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RESEARCH

Post-stroke motivational decline was associated with lesions in the left deep white matter involving the corticospinal tract and superior longitudinal fasciculus

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Abstract
Declined motivation is a common issue among patients recovering from stroke and is a key determinant of rehabilitation outcomes. This study aimed to identify brain lesion locations associated with declined motivation, as measured by the vitality index, an observational measure of motivation in activities of daily living (ADLs) that can be applied even in patients with aphasia or dementia, in a clinical cohort of stroke patients. A total of 147 individuals with first-ever stroke were included. Lesion-symptom mapping using support vector regression was conducted to identify brain regions associated with vitality index scores at admission, while controlling for lesion size and age. The extent to which these lesions disrupted major white matter tracts was further examined using a publicly available tractography analysis tool. The analysis revealed that lesions within a specific region of the left corona radiata were significantly associated with lower vitality index scores. This region overlapped with the corticospinal tract and the superior longitudinal fasciculus. Tractography results indicated that damage in this region affected more than 50% of the corticospinal tract as well as superior longitudinal fasciculus II and III. Lower vitality index scores were also associated with motor paralysis, aphasia, and reduced independence in activities of daily living. Although causality cannot be inferred from this cross-sectional design, these findings highlight a critical deep white matter region potentially contributing to motivational decline following stroke and suggest targets for early assessment and individualized rehabilitation strategies.

Keywords Motivation · Vitality index · Support vector regression lesion-symptom mapping · Stroke

Introduction

Stroke is known to result in secondary loss of motivation in many patients. (Fujita et al., 2024) Motivation has been identified as a psychological factor that contributes to improvements in motor function and activities of daily living (ADLs), as demonstrated by studies evaluating patients at 3 and 6 months following stroke.(Wang et al., 2014), (Rapoliene et al., 2018) Recent systematic reviews have highlighted its important role in determining rehabilitation outcome. (Verrienti et al., 2023) Thus, motivation is considered a key determinant of recovery in stroke patients.

Several indices have been developed to assess motivation, including the vitality index (VI) (Toba K et al., 2002) and the Apathy Scale. Although the VI was originally described as measuring "vitality," its conceptual basis includes core components of motivation, specifically voluntary behavior and responsiveness to encouragement in ADLs. As Toba et al. noted: "items describing voluntary action and response to encouragement… reflecting voluntary behavior were retained in the final vitality index." In Japan, the VI is widely accepted as an observational proxy of motivation, especially in patients with stroke, aphasia, or dementia where self-report measures are not feasible. The VI has previously been shown to have acceptable validity and reliability as a measure of motivation in clinical populations. Among these, VI is an objective measure for

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assessing motivation related to ADLs in frail older adults, offering a quicker and simpler evaluation compared to self-report questionnaires. Furthermore, because it is based on observations made by therapists or caregivers, it imposes no additional burden on patients with aphasia or dementia who have difficulty with verbal communication. Fujita et al. (Fujita et al., 2024) investigated the effects of motivation on independence in ADLs in subacute stroke patients. They reported that: "motivation to get up" was associated with independence in grooming and dressing; "motivation to eat" was associated with independence in feeding, grooming, dressing and transferring; and "motivation to engage in rehabilitation and activities" was associated with independence in dressing, toileting, and transferring. Ito et al. also reported that, in subacute stroke patients with cognitive impairment, VI was associated with admission Functional Independence Measure (FIM) motor scores and FIM motor gain (Ito et al., 2021). These findings underscore the close relationship between VI and ADL outcomes in stroke patients, highlighting VI's utility as a valuable indicator for monitoring recovery progress.

Post-stroke apathy, characterized by a general decline in motivation, is a common condition in stroke patients, and studies have identified associated brain lesion areas and related factors. (Caeiro et al., 2013; Douven et al., 2017) Additionally, research on treatment methods and rehabilitation interventions is ongoing. (Chen et al., 2019) However, despite the availability of research on apathy and post-stroke depression related brain lesion areas, no studies to date have specifically investigated the brain regions associated with reduced VI. Identifying brain lesion areas and factors associated with reduced VI could not only provide insights into the mechanisms underlying motivational decline but also contribute to the development of tailored interventions to promote functional recovery in stroke patients. When identifying brain regions associated with VI, it is necessary to take into account the effect of age, since declined motivation is more frequently observed in older adults. (Rapoliene et al., 2018) In recent years, support vector regression lesion-symptom mapping (SVR-LSM) has been used as an imaging analysis method for identifying brain regions. (Zhang et al., 2014) (DeMarco & Turkeltaub, 2018) This method allows the inclusion of specific factors as covariates, enabling the identification of brain regions associated with functional or performance deficits after adjusting for their effects. In particular, adjusting for age related effects enables a more precise identification of brain regions linked to VI decrease.

The aim of this study was to identify brain lesion areas associated with declined motivation using VI and SVR-LSM while adjusting for age effects, and to explore the associated functional decline and factors related to VI.

Materials and methods

Participants

Participants were selected following the same procedures as those in our previous study. (Nitto et al., 2025) Among 416 patients admitted with stroke between August 2021 and October 2023, 257 first-ever stroke cases were identified. Stroke was diagnosed by physicians based on CT or MRI findings. Patients were excluded if they had died, experienced clinical deterioration, had not undergone MRI, had been dependent in ADLs prior to onset, had incomplete imaging data, had severe comorbidities (e.g., spinal cord disorders or fractures), or had missing data. To eliminate patients with minimal functional disability, nine patients who were fully able to walk independently from the early post-onset stage were excluded. A total of 147 patients were included in the final analysis. Age, median (IQR), 73 (63–82) years; sex, 86 males/61 females; lesion side, 77 left/70 right; stroke type, 120 ischemic/27 hemorrhagic; days from onset to imaging, median (IQR), 10 (3–24) days; length of stay, median (IQR), 60 (35–82) days. The median time from stroke onset to admission was 0 days (IQR, 0–13 days). Our institution is a regional hospital with acute care and subacute rehabilitation capabilities. This study included patients in the acute or subacute phase who were prescribed physiotherapy following admission.

Data collection

Clinical information, such as age, side of brain lesion, pathology (cerebral infarction or cerebral hemorrhage), length of hospital stay, and days from stroke onset to imaging, was collected retrospectively from the medical records of patients included in the analysis, along with data on assessments conducted at admission and discharge. Motivation was assessed using VI, which consists of five items regarding ADLs: waking pattern, communication, feeding, toileting, and rehabilitation related activities. (Toba K et al., 2002) Importantly, the "communication" item does not strictly evaluate verbal ability, but assesses whether the patient attempts to express themselves—including nonverbal means, such as gestures, facial expressions, or nodding—thus allowing evaluation even in patients with aphasia (Toba K et al., 2002). The VI was evaluated by trained rehabilitation professionals through repeated observations across multiple ADL settings, thereby minimizing potential bias due to language impairment. The VI scores had been documented in the patients' medical records and were retrospectively collected for this study. Each item is rated on a scale of 0–2, with a total possible score of 10. The cut-off value is set at 7 points, with higher scores

indicating higher motivation. In addition, motor function of the upper and lower limbs, as well as language function, were assessed using the Stroke Impairment Assessment Set (SIAS) (Chino et al., 1996), and independence in ADLs was evaluated using the motor and cognitive subscales of the FIM (Kidd et al., 1995).

Lesion analysis

MRI acquisition was performed using a 1.5T scanner (SIGNA Explorer; GE Medical Systems, Chicago, IL, USA), following the protocol previously described by Nitto et al. (2025). Imaging parameters were as follows: T2-weighted imaging (TE 90 ms, TR 4,500 ms, flip angle 160 °, slice thickness 5 mm, acquisition matrix 320 × 224, image matrix 512 × 512, field of view 220 mm × 220 mm); diffusion-weighted imaging (TE 80 ms, TR 5,000 ms, flip angle 90 °, slice thickness 5 mm, acquisition matrix 128 × 128, image matrix = 256 × 256, field of view 220 mm × 220 mm); and FLAIR imaging (TE 130 ms, TR 10,000 ms, inversion time 2,600 ms, flip angle 110 °, slice thickness 5 mm, acquisition matrix 290 × 190, image matrix 512 × 512, field of view 220 mm × 220 mm). MRIcron (http://www.mricro.com/mricron) was used to identify lesions. DWI and FLAIR were co-registered to T2-weighted images. Lesion location and size were determined either from the DWI acquired closest to onset or from FLAIR images, in which hematomas appeared as low signals and surrounding ischemic areas as high signals. (Nitto et al., 2025) The intensity filter in MRIcron aided lesion detection. Areas with signal intensity ≥ 120% or < 80% of normal tissue were classified as lesions. (Nitto et al., 2025) When lesion sizes differed, the image with the largest lesion was used. (Nitto et al., 2025) Spatial standardization was performed using SPM12 (https://www.fil.ion.ucl.ac.uk/spm/software/spm12/). T2-weighted images were first masked with the manually defined lesion maps to exclude lesioned voxels. The masked T2 images were then normalized to MNI space using the "Normalize: Estimate & Write" function in SPM12, with the default TPM.nii tissue probability map as the template. The same deformation parameters were subsequently applied to the original lesion maps to maintain anatomical correspondence. Spatial accuracy was confirmed through visual inspection, after which the images were normalized to MNI space using the MNI152 template. Lesion volume was calculated by counting lesion voxels. All image analyses, including preprocessing, were conducted by experienced analysts (HA) at a separate institution, who were blinded to clinical data and had access only to imaging data. Clinical data were provided to the analysts only after the image analyses were completed and locked, ensuring that no further modifications could be made based on clinical information.

To examine the relationship between lesion areas and VI scores, we used SVR-LSM, a multivariate machine learning method. We applied an SVR-LSM tool in MATLAB (https://www.mathworks.com/products/matlab.html) to identify lesion sites associated with reduced VI scores (DeMarco & Turkeltaub, 2018). SVR-LSM (Zhang et al., 2014) considers all lesion voxels simultaneously to model lesion–behavior links. Behavioral scores and lesion maps were revisualized for lesion volume. Unlike VLSM, which tests each voxel separately and risks false results due to multiple comparisons and vascular anatomy, SVR-LSM models behavior with the full lesion map using nonlinear functions. This allows more precise detection of complex, distributed lesion–symptom relationships. SVR-LSM outperforms voxel based lesion symptom mapping when multiple regions contribute to a behavior, capturing their interactions more accurately. (Bennett et al., 2009; Herbet et al., 2015; Mah et al., 2014; Pustina et al., 2018; Sperber & Karnath, 2017).

In the present study, only voxels with lesions present in at least 10 participants were included in the final SVR-LSM analysis : voxels with lesion overlap in fewer than 10 participants were excluded due to insufficient representation. A total of 10,000 permutation tests were performed, and statistical maps were corrected on a voxel-by-voxel basis at the voxel-wise threshold ($p < 0.005$), with cluster-wise correction applied only to clusters exceeding the threshold ($p < 0.05$). (DeMarco & Turkeltaub, 2018; Nitto et al., 2025) We created a color map representing the z-scores of statistically significant voxels exceeding the cluster threshold. These voxels were overlaid on the JHU white-matter tract atlases, which are all included in Functional Magnetic Resonance Imaging of the Brain (FMRIB) Software Library (FSL) (http://www.fmrib.ox.ac.uk/fsl).

Quantification of disconnections in tract bundles

To anatomically contextualize the SVR-LSM results, a disconnectome analysis was performed using the BCBtoolkit (http://toolkit.bcblab.com/) (Foulon et al., 2018), in order to identify major white matter tracts intersecting with the lesion clusters. Disconnectome maps can illustrate inter-individual variability in tract reconstructions based on control/template data. These maps represent the probability of disconnection ranging from 0% to 100% for a given lesion. (Thiebaut de Schotten et al., 2015)We quantified the extent of disconnection by measuring the probability of tract disruption (Thiebaut de Schotten et al., 2014) using the Tractotron software, as part of the BCBtoolkit (Foulon et al., 2018). Although Tractotron (Foulon et al., 2018) provides disconnection estimates for a wide range of white matter tracts, we restricted our analysis to a subset of major, well-characterized tracts commonly reported in the literature.

These included the arcuate fasciculus (anterior, long, and posterior segments); superior longitudinal fasciculus (I–III); inferior fronto-occipital fasciculus; uncinate fasciculus; inferior longitudinal fasciculus; frontal aslant tract; cingulum bundle; corticospinal tract; thalamic projections; corpus callosum; and fornix.

Statistical analysis

SVR-LSM analyses included both lesion volume and age as covariates. Lesion volume was controlled to account for its known effect on the accuracy of lesion-symptom mapping, whereas age was included due to its previously reported association with motivation (Rapoliene et al., 2018). Spearman's rank correlation was used to examine the relationship between VI and other assessments, such as the SIAS and FIM.

All statistical analyses were conducted using R (v4.4.1, v4.5.0) and RStudio (v2024.12.1+563, v2025.4.11) on macOS. Statistical significance was defined as $p<0.05$.

Table 1 Patient characteristics and baseline clinical assessment scores at admission

	Median (interquartile range) ($n=147/n=95$)
Age	74 (63.5–82)/73 (61.5–81)
Sex (Male: Female)	86: 61/56: 39
Etiology (Ischemic: Hemorrhagic)	120: 27/75: 20
Lesion side (Right: Left)	70: 77/43: 52
Hospitalization period (days)	44 (17.5–93.5)/47 (18–100.5)
Time from stroke onset to imaging (days)	1 (0–4)/2 (0–4)
Time from stroke onset to admission (days)	0(0–13)/0 (0–14.5)
Time from admission to physiotherapy initiation (days)	0(0–1)/0 (0–1)
VI*	10 (8–10)/10 (8–10)
SIAS**- upper extremity function	9 (6–10)/8 (4–10)
SIAS**- lower extremity function	15 (11–15)/14 (8–15)
SIAS**-speech	3 (2–3)/3 (2–3)
FIM***-motor	42 (21–57)/49 (20–56)
FIM***-expression	6 (5–7)/6 (4.5–7)
FIM***-social interaction	7 (5–7)/7 (5–7)

VI Vitality Index

SIAS Stroke Impairment Assessment Set

FIM Functional Independence Measure

Continuous variables were summarized as median (IQR) because several distributions were skewed

Results

Patient characteristics

In SVR-LSM, a minimum lesion overlap threshold was set, and cases below this threshold were excluded, leaving 95 patients for the final analysis. Table 1 shows the demographics and clinical characteristics of all 147 patients and the final subset of 95 patients.

Results of lesion analysis

Lesion overlay maps of all analyzed subjects revealed that the lesions were predominantly located in the corona radiata, thalamus, and putamen regions (Fig. 1).

SVR-LSM analysis using VI scores at admission, with age as a covariate, identified a significant association in a narrow region of the left corona radiata (Fig. 2). SVR-LSM identified a significant cluster in the left corona radiata (cluster size, 43 voxels; 344 mm^3; peak at MNI coordinates x −28, y −8, z 28; FDR-corrected p, 0.035). Additional smaller clusters did not survive multiple comparison correction.

Anatomical analysis using FSL atlas-based tract mapping demonstrated that the VI-associated region overlapped with the anatomical courses of the superior longitudinal fasciculus (SLF) and corticospinal tract (CST) (Fig. 3).

Results of disconnection analysis in white matter tracts

Disconnectome mapping of white matter tracts using age-adjusted VI scores at admission demonstrated that disconnections were mainly located in the left CST and SLF (Fig. 4). Specifically, tracts exhibiting over 50% disconnection comprised the CST, SLF (including SLF II and III), frontal aslant tract, anterior thalamic projections, arcuate fasciculus (long segments) and corpus callosum (Table 2).

Correlations between VI on admission and various assessments

Correlation analysis between the VI at admission and various assessment measure in the final sample of 95 patients showed moderate correlations between VI scores and following variables: SIAS lower extremity function ($r=0.41$, $p<0.001$), SIAS language function ($r=0.46$, $p<0.001$), FIM motor ($r=0.51$, $p<0.001$), FIM expression ($r=0.41$, $p<0.001$), and FIM social interaction ($r=0.46$, $p<0.001$) (Table 3). A weak correlation was observed with SIAS upper extremity function at admission ($r=0.32$, $p=0.002$).

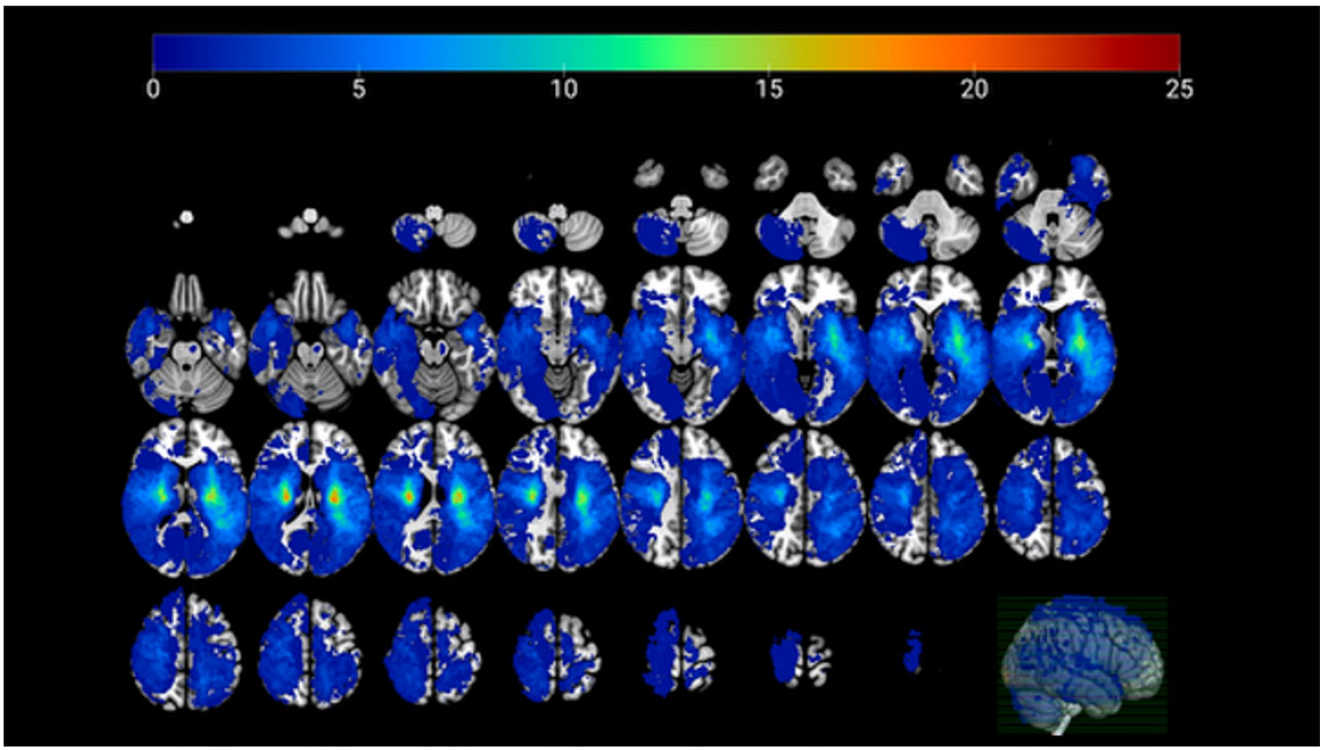

Fig. 1 Lesion overlay images of all patients. The color bar indicates the degree of overlap, with blue representing low overlap and red representing high overlap

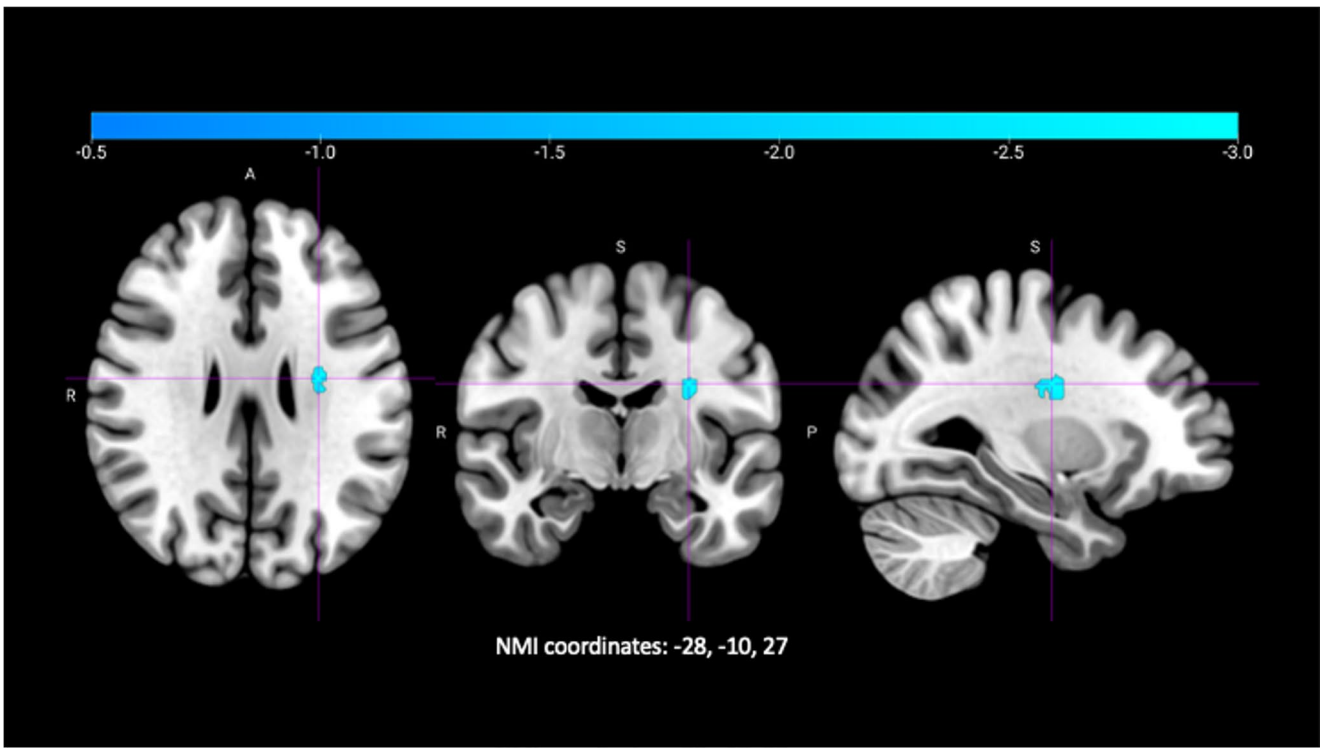

Fig. 2 SVR-LSM analysis of VI at admission, age-adjusted. The light blue bar shows VI-related regions in the left corona radiata, with color intensity reflecting z-score

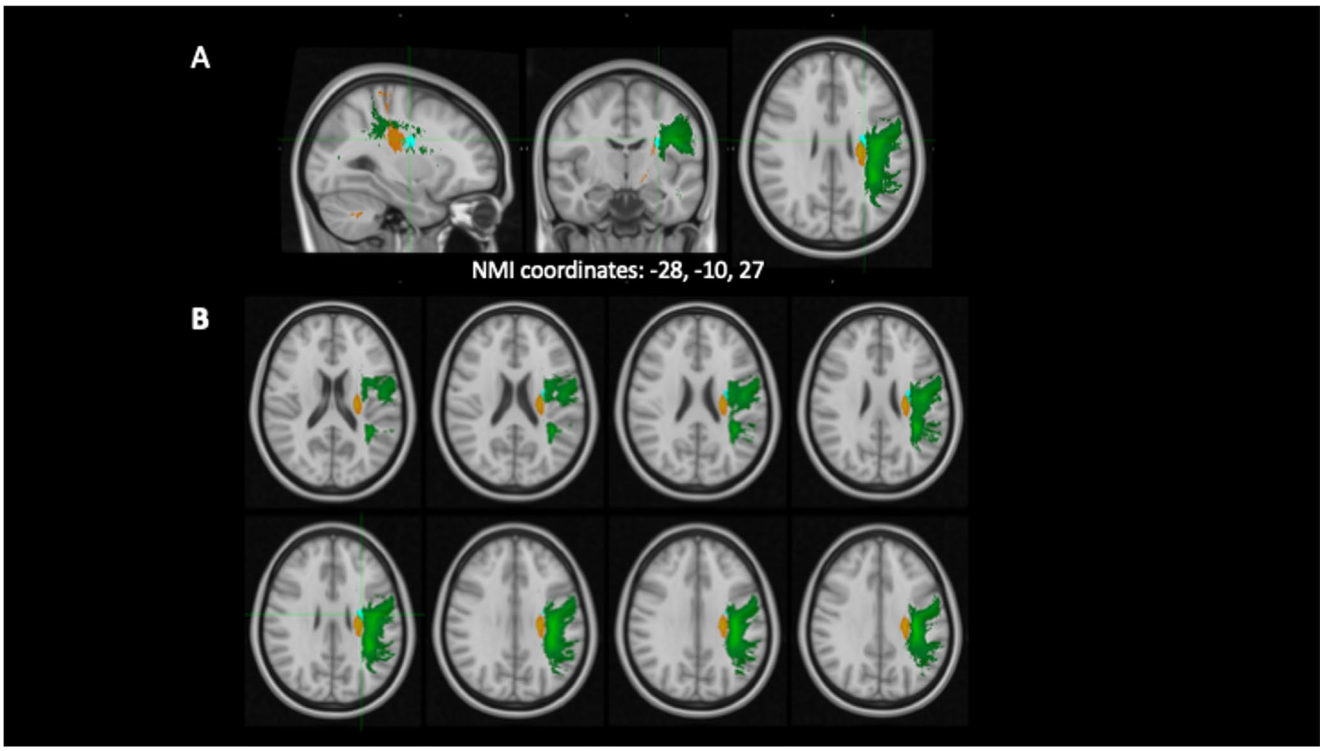

Fig. 3 Identification of relevant regions. Colored areas show VI-related regions (light blue), corticospinal tracts (orange), and superior longitudinal fasciculus (green). (**a**) VI-related regions overlapping with the corticospinal tract (**b**) VI-related regions overlapping with the superior longitudinal fasciculus

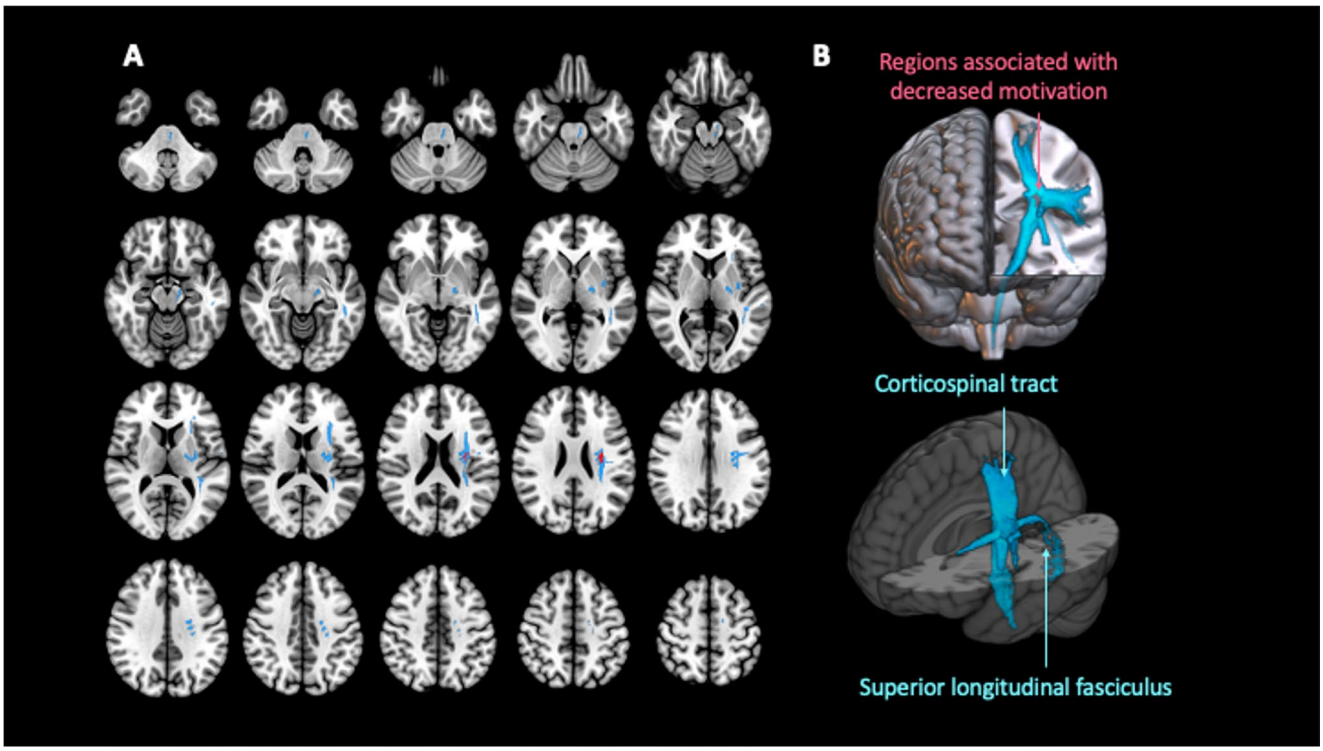

Fig. 4 Disconnectome mapping of tracts associated with admission VI, adjusted for age. After adjusting for age, we identified regions related to VI at admission and mapped the disconnectome tracts passing through these areas. Red areas indicate regions linked to reduced motivation by SVR-LSM. Major tracts with over 50% disconnection are shown in blue, mainly in the corticospinal tracts and superior longitudinal fasciculus

Table 2 Disconnection regions and probability of disconnection of over 50% of fiber bundles

Disconnection region	Disconnection probability(%)
Anterior thalamic projections (left)	66
Arcuate fasciculus (Long segment, left)	70
Corpus callosum	92.8
Corticospinal tract (left)	100
Frontal aslant tract (left)	92
Superior longitudinal fasciculus (III, left)	97.6
Superior longitudinal fasciculus (II, left)	91.2

Table 3 Correlation between admission VI scores and assessment measures

	Correlation coefficient (*r*)	*p*-value
Age	−0.18	0.09
Hospitalization period, days	−0.42	<0.001
Time from stroke onset to imaging (days)	−0.21	0.04
Time from stroke onset to physiotherapy initiation (days)	−0.09	0.37
SIAS*- upper extremity function	0.32	0.002
SIAS*- lower extremity function	0.41	<0.001
SIAS*-speech	0.46	<0.001
FIM**-motor	0.51	<0.001
FIM**-expression	0.41	<0.001
FIM**- social interaction	0.46	<0.001

SIAS Stroke Impairment Assessment Set

FIM Functional Independence Measure

Discussion

This study investigated brain regions related to motivation decline after stroke using SVR-LSM, with VI as a measure of motivation. Analysis using SVR-LSM with age as a covariate revealed that deep white matter regions involving the CST and SLF were associated with VI at admission. Disconnectome analysis confirmed that damage to the VI-related regions identified by SVR-LSM resulted in a disconnection probability of over 50% for the left CST, SLF II, and SLF III. Furthermore, VI at admission was significantly associated with motor paralysis indicators, including SIAS, upper extremity function and lower extremity function scores, and with verbal communication indicators, including SIAS speech, FIM expression, and social interaction. Additionally, it was significantly associated with independence in ADLs as measured by FIM motor function.

It is noteworthy that our results demonstrated significant associations between brain lesion location and the VI exclusively in the left hemisphere. Given that the left hemisphere is dominant for language and controls the dominant limb in most right-handed individuals, damage to this hemisphere may negatively affect motivation by disrupting frequently used motor and communicative functions.

The CST is the primary motor pathway in the human brain responsible for controlling distal limb movements, and damage to it can lead to motor impairment. (Jang, 2014) The results of the present study showed that VI at admission was associated with the CST and with upper and lower extremity motor function, as assessed by the SIAS. Furthermore, VI scores were associated with independence in ADLs, as measured by FIM motor function, which is consistent with the results of previous studies. (Fujita et al., 2024) (Ito et al., 2021) In addition, as studies have shown that motor impairment due to paralysis in stroke patients leads to activity limitations (Petruseviciene & Krisciunas, 2008), the onset of hemiplegia is directly associated with functional loss, thereby reducing independence in ADLs. The resulting loss of function and autonomy may, in turn, negatively affect motivation for engaging in ADLs. Furthermore, CST damage associated with lower VI scores at admission increases the risk of severe motor impairment, which may further hinder daily activities.

The SLF was also identified as a region related to VI on admission. The SLF forms part of the association fibers connecting the frontal lobe and other regions of the ipsilateral hemisphere, and is subdivided into SLF I, SLF II and SLF III (Janelle et al., 2022). Specifically, the left SLF II links the angular gyrus and the anterior intraparietal sulcus to the posterior portions of the superior and middle frontal gyrus, while the left SLF III connects the temporoparietal junction to the inferior frontal gyrus, where Broca's area is localized. Both tracts are thought to play roles in language functions, such as speech production, syntactic processing, language planning, and comprehension (Janelle et al., 2022; Wilson et al., 2011). Therefore, damage to the left SLF is considered to contribute to decline in language function. Previous research using diffusion tensor imaging for post-stroke aphasia has been reported to show reduced fractional anisotropy in the left SLF (Zhu et al., 2023). Supporting these results, SVR-LSM in the present study revealed that SLF II and SLF III, which were associated with VI, overlapped with areas of high probability for tract disconnection. Our study results also showed that VI on admission was related to the SLF, particularly on the left side. In addition, there were correlations with measures requiring verbal communication, including SIAS speech, FIM expression, and FIM social interaction. These findings suggest that aphasia symptoms may contribute to lower VI scores. However, it should be noted that the VI's "communication" item does not assess linguistic competence alone per se; rather it evaluates the patient's initiative to express themselves through any available means, verbal or nonverbal. (Toba K et al., 2002) This design helps minimize the confounding effects of

aphasia on VI-based motivation assessment. When aphasia impairs language comprehension and expression, it can hinder social interaction and the ability to express basic needs, thereby decline motivation for communication dependent activities. Furthermore, it is noteworthy that VI at admission correlated with the FIM social interaction scores. Previous studies have shown that post-stroke aphasia patients spend significantly less time outside the home and engage in fewer social interactions (Lee et al., 2015). This suggests that aphasia symptoms may contribute to decline in motivation to express intentions and participate in social activities, thereby resulting in a diminished proactive attitude toward daily engagement.

The results of this study could provide useful insights into care strategies for patients experiencing declined motivation post-stroke. To the best of our knowledge, this is the first study to investigate the brain regions associated with VI decrease and related factors. Motivation is an important factor influencing rehabilitation outcomes and recovery in physical and daily living functions in stroke patients. VI is a measure specifically designed to assess motivation through selected ADLs, making it an extremely useful tool for understanding functional outcomes in stroke rehabilitation. By using the VI to evaluate motivation, various factors contributing to reduced functional outcomes can be identified. Therefore, these identified factors may interact in the context of declined motivation. Taking these factors into account during rehabilitation, along with identifying patients in need of targeted support and providing appropriate interventions, may contribute to optimized care and improved ADLs.

Lesions involving the CST and/or left SLF aid in the early identification declined motivation and in the developmental of individualized rehabilitation strategies. In practice, this may involve task-oriented training combined with motivational interviewing for patients with CST involvement, and communication-based therapies incorporating motivational strategies for those with co-occurring aphasia. Dopaminergic agents may be considered on a case-by-case basis within current clinical guidance. These are hypothesis-generating suggestions that require prospective evaluation.

However, there are several limitations to the present study. First, there may be sampling bias, as many participants scored above the VI threshold of 7, reflecting only mild motivational decline. This restricted range may have reduced the sensitivity to detect lesion associations linked to more severe impairment. Future studies should focus on patients with more pronounced motivational decline to clarify whether distinct lesion patterns emerge. Second, although age was adjusted for, other clinical factors known to influence motivation, such as post-stroke depression, apathy, fatigue, and cognitive status, were not considered and may have acted as potential confounders. Future studies should incorporate multimodal assessments, combining the VI with standardized scales for apathy, depression, or cognitive function, to better isolate motivation-specific effects. Third, although the present study identified motivation-related brain regions in the left hemisphere, handedness and footedness were not systematically assessed due to the retrospective design. Nevertheless, given the well-established predominance of left-hemisphere dominance in the general population (Shimizu & Endo, 1983), this interpretation remains reasonable. Future studies should further examine whether right hemisphere lesions, such as those associated with neglect-related disengagement, also influence motivation. We also aim to investigate whether the identified brain regions and factors can predict prognosis and inform effective interventions, as well as explore their potential applications in rehabilitation. Fourth, although the VI is intended to capture motivational engagement through observable behaviors in daily activities, these behaviors may also be influenced by motor or language impairments. As such, the observed associations between lesion location and motivation may partly reflect reduced functional capacity rather than purely diminished intrinsic motivation. In this study, motivation was assessed at admission—relatively early after stroke onset. Since the cohort included some patients in the acute phase, it is difficult to determine whether the reduced VI scores were due to direct lesion effects on motivation-related neural systems or were secondary to motor or language deficits. Given the cross-sectional, retrospective nature of this study, these effects cannot be distinguished from each other. This represents a limitation of our findings. Future longitudinal studies using more specific and multimodal assessments, while controlling for physical and communicative impairments, are warranted to clarify these relationships.

Conclusion

In the present study, we conducted SVR-LSM analysis to investigate the relationship between motivation and brain regions in first-time stroke patients. When VI scores at admission were adjusted for age, significant associations were found in deep white matter regions overlapping with the CST and SLF. Additionally, VI at admission was significantly related to motor paralysis, aphasia, and reduced independence in ADLs. These findings suggest that these factors may interact in the context of declined motivation in stroke patients, and could inform assessment and rehabilitation planning for those with declined motivation post-stroke. Nevertheless, it is important to acknowledge that the vitality index was originally developed as a measure of “vitality,”

and its use as a proxy for motivation remains an approximation. While the scale captures volitional aspects of behavior, it does not encompass all dimensions of motivation. Therefore, interpretations regarding motivational impairment should be made with caution, especially in populations with overlapping cognitive and communicative impairments.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11682-026-01116-y.

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Author contributions Conceptualization: AO, RS, YH, KN, and HA; Methodology: AO and HA; Data analysis: AO, MS, and HA; Project administration: RS and YH; Data collection and participants recruitment: RS, YH, KN, and YY; Investigation: AO, RS, YH, KN, and YY; Writing—original draft preparation: AO and HA; Writing—review and editing: HA; Visualization: AO and HA; Supervision: RS and HA. All authors have read and agreed to the final version of the manuscript.

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Data availability The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Ethics approval This study was approved by the institutional ethics committee of Minami Tohoku Fukushima Hospital, Japan (approval no. 23-4) and was conducted in accordance with the Declaration of Helsinki.

Consent to participate This study used a retrospective design involving clinical data from routine care. The requirement for written informed consent was waived by the Institutional Review Board of Minami Tohoku Fukushima Hospital. Instead, informed consent was obtained via an opt-out procedure approved by the IRB. Study information was made publicly available, and participants were given the opportunity to decline participation.

Consent for publication Not applicable.

Clinical trial number Not applicable.

Competing interests The authors declare no competing interests.

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