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FUNCTIONAL MAGNETIC RESONANCE IMAGING (FMRI) AS A PREDICTIVE TOOL FOR REHABILITATION OUTCOMES IN STROKE PATIENTS

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ABSTRACT

BACKGROUND: Functional magnetic resonance imaging (fMRI) is a non-invasive technique providing valuable insights into brain activity. Its application in stroke rehabilitation is emerging as a potential tool for predicting recovery outcomes.

OBJECTIVE: This study aimed to explore the predictive capacity of baseline fMRI brain activation patterns on rehabilitation outcomes in stroke patients.

METHODS: With 150 stroke patients, we conducted a prospective cohort research to examine the correlation between baseline fMRI results and 6-month rehabilitation outcomes. The modified Rankin Scale (mRS) and the National Institutes of Health Stroke Scale (NIHSS) were used as outcome indicators.

RESULTS: Our findings revealed that the degree of brain activation within motor-related regions at baseline significantly correlated with functional improvement after six months. Both NIHSS score ($R^2 = 0.45$, $p<0.001$) and mRS score ($R^2 = 0.38$, $p<0.001$) were strongly associated with baseline fMRI data.

CONCLUSION: Our results suggest that baseline fMRI brain activation patterns can predict rehabilitation outcomes in stroke patients, providing a promising direction for individualizing stroke rehabilitation strategies.

KEYWORDS: Stroke Rehabilitation, Functional Magnetic Resonance Imaging, Predictive Modelling, Brain Activation, NIHSS, Mrs.

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INTRODUCTION

Stroke is one of the primary causes of disability in the world, leaving many survivors with cognitive, sensory, and motor impairments.(1, 2) Rehabilitation is essential for helping stroke victims regain their functional independence. (3) However, the likelihood of recovery and a patient's response to rehabilitation may vary significantly between individuals. This has prompted researchers to investigate the application of neuroimaging technologies, such as functional magnetic resonance imaging (fMRI), as indicators of rehabilitation progress.(4, 5)

Functional magnetic resonance imaging (fMRI) is a non-invasive method for detecting brain activity that looks for variations in blood flow.(6) This technique has shown promise in elucidating the neurobiological mechanisms underlying recovery after stroke.(7, 8) Studies have demonstrated that early changes in brain activity patterns, as observed via fMRI, can predict the potential for recovery. (9, 10)

Previous research has identified various brain regions and networks, including the motor and sensory cortices and the default mode network, whose activity levels and connectivity patterns have been associated with functional outcomes post-stroke.(11, 12) Moreover,

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fMRI has been used to assess the effectiveness of various rehabilitation therapies, including motor imagery, mirror therapy, and neurofeedback.(13, 14)

Despite these advances, the integration of fMRI into clinical practice to guide stroke rehabilitation is still in its nascent stages, and several challenges remain.(15, 16) Further research is needed to standardize fMRI protocols and to improve the reliability and accuracy of fMRI as a predictive tool.(17, 18)

MATERIALS AND METHODS

STUDY DESIGN

This prospective inquiry consisting of two years of observation was carried out between the years 2023 and 2025. The study was carried out in a manner that was compliant with the principles outlined in the Helsinki Declaration and with the authorization of the local ethics committee. Every participant gave their written informed assent before they were allowed to participate.

PARTICIPANTS

Participants included a sample of 150 stroke patients admitted to a rehabilitation center.(19)

INCLUSION CRITERIA:

In order to be eligible, patients need to be at least 18 years old.(20)

The diagnosis of the first-ever stroke was confirmed with the assistance of a neurologist and either computed tomography (CT) or magnetic resonance imaging (MRI). There was a delay of anything from seven days to six months between the start of the stroke and participation in the trial.(21)

EXCLUSION CRITERIA:

Severe cognitive impairment that would impede participation in the rehabilitation program or understanding of the study requirements.

Patients with a history of severe neurological disorders apart from stroke.

Presence of other medical conditions which could significantly affect motor recovery.

Contraindications for MRI such as pacemakers, certain implants, or severe claustrophobia.(22)

DATA COLLECTION PROCEDURE

A Systematic Approach to Information Gathering Methodology

At the beginning of the study, we gathered all of the demographic data, stroke characteristics (including the side of the brain affected and the kind of stroke), stroke severity according to the National Institutes of Health Stroke Scale (NIHSS), and functional status according to the Modified Rankin Scale (mRS).(23)

Functional MRI data were acquired within one week of study enrollment and at a 6-month follow-up. Standardized motor tasks were performed during fMRI scanning to assess brain activation patterns related to motor function.(24)

DATA ANALYSIS

fMRI data were analyzed using standard preprocessing steps and statistical parametric mapping. Changes in brain activation patterns were investigated using a paired t-test. Multiple regression analysis was performed to examine the predictive value of fMRI data for rehabilitation outcomes.

ETHICAL CONSIDERATION

All procedures were carried out in a manner that was compliant with the Helsinki Declaration of 1964 and any and all revisions or other ethical standards that were comparable to those standards, in addition to the ethical guidelines that were established by the study committee. Everyone who took part in the research gave their informed consent. It was made clear to each participant that they were free to withdraw from the study at any moment.

RESULTS

DEMOGRAPHIC AND CLINICAL CHARACTERISTICS

The mean age of participants was 65.2 years (SD = 11.3), with 60% males. The majority of strokes were ischemic (72%). The mean baseline NIHSS score was 14.3 (SD = 6.2), indicating moderate stroke severity. Detailed demographics and clinical characteristics are presented in Table 1.

Table 1: Demographic and Clinical Characteristics of Participants

Variable	Mean (SD) or N (%)
Age (years)	65.2 (11.3)
Gender (Male)	90 (60%)
Stroke Type (Ischemic)	108 (72%)
Baseline NIHSS Score	14.3 (6.2)
Baseline mRS Score	3.7 (0.7)

fMRI Results and Rehabilitation Outcomes

Our analysis revealed significant changes in brain activation patterns from baseline to 6-month follow-up, particularly within motor-related brain regions ($p<0.05$, corrected).

Furthermore, the degree of activation within these areas at baseline significantly predicted rehabilitation outcomes at 6 months. This was evident both for the NIHSS score ($R^2 = 0.45$, $p<0.001$) and mRS score (R^2

= 0.38, p<0.001), indicating that patients with greater initial brain activation within motor-related areas exhibited greater improvements. These results are summarized in Table 2.

Table 2: Correlation between Baseline fMRI Data and Rehabilitation Outcomes

Variable	Correlation Coefficient (R^2)	P value
NIHSS Score	0.45	<0.001
mRS Score	0.38	<0.001

DISCUSSION

This study underscores the potential utility of functional MRI in predicting rehabilitation outcomes among stroke patients. Our findings align with the growing body of evidence highlighting the predictive role of neuroimaging in stroke recovery.(25, 26) Notably, our results revealed that the degree of activation within motor-related brain regions at baseline significantly correlated with functional improvement after six months.(27) These findings corroborate prior research suggesting that the brain's initial response post-stroke may be indicative of its capacity for recovery.(28) Our study adds to the literature by providing further empirical evidence to support the incorporation of neuroimaging techniques, particularly fMRI, into routine clinical practice. fMRI has been identified as a promising tool to aid clinicians in identifying patients who are more likely to benefit from intensive rehabilitation programs, thereby personalizing treatment plans.(29)

However, despite these promising results, the clinical application of fMRI remains challenging due to factors such as standardization of protocols, variability in patient responses, and interpretation of imaging data. Further research is needed to address these challenges and to validate the predictive accuracy of fMRI in different stroke subtypes and recovery stages.(30)

CONCLUSION

In conclusion, our findings suggest that baseline brain activation patterns, as detected by fMRI, can predict rehabilitation outcomes in stroke patients. These results hold promising implications for individualizing stroke rehabilitation strategies and enhancing patient outcomes. Future studies should focus on further elucidating the underlying neurobiological mechanisms and refining fMRI protocols for better clinical applicability.

REFERENCES

1. Olafson E. Understanding and Predicting Recovery After Stroke Using Structural and Functional Magnetic Resonance Imaging: Weill Medical College of Cornell University; 2023.
2. Lu M, Du Z, Zhao J, Jiang L, Liu R, Zhang M, et al. Neuroimaging mechanisms of acupuncture on functional reorganization for post-stroke motor improvement: a machine learning-based functional magnetic resonance imaging study. Frontiers in Neuroscience. 2023;17:1143239.
3. Włodarczyk L, Cichon N, Saluk-Bijak J, Bijak M, Majos A, Miller E. Neuroimaging techniques as potential tools for assessment of angiogenesis and neuroplasticity processes after stroke and their clinical implications for rehabilitation and stroke recovery prognosis. Journal of Clinical Medicine. 2022;11(9):2473.
4. Tao J, Zhang S, Kong L, Zhu Q, Yao C, Guo Q, et al. Effectiveness and functional magnetic resonance imaging outcomes of Tuina therapy in patients with post-stroke depression: A randomized controlled trial. Frontiers in Psychiatry. 2022;13:923721.
5. Tang J, Xiang X, Cheng X. The Progress of Functional Magnetic Resonance Imaging in Patients with Poststroke Aphasia. Journal of Healthcare Engineering. 2022;2022.
6. Tahmi M, Kane VA, Pavol MA, Naqvi IA. Neuroimaging biomarkers of cognitive recovery after ischemic stroke. Frontiers in Neurology. 2022;13:923942.
7. Shin H, Kim JK, Choo YJ, Choi GS, Chang MC. Prediction of motor outcome of stroke patients using a deep learning algorithm with brain MRI as input data. European Neurology. 2022;85(6):460-6.
8. Ma Z-Z, Wu J-J, Hua X-Y, Zheng M-X, Xing X-X, Ma J, et al. Brain function and upper limb deficit in stroke with motor execution and imagery: A cross-sectional functional magnetic resonance imaging study. Frontiers in Neuroscience. 2022;16:806406.
9. Ma S, Huang H, Zhong Z, Zheng H, Li M, Yao L, et al. Effect of acupuncture on brain regions modulation of mild cognitive impairment: A meta-analysis of functional magnetic resonance imaging studies. Frontiers in Aging Neuroscience. 2022;14:914049.
10. Li Y, Yan S, Zhang G, Shen N, Wu D, Lu J, et al. Tractometry-Based Estimation of Corticospinal Tract Injury to Assess Initial Impairment and Predict Functional Outcomes in Ischemic Stroke Patients. Journal of Magnetic Resonance Imaging. 2022;55(4):1171-80.

11. Li Y, Li K, Feng R, Li Y, Li Y, Luo H, et al. Mechanisms of repetitive transcranial magnetic stimulation on post-stroke depression: a resting-state functional magnetic resonance imaging study. Brain Topography. 2022;35(3):363-74.
12. Lee J, Kim H, Kim J, Chang WH, Kim Y-H. Multimodal imaging biomarker-based model using stratification strategies for predicting upper extremity motor recovery in severe stroke patients. Neurorehabilitation and Neural Repair. 2022;36(3):217-26.
13. Imura T, Mitsutake T, Hori T, Tanaka R. Predicting the prognosis of unilateral spatial neglect using magnetic resonance imaging in patients with stroke: A systematic review. Brain Research. 2022;1789:147954.
14. Ghaleh RA, Rahimibarghani S, Shirzad N, Ahangari A, Nazem-Zadeh M-R, Abadi AMA, et al. The Role of Baseline Functional MRI as a Predictor of Post-Stroke Rehabilitation Efficacy in Patients with Moderate to Severe Upper Extremity Dysfunction. Journal of Behavioral and Brain Science. 2022;12(12):658-69.
15. Billot A, Lai S, Varkanitsa M, Braun EJ, Rapp B, Parrish TB, et al. Multimodal neural and behavioral data predict response to rehabilitation in chronic poststroke aphasia. Stroke. 2022;53(5):1606-14.
16. Yang HE, Kyeong S, Kang H, Kim DH. Multimodal magnetic resonance imaging correlates of motor outcome after stroke using machine learning. Neuroscience Letters. 2021;741:135451.
17. Lee J, Kim H, Kim J, Lee HJ, Chang W, Kim YH. Differential early predictive factors for upper and lower extremity motor recovery after ischaemic stroke. European Journal of Neurology. 2021;28(1):132-40.
18. Lai S, Billot A, Varkanitsa M, Braun E, Rapp B, Parrish T, et al., editors. An exploration of machine learning methods for predicting post-stroke aphasia recovery. The 14th PErvasive Technologies Related to Assistive Environments Conference; 2021.
19. Imura T, Mitsutake T, Iwamoto Y, Tanaka R. A systematic review of the usefulness of magnetic resonance imaging in predicting the gait ability of stroke patients. Scientific Reports. 2021;11(1):14338.
20. da Silva MAS, Cook C, Stinear CM, Wolf SL, Borich MR. Paretic upper extremity strength at acute rehabilitation evaluation predicts motor function outcome after stroke. medRxiv. 2021:2021.10. 05.21264572.
21. Blaschke SJ, Hensel L, Minassian A, Vlachakis S, Tscherpel C, Vay SU, et al. Translating functional connectivity after stroke: functional magnetic resonance imaging detects comparable network changes in mice and humans. Stroke. 2021;52(9):2948-60.
22. Ansado J, Chasen C, Bouchard S, Northoff G. How brain imaging provides predictive biomarkers for therapeutic success in the context of virtual reality cognitive training. Neuroscience & Biobehavioral Reviews. 2021;120:583-94.
23. Puig J, Blasco G, Alberich-Bayarri A, Schlaug G, Deco G, Biarnes C, et al. Resting-state functional connectivity magnetic resonance imaging and outcome after acute stroke. Stroke. 2018;49(10):2353-60.
24. Berginström N, Nordström P, Ekman U, Eriksson J, Andersson M, Nyberg L, et al. Using functional magnetic resonance imaging to detect chronic fatigue in patients with previous traumatic brain injury: changes linked to altered striato-thalamic-cortical functioning. The Journal of head trauma rehabilitation. 2018;33(4):266-74.
25. Zhang Y, Hua Y, Bai Y. Applications of functional magnetic resonance imaging in determining the pathophysiological mechanisms and rehabilitation of spatial neglect. Frontiers in neurology. 2020;11:548568.
26. Ramage AE, Aytur S, Ballard KJ. Resting-state functional magnetic resonance imaging connectivity between semantic and phonological regions of interest may inform language targets in aphasia. Journal of Speech, Language, and Hearing Research. 2020;63(9):3051-67.
27. Min Y-S, Park JW, Park E, Kim A-R, Cha H, Gwak D-W, et al. Interhemispheric functional connectivity in the primary motor cortex assessed by resting-state functional magnetic resonance imaging aids long-term recovery prediction among subacute stroke patients with severe hand weakness. Journal of clinical medicine. 2020;9(4):975.
28. Gu Y, Bahrani M, Billot A, Lai S, Braun EJ, Varkanitsa M, et al., editors. A machine learning approach for predicting post-stroke aphasia recovery: A pilot study. Proceedings of the 13th ACM International Conference on PErvasive Technologies Related to Assistive Environments; 2020.
29. Farrens A, Vatinno A, Seo NJ, Sergi F. Predicting individual treatment response using functional magnetic resonance imaging (FMRI). The American Journal of Occupational Therapy. 2020;74(4_Supplement_1):7411500006p1-p1.

30. Shea-Shumsky NB, Schoeneberger S, Grigsby J. Executive functioning as a predictor of stroke rehabilitation outcomes. The Clinical Neuropsychologist. 2019;33(5):854-72.