventions [55,56]. Recent clinical studies confirm the efficacy of AI in stroke rehabilitation, showing significant improvements in motor function and overall recovery outcomes through personalized therapy and continuous monitoring [55–60]. Protecting patient data remains a critical challenge in AI implementation [57,58].

4. CONCLUSION

Integrating Artificial Intelligence (AI) into stroke management has demonstrated transformative potential across diagnostic, treatment, and rehabilitation stages. This systematic review underscores AI's significant contributions to enhancing diagnostic accuracy, optimizing treatment decision-making, and improving rehabilitation outcomes techniques, particularly machine learning (ML) and deep learning, which have shown remarkable advancements in stroke detection through imaging, achieving high sensitivity and specificity. These technologies assist radiologists in interpreting complex imaging data more efficiently, leading to more accurate diagnoses. AI's predictive modeling capabilities have proven instrumental in treatment decision-making, identifying high-risk patients, and facilitating rapid intervention during critical early stages of a stroke. AI-driven rehabilitation programs offer personalized therapy, significantly enhancing motor function recovery and overall patient outcomes. Despite these advancements, challenges such as data privacy concerns, the need for extensive and diverse datasets, and the integration of AI into clinical workflows persist. Addressing these challenges requires standardized data formats, interoperability protocols, and comprehensive clinician training. Ethical considerations, including bias, transparency, and accountability, are paramount to ensure AI's safe and effective use in clinical practice. Future research and technological advancements are essential to further refine AI applications in stroke management. Continued innovation will enhance AI's predictive models, tailor treatment strategies, and improve patient care and outcomes globally. The promising future of AI in stroke management lies in its ability to provide personalized, efficient, and adequate healthcare interventions, revolutionizing the field and offering new hope for patients and clinicians alike.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author(s) hereby declare that generative AI technologies, such as Large Language Models, have been used during the writing or editing of this manuscript. Specifically, ChatGPT-4, Grammarly, QuillBot, and other similar tools were utilized to enhance clarity, proofread the text, and improve overall readability. These tools were employed without affecting the original data or research findings. The details of AI usage are as follows:

1. ChatGPT-4- Used for refining language, improving sentence structure, and enhancing the flow of the manuscript.
2. Grammarly - Employed for proofreading, checking for grammatical consistency, and ensuring proper punctuation.
3. QuillBot - Applied for paraphrasing and rephrasing sentences to improve coherence while maintaining the integrity of the original content.
4. Other Tools - Additional AI tools were used for minor edits and final touch-ups to ensure the manuscript's overall quality.

CONSENT AND ETHICAL APPROVAL

It's not applicable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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