Integrating Artificial Intelligence in Stroke Rehabilitation: Current Trends and Future Directions; A mini review.

Ayesha Afridi,[1] Sumaiyah Obaid,[2] Neha Raheel,[3] Farooq Azam Rathore[4]

Abstract

Rehabilitation following a stroke faces challenges in offering customized treatment and attaining the best possible outcomes. The utilization of artificial intelligence (AI) presents transformative solutions that have the potential to revolutionize existing practices. This mini-review discusses the use of AI in rehabilitation after stroke, in form of customized intervention, task-specific training with robotics, real time monitoring by wearable devices and remote monitoring through tele rehabilitation. Despite the recent advances, issues such as algorithm bias, concerns about data security, and access disparities remain. Future directions include creating predictive analytics for tailored stroke therapies, incorporating virtual reality for increased participation, and assuring ethical and equitable distribution. Collaborative efforts are necessary to address these challenges and advance AI-driven stroke therapy. This review highlights the potential of AI to revolutionize stroke rehabilitation outcomes through interdisciplinary collaboration and ethical implementation.

Keywords: Artificial Intelligence, Rehabilitation, Stroke, Technology, outcomes, recent advances

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Introduction

Stroke is a major cause of chronic disability in adults globally. It impairs function and mobility and reduces the quality of life (QOL) of stroke survivors. Rehabilitation can significantly improve the functional status and QOL for most of stroke survivors.[1] Recognizing the vital role of rehabilitation in quality healthcare, the WHO Rehabilitation 2030 agenda emphasizes its importance. Providing cost-effective and accessible rehabilitation services to the right recipients at the appropriate times poses a significant global health service challenge. This challenge is exacerbated in low- and middle-income countries (LMICs), where there is a considerable unmet demand for rehabilitation interventions.[2] Although conventional rehabilitation practices have evolved, the persistent variability in patient responses and the necessity for personalized interventions pose significant challenges in achieving maximal recovery.[3] Conventional rehabilitation services mainly rely on physical and occupational therapy sessions, which involve direct interactions between patients and healthcare professionals. These sessions are typically administered either during hospitalization, (acute and sub-acute stages), or via scheduled visits to outpatient clinics, during the chronic phase.[4]

Integrating AI and machine learning (ML) into rehabilitation strategies holds promise for addressing these challenges. AI is a field within computer science, seeking to replicate human cognitive functions. It encompasses a spectrum of techniques with varying complexities for addressing diverse problems.[5] Machine learning, notably advanced deep learning methods, has recently attracted considerable attention. ML endeavors to autonomously discern intricate patterns within datasets, enabling predictions or classifications with novel datasets. ML includes supervised, unsupervised, and reinforcement learning. Supervised ML, particularly pertinent in precision medicine, relies on labelled data to train models for pattern recognition in feature data, offering valuable insights for medical applications.[5]

Novel developments in AI offer potential solutions for the limitations observed in traditional rehabilitation services delivery. This includes challenges related to time constraints, geographical distances, fatigue factor for the therapist, financial constraints, and restricted access to clinical settings. Proposed strategies range from real-time communication platforms enabling guidance and motivation from rehabilitation professionals while monitoring patient progress to advanced methodologies integrating sensor technologies and information and communication technologies (ICTs). These innovations, occasionally incorporating AI algorithms, facilitate remote monitoring and assistance in diverse contexts.[4]

This mini review discusses current trends and future directions of application of AI in stroke rehabilitation. It examines potential benefits, challenges, and ethical considerations while emphasizing stakeholder

[1-3]Faculty of Rehabilitation and Allied Health Sciences, Riphah International University, Islamabad, [4]Quetta Institute of Medical Sciences, Quetta, Pakistan
Correspondence: Farooq Azam Rathore. **Email:** farooqrathore@gmail.com

involvement and multidisciplinary cooperation.

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AI applications are important for advancing a decentralized rehabilitation model, where intelligent connected tools aid clinical decision-making and health outcomes monitoring. In the Recent years many AI-based methods and solutions were proposed to facilitate assisted physical therapy and assessments in a minimally supervised and decentralized fashion, ideally within the patient's home.[4]

• **Customized intervention using AI algorithms:** A study conducted by Victor et al based on personalized algorithms suggested that it can record functional disparities among stroke participants, facilitating tailored rehabilitation exercises aimed at enhancing bilateral and symmetric mobility.[6] Another study conducted on interactive machine learning strategy that progressively merged a data-driven model with expert insights to evaluate the effectiveness of rehabilitation exercises. Within a wide array of kinematic features associated with exercise movements, their method employed reinforcement learning to pinpoint the most significant features for evaluation. Subsequently, it produced a personalized analysis tailored to individual users, seeking input from therapists to ascertain the relevance of specific features for personalized rehabilitation assessment. By incorporating therapist feedback regarding feature relevance, this interactive hybrid approach has the capability to refine a standard assessment model into a personalized one.[7]

• **Robot assisted task specific training:** Robot-assisted rehabilitation, by repetitive, intensive, task specific and precise physical training, contributes positively to motor function recovery in stroke patients. However, , there is a pressing need for greater intelligence and reliability in current robotic systems for clinical deployment.[8] Machine learning algorithms adept at learning from data and predicting future conditions, offer potential to enhance the effectiveness of robot-assisted rehabilitation. Rehabilitation robots demonstrate the ability to accurately adhere to predetermined trajectories, execute a variety of training modes tailored to the patient's recovery status, objectively record patient data, and assess performance during exercises.[8]

• **Early detection of Stroke through AI-driven diagnostic tools:** AI has the potential to significantly enhance the speed and accuracy of stroke diagnosis, which can indirectly improve patient outcomes in rehabilitation. Early detection of stroke through AI-driven diagnostic tools, such as medical imaging that closely inspects brain images for early indicators like internal haemorrhage and arterial blockages, allows for timely intervention. Early identification of stroke risk factors can now be done through wearable technology (e.g., AI algorithms in smartwatches that track heart rate and rhythm).[9] This can lead to early and timely interventions resulting in better outcomes

• **Tele rehabilitation technologies:** Tele-rehabilitation provides affordable alternatives that reduce hospital stays, address transportation issues, and the lack of nearby rehabilitation facilities by enabling service users to remotely access treatments through video conferencing or phone conversations. By offering consistent direction and feedback, this approach successfully involves stroke patients in at-home training.[10]

Challenges and Considerations

The quest for AI has captured the attention of both researchers and industry leaders, envisioning a future where machines exhibit human-like cognitive capabilities. Nonetheless, this ambitious pursuit is accompanied by complex challenges and ethical considerations that demand thorough scrutiny.[11] The integration of AI into healthcare can introduce biases and disparities, potentially exacerbating healthcare inequity. Models trained on relatively homogeneous data, lacking diversity in patient populations, and often derived from limited clinical settings, may lead to biased AI-driven decisions, and hinder the generalizability of results.[12] AI programmes require accurately labelled data for generating precise AI-driven conclusions. However, there are ethical considerations associated with granting commercial access to patient data like accountability and transparency. Safeguarding patient privacy and preventing unethical data utilization are crucial imperatives in this context.[13]

Future directions in the use of AI

In clinical practice, AI's role should involve integrating multidisciplinary teams including medical, psychological, and technical expertise through embedded algorithms that analyze and process data generated by digital technologies in real-time. AI is anticipated to play a pivotal role in clinical decision-making, adapting therapy exercises online, and monitoring progress by extracting validated assessment scores.[14] Future research in AI-supported stroke rehabilitation should prioritize refining predictive analytical model to anticipate patient recovery trajectories and therapeutic responses. Utilizing machine learning algorithms, these models can discern predictive factors from diverse data sources like genetic profiles and clinical assessments, requiring collaborative efforts for

comprehensive data collection, validation, and clinical integration. Longitudinal studies are required to evaluate the accuracy and practical utility of predictive analytics in guiding stroke rehabilitation efforts.[15]

Integrating Virtual Reality (VR) into stroke therapy could enhance patient outcomes, motivation, and engagement. Future studies should explore novel VR-based approaches to stimulate brain rewiring, improve motor skills, and aid cognitive recovery through immersive environments, game-like challenges, and interactive platforms. Conducting randomized controlled trials to compare VR therapies with conventional methods is essential for assessing effectiveness, safety, and cost-efficiency.[16] Addressing technical issues like motion sickness and simplifying device use could improve accessibility for stroke survivors. Maximizing the benefits of AI-driven stroke rehabilitation necessitates ensuring fair and ethical distribution. This involves addressing issues such as biased algorithms, data privacy, and access disparities. Establishing clear guidelines is necessary for the ethical development, deployment, and oversight of AI-based rehabilitation tools. This will require collaboration among policymakers, rehabilitation physicians, neurologists, businesses, and patient advocacy groups to create inclusive solutions that uphold ethical standards and cater to diverse patient needs.[16]

Conclusion

Integrating AI into stroke rehabilitation holds promise for personalized care and decentralized services. Current trends highlight AI's potential in customized interventions, robot-assisted training, early detection, and remote monitoring. However, addressing algorithm bias and ethical considerations is crucial. Future directions include refining predictive analytics, integrating virtual reality, and ensuring equitable distribution. Collaboration among stakeholders is essential for maximizing AI's impact in stroke rehabilitation.

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