Artificial Intelligence, Machine Learning, & Robotics in Business

Stroke Rehabilitation: Potential Artificial Intelligence Contributions

James Cauraugh, Ph.D.*

*** Correspondence: cauraugh@ufl.edu, College of Health and Human Performance, University of Florida, USA.**

Abstract: Artificial intelligence and stroke are an intriguing union with vast improvements in health benefits anticipated. Impactful artificial intelligence contributions are emerging in stroke diagnosis, rehabilitation protocols, and movement activity monitoring. Identifying stroke locations via magnetic renounce images will shorten the time delay post stroke and minimize the effects of the disrupted blood flow in the brain. Insightful rehabilitation protocols will be evidence-based as well as prescribed for specific individuals post stroke. Machine learning, immersive virtual reality, and deep learning will further substantiate the importance of voluntary movements as the basis for neural plasticity post stroke.

Keywords: Stroke Motor Recovery, Artificial Intelligence, Rehabilitation Protocols, Relearning Movements, Machine Learning, Deep Learning

Introduction

Leading questions in stroke rehabilitation concern the potential contribution of artificial intelligence (AI) to motor recovery. How can AI facilitate the rehabilitation process? Will various forms of AI shorten therapy, and will functional movement gains be retained longer? If motor recovery is assisted by AI, then will deep learning be activated? The purpose of the current mini review is to update the novel and innovative stroke motor recovery approaches that have begun to use AI.

Strokes are cerebrovascular accidents that occur when the blood supply in an area of the brain is interrupted. This interferes with the delivery of oxygen and nutrients to brain tissues. Strokes are caused by two types of blood supply interruptions: (a) ischemic, an obstructive blockage and (b) hemorrhagic, an uncontrolled bleed. Primary consequences of both stroke types are partial or full paralysis of an arm or leg depending on the exact location in the impaired hemisphere. Time since stroke onset defines two stages of the recovery process. The first month post stroke is known as an acute or subacute stage. Common characteristics of this stage may include cognitive impairments, speech impediments, and limb paralysis. Traditional therapy prescriptions during the acute stage usually help individuals regain basic movement activities of daily living. Six months post stroke begins the chronic stage of recovery, and this stage may last for years. Dominant characteristics involve functional disabilities of the motor system. Indeed, the affected upper extremity may display partial paralysis in the fingers, wrist, elbow, and shoulder. Moreover, flexor synergies are frequently present in the chronic stage of recovery.

Rehabilitation Basis

Neuroplasticity is defined as the ability of the nervous system to respond to stimuli by reorganizing the brain's structure, function, and connections. A consistent finding across various traditional stroke therapies is that actions that require movements stimulate neural plasticity in the brain. Activity-based neural plasticity involves creating new pathways for motor commands. Importantly, activity-based neural plasticity is the foundation for effective stroke rehabilitation protocols.

Traditional Treatments for the Upper Extremities

Post stroke rehabilitation protocols are designed to minimize and eliminate impairments in the motor system. Indeed, overcoming motor deficits in the upper extremities requires an extensive amount of activity-based rehabilitation. Typically, rehabilitation specialists assist in moving the arm as well as apply resistance during movement attempts. A consideration in selecting a rehabilitation protocol to practice moving with the goal of decreasing motor deficits concerns the type of movements to be executed. Passive movements are when participants relax the muscles of their impaired arm or leg while a person or machine moves the limb through a range of motion. In contrast, active movements are when participants voluntarily attempt to initiate a movement by contracting their impaired arm or leg muscles. Without any assistance a full range of motion is limited early in rehabilitation. However, participants who repeatedly contract their arm muscles during voluntary movement initiation excel in stroke motor recovery.

An extension of active movement preferences is a type of stroke rehabilitation known as coupled active neuromuscular stimulation and bilateral movement training. This rehabilitation program involves combining two effective treatment protocols simultaneously. As participants actively try to initiate goal-directed movements, an electrical unit monitoring EMG activity provides electrical stimulation once a baseline level of muscle activity is exceeded. Moving the unimpaired arm along with the impaired arm provides additional neural stimulation via bilateral movement training.

AI and Stroke Rehabilitation

Stroke incidence in the United States is near 800,000 cases per year while stroke mortalities have decreased the past three years. Thus, more individuals are enrolling in rehabilitation programs. Such a situation has become a public health priority, and alleviating this pressing health concern would be impactful. Novel AI protocols should help relieve the rehabilitation burden on our health care system. AI is a concept that offers novel and innovative approaches for effective stroke recovery. A primary AI benefit concerns magnetic resonance imaging (MRI). Medical diagnosis of images taken after a stroke can be readily examined with machine learning. Identifying brain damage patterns and determining the signals-in-the noise will be enhanced with AI and machine learning. Stroke and AI researchers at the University of Florida have a distinct advantage in processing MRI scans on NVIDIA's supercomputer, HiPerGator AI. This on campus supercomputer cluster includes a HiPerGator AI NVIDIA DGX A 100 SuperPod.

Improved stroke diagnosis will facilitate decision making with the goal of prescribing patient specific rehabilitation. Individual stroke rehabilitation protocols will further advance learning effects beyond transient performance. Prescribing effective therapy programs and monitoring functional improvement changes will provide evidence of an efficacious treatment. Concomitant motor recovery progress is expected with advanced diagnosis, treatment prescription, and feedback monitoring. AI will provide an integral role during this process. Moreover, AI is a vital resource for creating personalized stroke rehabilitation treatment protocols which is consistent with current trends in medicine.

As basic and clinical researchers search for novel approaches to stroke rehabilitation deep learning should be considered. Motor tasks that demand repetitive movements as well problem solving in transfer tasks can be structured so that deep learning occurs. Indeed, immersive virtual reality for stroke rehabilitation includes deep learning components. Immersive virtual reality is an interacting environment that challenges individuals to execute movements to projected targets regardless of their motor capabilities. Performing target aiming tasks while varying movement distance (short or long), size (small or large), and time (slow or fast) simulates real-world motor actions. Further, a virtual environment can accommodate individuals post stroke who prefer self-paced movements. Extensive practice in an immersive environment shows high promise for activating deep learning while increasing functional capabilities. Moreover, the high incidence of motor disabilities shown by individuals in the chronic recovery stage treatment protocols such as immersive virtual reality should generate sustained learning benefits.

Another AI and stroke rehabilitation avenue is robot-assisted movement protocols. Robot devices have a long history of being programmed to repetitively guide a limb through various movements. Participants learn to overcome a flexor synergy in specific joints and control their limbs. Completing a high number of practice trials in a brief time is an advantage to both participants and therapists. Second and third generation robots for rehabilitation include advanced programming options. These AI options as well as force sensors interact with participants during movements. The level of resistance or load provided by a robotic-arm or -leg can be modified during movements to match the motor capabilities of individual participants. Certainly, machine learning is a primary component of these new generation robots assisting movements.

Conclusion

The potential contribution of AI to the stroke arena is unlimited. Identifying post stroke MRI patterns rapidly and reliably will advance diagnosis and minimize time in prescribing appropriate rehabilitation protocols. Both AI contributions will help individuals post stroke as well as the therapy treatment system. Indeed, AI assisted rehabilitation prescriptions depending on specific stroke locations will minimize uncertainty in activity-based neural plasticity.

Stroke motor recovery studies that have integrated AI into the diagnosis and rehabilitation processes have revealed promising findings. Importantly, AI facilitated improved motor capabilities. Soon deep learning and long-term retention of functional movements are expected. Certainly, AI presents multiple possibilities in identifying and implementing innovative motor recovery post stroke.

REFERENCE

Cauraugh, J. H., & Kim, S. (2002). Two coupled motor recovery protocols are better than one: electromyogram-triggered neuromuscular stimulation and bilateral movements. *Stroke*, *33*(6), 1589-1594.

http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=12052996
Cauraugh, J. H., & Summers, J. J. (2005). Neural plasticity and bilateral movements: A rehabilitation approach for chronic stroke. *Progress Neurobio*, *75*(5), 309-320. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=15885874
Cramer, S. C. (2000). Stroke recovery: how the computer reprograms itself. Neuronal plasticity: the key to stroke recovery. Kananskis, Alberta, Canada, 19-22 March 2000. *Mol Med Today*, *6*(8), 301-303. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=11041652
Cramer, S. C. (2020). Issues important to the design of stroke recovery trials. *Lancet Neurol*, *19*(3), 197-198. https://doi.org/10.1016/S1474-4422(20)30030-2
Hummel, F. C., & Cohen, L. G. (2005). Drivers of brain plasticity. *Curr Opin Neurol*, *18*(6), 667-674. https://doi.org/00019052-200512000-00009 [pii]
Kang, N., Ko, D. K., & Cauraugh, J. H. (2022). Bimanual motor impairments in older adults: an updated systematic review and meta-analysis. *EXCLI J*, *21*, 1068-1083. https://doi.org/10.17179/excli2022-5236
Montero-Almagro, G., Bernal-Utrera, C., Geribaldi-Doldan, N., Nunez-Abades, P., Castro, C., & Rodriguez-Blanco, C. (2024). Influence of High-Intensity Interval Training on Neuroplasticity Markers in Post-Stroke Patients: Systematic Review. *J Clin Med*, *13*(7). https://doi.org/10.3390/jcm13071985
Nudo, R. J. (2006). Plasticity. *NeuroRx*, *3*(4), 420-427. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17012055
Quattrocelli, S., Russo, E. F., Gatta, M. T., Filoni, S., Pellegrino, R., Cangelmi, L., Cardone, D., Merla, A., & Perpetuini, D. (2024). Integrating Machine Learning with Robotic Rehabilitation May Support Prediction of Recovery of the Upper Limb Motor Function in Stroke Survivors. *Brain Sci*, *14*(8). https://doi.org/10.3390/brainsci14080759
Sanchez, N., & Winstein, C. J. (2021). Lost in Translation: Simple Steps in Experimental Design of Neurorehabilitation-Based Research Interventions to Promote Motor Recovery Post-Stroke. *Front Hum Neurosci*, *15*, 644335. https://doi.org/10.3389/fnhum.2021.644335

James Cauraugh, Ph.D. is a Professor in Applied Physiology and Kinesiology and the Associate Dean for Research in the College of Health and Human Performance. He investigates motor control and bimanual coordination in post stroke individuals. His primary emphasis is chronic stroke motor recovery and various rehabilitation protocols to stimulate relearning basic movements. Recent strategic initiatives at the University of Florida provided insights into artificial intelligence and health.