INTRODUCTION

The prediction of outcome is critically important when planning appropriate rehabilitation for stroke patients. Magnetic resonance imaging, transcranial magnetic stimulation, magnetoencephalography, and other modalities have been used for rehabilitation planning. A recent systematic review suggested that magnetic resonance diffusion tensor imaging (DTI) is potentially one of the most useful techniques to predict poststroke motor recovery. Fractional anisotropy (FA) is the most frequently used DTI-derived parameter, and several studies have found an association between decreased FA in the corticospinal tracts and poorer outcome.

A variety of factors have been suggested to affect stroke outcome. Some previous studies have identified age as the strongest predictor of stroke outcome, whereas others have indicated that the type of stroke (hemorrhagic or ischemic) is also important. Furthermore, recent studies have suggested a possible contribution of the neural integrity...
METHODS

Study Samples

The work presented here is an extension of earlier studies by our research group\(^1\text{7–19}\) and is based on further analysis of previously reported data.\(^1\text{9}\) The study population consisted of 80 stroke patients (40 with hemorrhagic lesions, 40 with ischemic lesions).\(^1\text{7,18}\) Patient demographics (e.g., age, lesion site, severity of hemiparesis) have been reported elsewhere.\(^1\text{7,18}\) The study protocol was approved by the Hyogo College of Medicine Ethics Committee (No. 2454).

Most patients were transferred to our hospital soon after the onset of symptoms. The diagnosis of stroke was confirmed on computed tomography and/or diffusion-weighted magnetic resonance images. All patients underwent physical, occupational, and speech therapy for up to 180 min daily, in line with the recommendations of the Japanese Guidelines for the Management of Stroke.\(^2\text{0}\) The study population was limited to patients with first-ever stroke with hemorrhagic or ischemic supratentorial lesions who had been able to walk unaided and had been functionally independent in activities of daily living (ADL) before the stroke. This limitation was imposed to minimize the effects of variability in pre-stroke health status and lesion site. To minimize the effects of variability resulting from differences in the rehabilitation regimen, we used only data for patients who were transferred to our affiliated long-term rehabilitation facility (Nishinomiya Kyoritsu Rehabilitation Hospital) for at least 1 month of inpatient rehabilitation.

Acquisition of Diffusion Tensor Images

DTI was performed between 14 and 21 days post-admission using a 3.0-T magnetic resonance scanner (Trio; Siemens AG, Erlangen, Germany) with a 32-channel head coil. The DTI acquisition protocol has been described in detail elsewhere.\(^2\text{1}\) Following this protocol, a single-shot echoplanar imaging sequence was used to obtain 1 non-diffusion-weighted image (\(b=0\) s/mm\(^2\)) and 12 images with noncollinear diffusion gradients (\(b=1000\) s/mm\(^2\)) for a total of 64 axial slices per patient (field of view, 230.4 mm \(\times\) 230.4 mm; acquisition matrix, 128 \(\times\) 128; gapless slice thickness, 3 mm; echo time, 83 ms; and repetition time, 7000 ms).

Outcome Measures

The functional status of the extremities was assessed using the Brunnstrom staging system (BRS),\(^2\text{2}\) which is widely used by Japanese rehabilitation therapists.\(^2\text{0}\) The BRS assesses stroke-related motor impairment (hemiparesis) of the upper and lower extremities. The recovery of affected extremities was evaluated using flexion and extension synergy patterns on a 6-point scale (1, very poor; 6, normal). BRS is widely used for functional evaluation of the lower extremity as well as the proximal (shoulder/elbow/forearm) and distal (hand/finger) components of the upper extremity, and its reliability and validity have been confirmed.\(^2\text{3}\) Scores at discharge from the rehabilitation facility were entered into the analysis database.

We also obtained scores for the motor component of the Functional Independence Measure (FIM-motor).\(^2\text{4}\) This measure comprises a battery of tests used to evaluate stroke patients during rehabilitation.\(^2\text{0}\) It consists of the following 13 items, each graded on a 7-point scale (1, total dependence; 7, complete independence): eating, grooming, bathing, dressing the upper body, dressing the lower body, toileting, bladder management, bowel management, transfers to a bed/chair/wheelchair, transfers to a toilet, transfers to a tub/shower, walking/propelling a wheelchair, and using stairs. The total score for these items is frequently employed as an index of independence in ADL (scale range, 13–91). Patients were considered eligible for discharge from the rehabilitation hospital when there was no further increase in the FIM-motor score. The BRS stage and FIM-motor score were assessed at monthly intervals, and the data were collected at discharge from the facility. The length of hospital stay (LOS) was recorded in all cases.

Image Processing

We processed all images using the FSL brain image analysis package (version 6.0.1, Oxford Centre for Functional MRI of the Brain, Oxford, UK).\(^2\text{5}\) The methods used have been described elsewhere.\(^2\text{2}\) In summary, the DTI data were initially corrected for motion and eddy current distortions via alignment of later images to the first image (\(b=0\) s/mm\(^2\)). Extracerebral regions were then removed from the images. Next, regional FA values for the brain were calculated to generate an FA brain map. This map was subsequently converted to a standard stereotaxic space. Regions of interest (ROIs) were
set within the corticospinal tracts in the right and left cerebral peduncles (Fig. 1). These regions were selected because of the potential for magnetic resonance susceptibility effects of supratentorial stroke lesions to interfere with the validity of DTI data.\(^{26}\) The ROIs for the cerebral peduncles were set with reference to the International Consortium for Brain Mapping DTI-8\(^{27}\) (Fig. 1). FA values were calculated for the left and right ROIs with subsequent estimation of mean values for single voxels. The ratio of FA values between the ipsilesional and contralesional hemispheres (rFA) was calculated as the index of neural degeneration in the corticospinal tracts for each patient (Fig. 1).\(^{5,28}\)

**Statistical Analysis**

Data were analyzed by multivariate regression, and separate analyses were performed for the BRS subsets, FIM-motor, and LOS. rFA, contralesional FA, age, and type of stroke were set as explanatory variables in all analyses. A dummy variable for the type of stroke took the value of 1 for hemorrhagic stroke and 0 for ischemic stroke. The parameters included in the final regression models were identified by forward stepwise selection (P <0.1). Spearman’s correlation test was performed for all possible pairings of the four explanatory variables to identify any multicollinearity. All statistical analyses were performed using the JMP software package (SAS Institute Inc., Cary, NC, USA). A P-value <0.05 was considered statistically significant.

**RESULTS**

Patient demographics and clinical characteristics are shown in Table 1. The study population included 80 patients (40 with hemorrhagic stroke, 40 with ischemic stroke; 47 men, 33 women). The lesion was in the right hemisphere in
Patient demographics showed an almost normal distribution and were appropriate for regression analysis.

Table 2 shows the results of multivariate regression analyses for the BRS subsets. The rFA and contralesional FA values for the shoulder/elbow/forearm and hand/finger components were taken into the final models. The t-values indicated that more of the variability in BRS outcome data was accounted for by rFA than by the contralesional FA. When the type of stroke was added to rFA and contralesional FA in the final model, the BRS scores suggested a strong association between hemorrhagic stroke and poorer lower extremity function. Age was not included in the final model.

Table 3 shows the results obtained by multivariate regression for FIM-motor and LOS. Unlike for BRS, age was included in the final models for both FIM-motor and LOS. The t-values obtained for FIM-motor indicated that age contributed as much as rFA to stroke outcome. The bottom row in Fig. 2 shows scatter plots of the observed and predicted values derived from the parameter estimates shown in Table 3.

Table 4 shows the correlations between the explanatory variables. Hemorrhage (dummy value, 1) was associated with a lower rFA (P=0.002), indicating that neural damage was more severe in patients with hemorrhagic stroke. Although not a statistically significant finding, patients with hemorrhagic stroke were younger than those with ischemic stroke (P=0.065). This result was consistent with the negative correlation between age and rFA (P=0.046).

Discussion

Multivariate regression analyses of patients with supratentorial hemorrhagic or ischemic stroke in this study revealed that FA in the cerebral peduncles of the ipsilesional and contralesional hemispheres was associated with long-term outcome. Furthermore, age influenced the FIM-motor and
LOS outcome data. However, the type of stroke had a minimal effect on outcome, except for the function of the lower extremities. These findings highlight the contributions of age and neural integrity in the corticospinal tracts to stroke outcome.

Previous studies have identified age as one of the most powerful predictors of stroke outcome.\(^{29,30}\) This study quantitatively evaluated the impact of age in combination with neural integrity on outcome measures of BRS, FIM-motor, and LOS. For FIM-motor, multivariate regression analysis revealed that the impact of age was as robust as that of neural damage indexed by rFA. However, age had a minimal effect on outcome in terms of function in the extremities as assessed by the BRS. This discrepancy may reflect differences in the nature of the measures used, in that the BRS evaluates impairment, whereas FIM-motor assesses disability. Nevertheless, this finding suggests a direct relationship between impairment and neural damage, whereas disability reflects broader factors, including age.

The literature suggests that DTI-FA, an index of the integrity of neural fibers, can be used to predict the stroke outcome.\(^{4,9,31}\) Many previous studies have used the severity of neural damage in the ipsilesional hemisphere relative to that in the intact contralesional hemisphere, which is indexed by rFA.\(^{4,9,31}\) As in those studies, we found a strong correlation between rFA as an index of neural damage and stroke outcome (Tables 2 and 3). Correlation analyses of the explanatory variables indicated that hemorrhagic stroke was
associated with a lower rFA (Table 4). However, multivariate regression analyses did not take the type of stroke into the final models, except for the lower extremity data. This observation suggests that hemorrhagic stroke is associated with more severe neural damage and symptoms. However, the neural damage indexed by rFA accounted for most of the variability in clinical severity. These findings confirm the usefulness of rFA in the cerebral peduncles for predicting outcome in stroke patients with hemorrhagic or ischemic lesions. It has been suggested that a small number of corticospinal fibers project ipsilaterally and that they may contribute to motor recovery in patients with hemiparesis after stroke. As in previous studies, FA in the contralesional hemisphere was used in the final models for all multivariate regression analyses in the present study. This observation implies that better neural integrity within the ipsilateral corticospinal tracts is associated with a more favorable outcome. However, our results for parameter estimates (t-values) suggest that the contribution of FA in the contralesional hemisphere was relatively small (Tables 2 and 3). Accordingly, in terms of clinical significance, the role of ipsilateral (contralesional) corticospinal projections in motor recovery remains unclear.

Clinical severity in the initial phase of stroke is another important determinant of long-term outcome. We previously reported that the National Institutes of Health Stroke Scale score during the acute phase can predict the extent of FIM-motor recovery. The speed of recovery is also important for predicting stroke outcome. However, in this study, we could not systematically obtain data for initial clinical severity or for the speed of recovery because of the retrospective nature of the research. Nevertheless, the predictive accuracy of the models derived from multivariate regression analyses (adjusted $R^2$) ranged from 0.321 to 0.526. Greater accuracy could be expected if the initial clinical severity and speed of recovery were included as explanatory variables. Further studies are needed to clarify this issue.

This study has several limitations. First, the outcome measures used were somewhat crude in that we sampled only BRS, FIM-motor, and LOS. However, patients with stroke have a variety of symptoms, including dysphagia, hemiparesis, and higher brain dysfunction (e.g., aphasia and hemispatial neglect), so our outcome measures might not have adequately accounted for other important symptoms. Second, we did not include a confirmatory analysis of the models derived from the multiple regression analyses. As a result of our stringent inclusion criteria, data for only 80 patients were used in the analysis. Therefore, the focus of the study was on model development. Future studies with larger numbers of patients are needed to assess the applicability of the models derived in the present study. However, given that the aim of this study was to assess the contributions of age, type of stroke, and FA in the ipsilesional and contralesional cerebral peduncles, we believe that our analysis was appropriate. Third, only patients who were functionally independent before stroke were enrolled in the study; such patients are likely to have a relatively good recovery. Moreover, we

### Table 3. Results of multivariate regression analyses for FIM-motor and LOS

|          | Estimate | SE  | t     | P    | Estimate | SE  | t     | P    |
|----------|----------|-----|-------|------|----------|-----|-------|------|
| Age      | -0.26    | 0.06| -4.09 | <0.001 | 0.84     | 0.39| 2.19  | 0.032|
| rFA      | 34.72    | 7.62| 4.56  | <0.001 | -332.88  | 46.60| -7.14 | <0.001|
| Contralesional FA | 57.99   | 23.91| 2.42  | 0.018 | -317.44  | 146.29| -2.17 | 0.033|
| Type of Stroke | -       | -   | -     | -    | -        | -   | -     | -    |
| Intercept | 29.22    | 15.14| 1.93  | 0.057 | 562.01   | 92.59| 6.07  | <0.001|

Adjusted $R^2$ 0.321 0.420

Dummy values were assigned for the type of stroke; 1, hemorrhagic; 0, ischemic.

### Table 4. Correlations between explanatory variables

|          | Age          | rFA | Contralesional FA |
|----------|--------------|-----|------------------|
| rFA      | 0.224 (P=0.046) | -   | -                |
| Contralesional FA | -0.067 (P=0.555) | 0.085 (P=0.452) | -                |
| Type of stroke | -0.208 (P=0.065) | -0.340 (P=0.002) | -0.055 (P=0.628) |

Dummy values are assigned for the type of stroke: 1, hemorrhagic; 0, ischemic.
did not include patients with subarachnoid hemorrhage or those with brainstem or cerebellum lesions because their symptoms (altered consciousness, ataxia) are different from those in patients with supratentorial intramedullary lesions. Therefore, caution is needed when generalizing the present findings to the entire stroke population. Nevertheless, despite these limitations, the present study confirms that neural integrity within the corticospinal tracts and patient age are critical factors for predicting long-term stroke outcome.

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**CONFLICTS OF INTEREST**

The authors declare that there are no conflicts of interest.

**REFERENCES**

1. Veerbeek JM, Kwakkel G, van Wegen EE, Ket JC, Heymans MW: Early prediction of outcome of activities of daily living after stroke: a systematic review. Stroke 2011;42:1482–1488. DOI:10.1161/STROKEAHA.110.604090, PMID:21474812

2. Stinear CM, Byblow WD, Ackerley SJ, Barber PA, Smith MC: Predicting recovery potential for individual stroke patients increases rehabilitation efficiency. Stroke 2017;48:1011–1019. DOI:10.1161/STROKEAHA.116.015790, PMID:28280137

3. Stinear CM, Smith MC, Byblow WD: Prediction tools for stroke rehabilitation. Stroke 2019;50:3314–3322. DOI:10.1161/STROKEAHA.119.025696, PMID:31610763

4. Boyd LA, Hayward KS, Ward NS, Stinear CM, Rosso C, Fisher RJ, Carter AR, Leff AP, Copland DA, Carey LM, Cohen LG, Basso DM, Maguire JM, Cramer SC: Biomarkers of stroke recovery: consensus-based core recommendations from the Stroke Recovery and Rehabilitation Roundtable. Int J Stroke 2017;12:480–493. DOI:10.1177/1747493017714176, PMID:28697711

5. Kim B, Weinstein C: Can neurological biomarkers of brain impairment be used to predict poststroke motor recovery? A systematic review. Neurorehabil Neural Repair 2017;31:3–24. DOI:10.1177/1545968316662708, PMID:27503908

6. Puig J, Blasco G, Daunis-I-Estadella J, Thomalla G, Castellanos M, Figueras J, Remollo S, van Eendenburg C, Sánchez-González J, Serena J, Pedraza S: Decreased corticospinal tract fractional anisotropy predicts long-term motor outcome after stroke. Stroke 2013;44:2016–2018. DOI:10.1161/STROKEAHA.111.000382, PMID:23652266

7. Lindenberg R, Renga V, Zhu LL, Betzler F, Als D, Schlaug G: Structural integrity of corticospinal motor fibers predicts motor impairment in chronic stroke. Neurology 2010;74:280–287. DOI:10.1212/WNL.0b013e3181ccc6d9, PMID:20101033

8. Lindenberg R, Zhu LL, Rüber T, Schlaug G: Predicting functional motor potential in chronic stroke patients using diffusion tensor imaging. Hum Brain Mapp 2012;33:1040–1051. DOI:10.1002/hbm.21266, PMID:21538700

9. Moura LM, Luccas R, de Paiva JPQ, Amaro E Jr, Leemans A, Leite CDC, Otaduy MCG, Conforto AB: Diffusion tensor imaging biomarkers to predict motor outcomes in stroke: a narrative review. Front Neurol 2019;10:445. DOI:10.3389/fneur.2019.00445, PMID:31156529

10. Wong WW, Fang Y, Chu WCW, Shi L, Tong KY: What kind of brain structural connectivity remodeling can relate to residual motor function after stroke? Front Neurol 2019;10:1111. DOI:10.3389/fneur.2019.01111, PMID:31708857

11. Scrutinio D, Lanzillo B, Guida P, Mastropasqua F, Monitillo V, Pusineri M, Formica R, Russo G, Guarinaschelli C, Ferretti C, Calabrese G: Development and validation of a predictive model for functional outcome after stroke rehabilitation. Stroke 2017;48:3308–3315. DOI:10.1161/STROKEAHA.117.018058, PMID:29051222

12. de Ridder IR, Dijkland SA, Scheele M, den Hertog HM, Dirks M, Westendorp WF, Nederkoorn PJ, van de Beek D, Ribbers GM, Steyerberg EW, Lingsma HF, Dippel DW: Development and validation of the Dutch Stroke Score for predicting disability and functional outcome after ischemic stroke: a tool to support efficient discharge planning. Eur Stroke J 2018;3:165–173. DOI:10.1177/2396987318754591, PMID:29900414
13. Paolucci S, Antonucci G, Grasso MG, Bragoni M, Coiro P, De Angelis D, Fusco FR, Morell D, Venturiero V, Troisi E, Pratesi L: Functional outcome of ischemic and hemorrhagic stroke patients after inpatient rehabilitation: a matched comparison. Stroke 2003;34:2861–2865. DOI:10.1161/01.STR.0000102902.39759.D3, PMID:14615613

14. Douiri A, Grace J, Sarker SJ, Tilling K, McKevitt C, Wolfe CD, Rudd AG: Patient-specific prediction of functional recovery after stroke. Int J Stroke 2017;12:539–548. DOI:10.1177/1747493017706241, PMID:28440112

15. Bradnam LV, Stinear CM, Barber PA, Byblow WD: Contralesional hemisphere control of the proximal paretic upper limb following stroke. Cereb Cortex 2012;22:2662–2671. DOI:10.1093/cercor/bhr344, PMID:22139791

16. Wen H, Alshikho MJ, Wang Y, Luo X, Zafonte R, Herbert MR, Wang QM: Correlation of fractional anisotropy with motor recovery in patients with stroke after postacute rehabilitation. Arch Phys Med Rehabil 2016;97:1487–1495. DOI:10.1016/j.apmr.2016.04.010, PMID:27178097

17. Koyama T, Marumoto K, Uchiyama Y, Miyake H, Domen K: Outcome assessment of hemiparesis due to intracerebral hemorrhage using diffusion tensor fractional anisotropy. J Stroke Cerebrovasc Dis 2015;24:881–889. DOI:10.1016/j.jstrokecerebrovasdis.2014.12.011, PMID:25724241

18. Koyama T, Domen K: Diffusion tensor fractional anisotropy in the superior longitudinal fasciculus correlates with functional independence measure cognition scores in patients with cerebral infarction. J Stroke Cerebrovasc Dis 2013;22:72–79. DOI:10.1016/j.jstrokecerebrovasdis.2011.06.014, PMID:21795065

19. Koyama T, Kouro M, Uchiyama Y, Domen K: Utility of fractional anisotropy in cerebral peduncle for stroke outcome prediction: comparison of hemorrhagic and ischemic strokes. J Stroke Cerebrovasc Dis 2018;27:878–885. DOI:10.1016/j.jstrokecerebrovasdis.2017.10.022, PMID:29174878

20. Shinohara Y, Yanagihara T, Abe K, Yoshimine T, Fujinaka T, Chuma T, Ochi F, Nagayama M, Ogawa A, Suzuki N, Katayama Y, Kimura A, Liu M, Eto F: VII. Rehabilitation. J Stroke Cerebrovasc Dis 2011;20(Suppl):S145–S180. DOI:10.1016/j.jstrokecerebrovasdis.2011.05.014, PMID:21835355

21. Koyama T, Tsuji M, Miyake H, Ohmura T, Domen K: Motor outcome for patients with acute intracerebral hemorrhage predicted using diffusion tensor imaging: an application of ordinal logistic modeling. J Stroke Cerebrovasc Dis 2012;21:704–711. DOI:10.1016/j.jstrokecerebrovasdis.2011.03.004, PMID:21511497

22. Brunnstrom S: Motor testing procedures in hemiplegia: based on sequential recovery stages. Phys Ther 1966;46:357–375. DOI:10.1093/ptj/46.4.357, PMID:5907254

23. Safaz İ, Ylmaz B, Yaşar E, Alaca R: Brunnstrom recovery stage and motricity index for the evaluation of upper extremity in stroke: analysis for correlation and responsiveness. Int J Rehabil Res 2009;32:228–231. DOI:10.1097/MRR.0b013e32832a62ad, PMID:19339892

24. Heinemann AW, Linacre JM, Wright BD, Hamilton BB, Granger C: Relationships between impairment and physical disability as measured by the functional independence measure. Arch Phys Med Rehabil 1993;74:566–573. DOI:10.1016/0003-9993(93)90153-2, PMID:8503745

25. Jenkinson M, Beckmann CF, Behrens TE, Woolrich MW, Smith SM: FSL. Neuroimage 2012;62:782–790. DOI:10.1016/j.neuroimage.2011.09.015, PMID:21979382

26. Koyama T, Tsuji M, Nishimura H, Miyake H, Ohmura T, Domen K: Diffusion tensor imaging for intracerebral hemorrhage outcome prediction: comparison using data from the corona radiata/internal capsule and the cerebral peduncle. J Stroke Cerebrovasc Dis 2013;22:72–79. DOI:10.1016/j.jstrokecerebrovasdis.2011.06.014, PMID:21795065

27. Mori S, Oishi K, Jiang H, Jiang L, Li X, Akhter K, Hua K, Faria AV, Mahmood A, Woods R, Toga AW, Pike GB, Neto PR, Evans A, Zhang J, Huang H, Miller MI, van Zijl P, Mazzotti J: Stereotaxic white matter atlas based on diffusion tensor imaging in an ICBM template. Neuroimage 2008;40:570–582. DOI:10.1016/j.neuroimage.2007.12.035, PMID:18255316

28. Cassidy JM, Tran G, Quinlan EB, Cramer SC: Neuroimaging identifies patients most likely to respond to a restorative stroke therapy. Stroke 2018;49:433–438. DOI:10.1161/STROKEAHA.117.018844, PMID:29321336
29. Duarte E, Marco E, Muniesa JM, Belmonte R, Aguilar JJ, Escalada F: Early detection of non-ambulatory survivors six months after stroke. NeuroRehabilitation 2010;26:317–323. DOI:10.3233/NRE-2010-0568, PMID:20555154

30. Kwakkel G, Kollen BJ: Predicting activities after stroke: what is clinically relevant? Int J Stroke 2013;8:25–32. DOI:10.1111/j.1747-4949.2012.00967.x, PMID:23280266

31. Puig J, Blasco G, Schlag G, Stinear CM, Daunis-Estadella P, Biarnes C, Figueras J, Serena J, Hernández-Pérez M, Alberich-Bayarri A, Castellanos M, Liebeskind DS, Demchuk AM, Menon BK, Thomalla G, Nael K, Wintermark M, Pedraza S: Diffusion tensor imaging as a prognostic biomarker for motor recovery and rehabilitation after stroke. Neuroradiology 2017;59:343–351. DOI:10.1007/s00234-017-1816-0, PMID:28293701

32. Ward NS, Newton JM, Swayne OB, Lee L, Thompson AJ, Greenwood RJ, Rothwell JC, Frackowiak RS: Motor system activation after subcortical stroke depends on corticospinal system integrity. Brain 2006;129:809–819. DOI:10.1093/brain/awl002, PMID:16421171

33. Schaechter JD, Fricker ZP, Perdue KL, Helmer KG, Vangel MG, Greve DN, Makris N: Microstructural status of ipsilesional and contralesional corticospinal tract correlates with motor skill in chronic stroke patients. Hum Brain Mapp 2009;30:3461–3474. DOI:10.1002/hbm.20770, PMID:19370766

34. Otsuka N, Miyashita K, Krieger DW, Naritomi H: Compensatory contribution of the contralateral pyramidal tract after stroke. Front Neurol Neurosci 2013;32:45–53. DOI:10.1159/000348821, PMID:23859962

35. Alawieh A, Tomlinson S, Adkins D, Kautz S, Feng W: Preclinical and clinical evidence on ipsilateral corticospinal projections: implication for motor recovery. Transl Stroke Res 2017;8:529–540. DOI:10.1007/s12975-017-0551-5, PMID:28691140

36. Doughty C, Wang J, Feng W, Hackney D, Pani E, Schlag G: Detection and predictive value of fractional anisotropy changes of the corticospinal tract in the acute phase of a stroke. Stroke 2016;47:1520–1526. DOI:10.1161/STROKEAHA.115.012088, PMID:27217504

37. Connell LA, Smith MC, Byblow WD, Stinear CM: Implementing biomarkers to predict motor recovery after stroke. NeuroRehabilitation 2018;43:41–50. DOI:10.3233/NRE-172395, PMID:30056436

38. Goldstein LB, Bertels C, Davis JN: Interrater reliability of the NIH stroke scale. Arch Neurol 1989;46:660–662. DOI:10.1001/archneur.1989.00520420080026, PMID:2730378

39. Saito J, Koyama T, Domen K: Long-term outcomes of FIM motor items predicted from acute stage NIHSS of patients with middle cerebral artery infarct. Ann Rehabil Med 2018;42:670–681. DOI:10.5535/arm.2018.42.5.670, PMID:30404416