

Correlation of Radio-anatomic Site of Stroke with Motor Recovery and Functional Outcome in Ischemic Stroke Patients: A Hospital-based Prospective Cohort Study

¹Kaustav B Thakur, ²Romi S Nongmaithem, ³Jotin S Yengkhom, ⁴Utpalendu Debnath, ⁵Lisham R Singh

ABSTRACT

Introduction: Stroke is a global health problem and a leading cause of morbidity and mortality. The site of lesion in stroke is determined with either non contrast computed tomography or Magnetic resonance imaging (MRI) scan of brain. Clinical evidence suggests that the site of damage influences the pattern of motor deficits. Thus, motor recovery and functional outcome after stroke may vary according to the location and size of brain lesions. The relationship between the location of brain lesions and motor and functional outcomes in stroke patients still remains controversial. The present study was performed to find out such association, if any.

Materials and methods: A prospective cohort study was conducted in the department of physical medicine and rehabilitation (PMR), regional institute of medical sciences (RIMS) with 60 patients fulfilling the inclusion and exclusion criteria attending between September 2015 and August 2017. Valid informed consent from patients and ethical approval were taken. The outcome measures used were Functional Independence Measure (FIM) and Brunnstrom stages of recovery. Stroke severity was assessed by National Institutes of Health (NIH) Stroke Scale. Follow-up assessment was done at 3rd and 6th month post stroke. Data were entered and analyzed in SPSS version 21. A two-way mixed analysis of variance (ANOVA) was done to find out the effect of location of lesion on motor recovery and functional outcome; p-value < 0.05 was taken as statistically significant.

Results: A total of 60 patients were included in our study with a mean age of 58.47 ± 7.67 years. Male constituted 56.7% and female 43.3% in our study. Maximum patients were in the age group of 61 to 65 years (53.3%). Subcortical stroke was found to be the most common site of lesion (56.7%). Computed tomography (CT) scan was positive for ischemic features in 44 patients (73.33%). The rest of the 16 patients (26.67%) either showed normal study or location not correlating with the clinical features the patients presented with. Magnetic resonance imaging was advised for these patients and showed positive ischemic features confirming stroke or affecting other anatomical sites. Stroke in basal ganglia showed a statistically significant improvement in motor recovery ($p = 0.0008$) and functional outcome ($p = 0.047$). Similarly, minor stroke had the best motor recovery and functional outcome ($p < 0.001$).

Conclusion: The present study showed the relationship of radio-anatomic site of stroke with motor recovery and functional outcome. It also found that stroke in basal ganglia had a statistically significant improvement in motor recovery and functional outcome.

Keywords: Functional outcome, Ischemic stroke, Motor recovery, National Institutes of Health stroke scale, Stroke rehabilitation.

How to cite this article: Thakur KB, Nongmaithem RS, Yengkhom JS, Debnath U, Singh LR. Correlation of Radio-anatomic Site of Stroke with Motor Recovery and Functional Outcome in Ischemic Stroke Patients: A Hospital-based Prospective Cohort Study. Indian J Phy Med Rehab 2017;28(4):115-121.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

Stroke is now considered a global health problem and is a leading cause of morbidity and mortality worldwide.¹ The World Health Organization (WHO) defines stroke as "rapidly developing clinical signs of focal (or global) disturbance of cerebral function, with symptoms lasting 24 hours or longer or leading to death, with no apparent cause other than of vascular origin."² Stroke can be broadly classified into two major types: (1) Ischemic (85%) and (2) hemorrhagic (15%).³

Stroke is the third leading cause of death in the United States after heart disease and cancer. The prevalence of stroke in India is about 1.54 per 1,000 and the death rate is 0.60 per 1,000. The incidence of stroke is age related, uncommon before age 50, but doubling each decade after age 55. In younger cohorts, stroke is more common among men than among women, but more common among women for individuals over the age 85.^{2,4}

Risk factors for stroke have been divided into modifiable and non-modifiable factors. Hypertension is the leading risk factor for two of the top three causes of death in USA: coronary heart disease and stroke. Other modifiable risk factors include smoking, hypercholesterolemia, diabetes, obesity, hyperhomocystenemia. Non-modifiable factors include age, race, gender, and family history.⁵

The diagnosis of stroke requires imaging of the brain either CT or MRI.⁶ At most institutions, CT of the brain is performed as part of the initial evaluation of a patient

^{1,3-5}Postgraduate Student, ²Professor

¹⁻⁵Department of Physical Medicine and Rehabilitation, Regional Institute of Medical Sciences, Imphal, Manipur, India

Corresponding Author: Romi S Nongmaithem, Professor Department of Physical Medicine and Rehabilitation, Regional Institute of Medical Sciences, Imphal, Manipur, India, e-mail: dr.romi.singh@gmail.com

with suspected stroke. However, it is insensitive to early ischemic changes and is usually of little value for establishing the diagnosis of acute stroke. However, diffusion weighted MRI has shown promise for the early diagnosis of stroke.⁷ In theory, a full MRI study, including diffusion- and perfusion-weighted imaging, MR angiography, and standard T1- and T2-weighted images, could be performed within 30 minutes.⁸

Hemiplegia contributes to about 90% of patients.² The degree of involvement of the limbs and trunk depends on the site and extent of lesion.⁹ Motor sequelae of stroke are the primary reason for its disabling effect. Currently, there is some evidence that subjects with stroke improve their motor function even in chronic state (longer than 6 months) due to neuroplasticity.¹⁰ Hemiparesis and motor recovery have been the most studied of all stroke impairments.¹¹ Twitchell, in his classical report, described in detail the "classic" pattern of motor recovery following stroke. In majority of hemiparetic patients, the arm is more involved than the leg and the degree of functional motor recovery in the arm is less than in the leg.⁴

The patterns of motor recovery and functional outcome have been described in detail by the authors of the Copenhagen Stroke Study;¹² 95% of stroke survivors reached their best neurologic level within 11 weeks of onset. Individuals with milder stroke recovered more quickly and those with severe strokes reached their best neurologic level in 15 weeks on an average. After an early phase of progressive improvement, the course of motor recovery reaches a plateau and only minor additional improvement occurs after 6 months post onset. However, in some stroke survivors with partial return of voluntary movement, recovery may continue over a longer period of time.

The extent of motor recovery and final functional outcome after stroke varies among individuals. Some motor functions recover rapidly, while others remain as permanent deficit.¹³ Clinical evidence suggests that the site of damage of the sensorimotor cortex influences the pattern of motor deficits.¹⁴ Thus, motor recovery and functional outcome after stroke may vary according to the location and size of brain lesions. While several studies suggested that the size of lesions correlates with final outcomes,¹⁵⁻¹⁸ other studies found no such association.^{19,20}

Most patients with significant neurological impairment who survive a stroke are initially dependent in basic Activities of daily living (ADL), that is, bathing, dressing, feeding, toileting, grooming, transfers, and ambulation. The capacity of individuals to perform these activities is usually scored on ADL scales, such as the FIM. Almost all patients show improved function in ADLs as recovery occurs. The relationship between the location of brain lesions and motor and functional outcomes in stroke patients therefore remains controversial.

This study was therefore conducted to find out the correlation between the radio-anatomic site of stroke diagnosed by CT/MRI with the motor recovery and functional outcome.

AIMS AND OBJECTIVES

To study the correlation of radio-anatomic site of stroke with motor recovery and functional outcome in ischemic stroke patients

MATERIALS AND METHODS

A prospective cohort study was done in the Department of Physical Medicine and Rehabilitation, Regional Institute of Medical Sciences, Imphal for a period of 2 years from September 2015 to August 2017. All ischemic stroke patients attending the department of PMR during the study period fulfilling the inclusion and exclusion criteria were included in the study.

Inclusion Criteria

- First ever ischemic stroke confirmed by CT/MRI
- Patients within 3 months of stroke
- Age 40 to 65 years

Exclusion Criteria

- Comatose patients
- Severely moribund patients
- Active medical problems
- Other peripheral or central nervous system dysfunction
- Uncooperative patients

Study Variables

- Age: Patients in age group 40 to 65 years
- Gender
- Side of lesion
- Reporting time interval for rehabilitation
- CT scan findings:
Site: classified as
 - Cortical (C)
 - Subcortical (S)
 - Combined cortical and subcortical (CCS)
 - Basal ganglia (BG)
 - Combined cortical, subcortical, and basal ganglia (CSBG)

Outcome Measures

- The FIM is the functional outcome measure developed by Uniform Data System for Medical Rehabilitation and its validity and reliability in stroke are well

established.²¹ It contains 18 items, each item ranging from 1 to 7. A FIM item score of 7 is categorized as “complete independence”, while a score of 1 is “complete dependence”. Scores below 6 require another person for supervision or assistance. Possible total score ranges from 18 to 126, and lower score indicates more dependent in respect to functional activities.

- Motor recovery was assessed by Brunnstrom’s stages of motor recovery.⁴ It emphasizes the synergistic pattern of movement which develops during recovery from hemiplegia. It has six stages ranging from complete flaccid to near normal voluntary movement. A patient can plateau at any of these stages but will generally follow this sequence if he or she makes a full recovery.
- National Institutes of Health Stroke Scale (NIHSS) was originally designed to assess stroke severity in controlled clinical studies of ischemic stroke patients.²² Despite this, it is now commonly used to measure neurologic function and guide treatment after spontaneous intracerebral hemorrhage in day-to-day clinical settings as well.²³ The NIHSS contains 15 items, including level of consciousness, eye movement, visual field deficit, and motor and sensory involvement. Scale items are scored by the degree of severity using weighted scores.²⁴ Possible total score ranges from 0 to 42. The reliability and validity of this scale are well established.²²

Procedure

All ischemic stroke patients attending the PMR department, RIMS fulfilling the inclusion and exclusion criteria were included in the study. Patients were subjected to clinical and neurological examination. A baseline initial assessment was done at the time of admission post stroke using the assessment tools. A follow-up assessment was done at 3rd month and 6th month post stroke. From the day of initial examination, all patients received the standard therapy (e.g. bilateral hemi-positioning, range of motion exercises, and Neurodevelopmental training) routinely given in the PMR department, RIMS. CT/MRI scan findings for each patient were recorded separately.

Data Management and Statistical Analysis

Data were entered and analyzed by using SPSS version 21. Descriptive statistics, such as mean, frequency, and percentages were calculated. Analysis was done using a two-way mixed ANOVA to find out the effect of location of lesion on motor recovery and functional outcome. A p-value <0.05 was taken as statistically significant.

Informed Consent and Ethics Approval

All the participants were informed about the nature of the project and those who agreed to participate were asked to sign the informed consent form. Participants were assured that they could withdraw from the project at any time. The approval of the Research Ethics Board, RIMS was taken before starting the study.

RESULTS AND OBSERVATION

A total of 60 patients following ischemic stroke fulfilling the inclusion and exclusion criteria were studied. The study consisted of thirty-four (34) males and twenty-six (26) females. The mean age was found to be 58.47 ± 7.67 years. The majority of the patients were from the age group of 61 to 65 years (53.3%). The mean duration of stroke was 39.7 ± 27.24 days and the time interval since stroke and rehabilitation was 28.31 ± 20.60 days. Majority of the patients came with a subcortical stroke confirmed by CT scan/MRI accounting 56.7%, followed by a basal ganglia stroke (30%) and cortical stroke (13.3%). Out of 60 patients, CT scan was positive for ischemic features in 44 patients (73.33%). The rest of the 16 patients (26.67%) either showed normal study or location not correlating with the clinical features the patients presented with. So, MRI was advised for these patients and showed positive ischemic features confirming our diagnosis (Tables 1 and 2).

The mean values of motor recovery of cortical, sub-cortical, and basal ganglia strokes showed an increase from baseline to 6 months. But the maximum increase in the mean value was found in stroke of basal ganglia and was found to be statistically significant (p-value <0.05). So, stroke in basal ganglia showed statistically significant improvement in motor recovery following ischemic stroke (Table 3).

Table 1: Background characteristics of the study participants

Characteristics	Frequency	Percentage
Age (in years), mean \pm (SD)	58.47 ± 7.67	
Age group (in years)	40–45	6
	46–50	6
	51–55	6
	56–60	10
	61–65	32
Gender	Male	34
	Female	26
Duration of stroke (in days), mean (SD)	39.7 ± 27.24	
Time interval since stroke and rehabilitation (in days), mean (SD)	28.31 ± 20.60	

Table 2: Baseline measurements of the study participants

Characteristics		Frequency	Percentage
Site of lesion	Cortical	8	13.3
	Subcortical	34	56.7
	Combined cortical and subcortical	0	0
	Basal ganglia	18	30.0
	All combined	0	0
Stroke	No stroke	0	0
Severity grade (NIH)	Mild	24	40
	Moderate	34	56.7
	Moderate-to-severe	2	3.3
	Severe	0	0
CT scan positive		44	73.33
Brunnstrom's stage	Stage 1	4	6.7
	Stage 2	30	50.0
	Stage 3	8	13.3
	Stage 4	16	26.7
	Stage 5	0	0
	Stage 6	2	3.3
Functional independence measure motor score \pm SD		41.00 \pm 16.80	

The mean values of functional outcome of cortical, subcortical, and basal ganglia strokes showed an increase from baseline to 6 months. But the maximum increase in the mean value was found in stroke of basal ganglia and was statistically significant (p -value < 0.05). So, stroke in basal ganglia showed a statistically significant increase in the functional outcome following ischemic stroke (Table 4).

The mean values of functional outcome of minor, moderate, and moderate-to-severe strokes showed an increase from baseline to 6 months. But the maximum increase in the mean value was found in minor stroke and was statistically significant (p -value < 0.05). So, minor stroke, according to the NIH stroke scale, showed a statistically significant increase in the functional outcome following ischemic stroke (Table 5).

Table 3: Relationship of radio-anatomic site of stroke and Brunnstrom's scores at baseline, 3 months', and 6 months' follow-up

Radio-anatomic site	Brunnstrom's mean (SD)			p -value*
	Baseline	3 months	6 months	
Cortical	2.75 (2.05)	3.50 (1.60)	3.75 (2.05)	0.008
Subcortical	2.59 (0.92)	3.88 (0.97)	4.82 (1.22)	
Basal ganglia	3.0 (0.97)	4.78 (1.16)	5.89 (0.79)*	

Two-way mixed ANOVA; * p -value < 0.05 was taken as statistically significant

The mean values of motor recovery of minor, moderate, and moderate-to-severe strokes showed an increase from baseline to 6 months. A maximum increase in the mean value was found in minor stroke, and Motor recovery was found to be statistically significant (p -value < 0.05) in minor stroke. So, minor stroke, according to the NIH stroke scale, showed a statistically significant improvement in motor recovery following ischemic stroke (Table 6).

DISCUSSION

This prospective cohort study was conducted on 60 patients suffering from hemiplegia due to ischemic type of cerebrovascular accident admitted within three months of stroke onset. The present study was done to establish a relation of radio-anatomic site of stroke with motor recovery and functional outcome in ischemic stroke patients.

The mean age of patients in the present study was 58.47 ± 7.67 years. Forty-two out of 60 participants (70%) belonged to the age group of 56 to 65 years, showing the increased incidence after the age of 55 years. Sridharan et al²⁵ conducted a study where the median age of the participants was 67 years. Another study by Carvalho et al²⁶ showed the participants having a mean age of 67.7 ± 14.4 years. The slight disparity can be explained by the exclusion of patients older than 65 years in our study, but it proved that ischemic stroke is more common after the age of 55 years.

Table 4: Relationship of radio-anatomic site of stroke and FIM scores at baseline, 3 months' and 6 months' follow-up

Radio-anatomic site	FIM score mean (SD)			p -value*
	Baseline	3 months	6 months	
Cortical	55.25 (21.32)	67.0 (12.44)	71.0 (12.51)	0.047
Subcortical	59.71 (20.55)	73.53 (20.89)	81.88 (19.88)	
Basal ganglia	68.22 (21.52)	80.44 (15.99)	96.44 (9.69)*	

Two-way mixed ANOVA; * p -value < 0.05 was taken as statistically significant

Table 5: Relationship between severity of stroke and FIM scores at baseline, 3 months' and 6 months' follow-up

Severity of stroke	FIM score mean (SD)			p -value*
	Baseline	3 months	6 months	
Minor	77.67 (18.70)	93.67 (7.83)	100.92 (10.61)*	< 0.001
Moderate	52.29 (14.47)	62 (18.49)	74.41 (14.49)	
Moderate-to-severe	29.0 (0.01)	61.0 (0.01)	68.0 (0.01)	

Two-way mixed ANOVA; * p -value < 0.05 was taken as statistically significant

Table 6: Relationship between severity of stroke and Brunnstrom scores at baseline, 3 months' and 6 months' follow-up

Severity of stroke	Brunnstrom's mean (SD)			p-value*
	Baseline	3 months	6 months	
Minor	3.08 (1.14)	4.58 (1.14)	5.75 (0.85)*	<0.001
Moderate	2.59 (1.05)	3.88 (1.05)	4.65 (1.34)	
Moderate-to-severe	1.00 (0.01)	2.0 (0.01)	2.0 (0.01)	

Two-way mixed ANOVA; p-value <0.05 was taken as statistically significant

Overall, stroke is thought to be more common in males. In the present study also, males accounted for 56.7% with a ratio of 1.3:1. A study conducted by Dhamija et al²⁷ also had a similar finding of 1.2:1. A literature review by Appelros P et al also showed higher incidence of stroke in males worldwide with ratios varying from 0.95 to 2.13. Only few studies have shown higher incidence in females like Carvalho et al. Females have less incidence of stroke because of several factors like positive effect of estrogen on cerebral circulation, lower blood pressure than men of same age, and lower incidence of diseases like peripheral vascular disease and ischemic heart disease, and a better healthy lifestyle than men.

Our study showed that most patients had a subcortical stroke (56.7%) followed by basal ganglia stroke (30%) and then cortical stroke (13.3%). The findings are similar to another study conducted by Chen et al²⁸ where most patients had a subcortical stroke (49.1%), followed by basal ganglia stroke (38%) and then cortical stroke (12.72%).

Sivakumar et al²⁹ conducted a study with 120 first-time cerebral infarct patients with hemiparesis to evaluate the effect of cerebral infarct location on motor and functional outcome for first three months post stroke. They found that the location of infarct had an influence on motor scores as well as functions like hand function, walking, sitting to standing, and stair climbing. Cortical lesions were found to have greater motor scores and minimal functional disabilities than subcortical or transcerebral infarction.

Our study also showed a clear association between the location of ischemic stroke with motor recovery and functional outcome. However, stroke in basal ganglia was found to have a statistically significant improvement in both motor recovery and functional outcome. Cortical stroke and subcortical stroke also showed improvement, but were not significant in contrast to the study conducted by Sivakumar et al. The reasons could be: (1) the follow-up period was longer (6 months) in our study, (2) cortical stroke patients in their study may not have involved the pre motor cortex which resulted in a better motor and functional outcome, (3) basal ganglia was not separately classified by CT/MRI, and (4) the outcome measures used (Stroke rehabilitation assessment of movement and motor

assessment scale) were different which may have resulted in the disparity. Both the studies showed poorer outcomes in subcortical strokes, the reason being, such infarcts can disrupt facilitation of secondary motor system.

Miyai et al³⁰ recruited 132 patients to analyze the effect of stroke in MRI positive basal ganglia and thalamus on the functional outcome after 4 months of inpatient rehabilitation using the FIM score. They concluded that subcortical lesions to multiple structures in the basal ganglia permitted enhanced motor recovery and functional outcome. Our study also showed that ischemic stroke in basal ganglia had a better result in terms of enhanced motor recovery and functional outcome.

Miyai et al³¹ conducted another study with 42 consecutive patients with single cerebral infarction in the territory of the middle cerebral artery to assess the degree to which premotor cortex damage affected functional outcome. They found that premotor cortex spared group demonstrated significant gain in mobility and function compared to the premotor cortex group. In our study, cortical stroke did not show significant improvement in motor recovery and functional outcome in contrast to several other studies which showed maximum improvement in cortical stroke patients. The possible reason may be the fact that the cortical stroke patients in our study may have had involvement of the premotor cortex, which was not taken into account and which may have hindered motor recovery at the end of 6 months in contrast to other studies.

Fu et al³² conducted a study on 4 hemiplegic patients with basal ganglia infarction to assess the motor recovery of contralateral hand using functional MRI. On follow-up 3, patients achieved significant recovery of motor function of affected limbs with activation of bilateral sensorimotor cortex in 2 patients and cerebellar activation in all patients. No remarkable recovery was seen in 1 patient with left basal ganglia infarction. Similar finding was observed in our study where basal ganglia infarction showed a significant improvement in motor recovery and functional outcome.

MRI is more sensitive than CT in demonstrating the changes of acute stroke in the first 48 hours.³ CT scan is preferred, as it is less costly, widely available, and less time consuming. In the present study, MRI was able to

detect ischemic changes in patients showing normal study on CT scan and not clinically improving with time.

There were several limitations in our study. The sample size was small. Patients >65 years were not included in the study. The duration of treatment was short and there was a lack of long-term follow-up. The size of the infarct was not taken into account during analysis of outcome in the study. Future studies incorporating a larger sample population with a longer follow-up period, CT/MRI-guided brain lesion profiles which are a combination of location and size of stroke are suggested for establishing the relation.

CONCLUSION

The present study was done to find out the correlation of radio anatomic site of stroke with motor recovery and functional outcome in CT/MRI-confirmed ischemic stroke. The study confirmed the relation of radio-anatomic site of stroke with motor recovery and functional outcome. It also found that stroke in basal ganglia of the brain had a significant improvement in motor recovery and functional outcome among all the other locations of stroke. The study also confirmed that there is a significant improvement in motor recovery and functional outcome in patients with minor stroke according to the NIH stroke scale. It was also found that MRI should be advised to patients whose clinical outcome is not correlating with the site of stroke or showing normal findings on a CT scan.

The localization of infarction is particularly important for predicting the probability of motor recovery after stroke. Studying functions as a reflection of motor impairment is imperative to plan a training program. The results of this study project a requirement for intensified rehabilitation for infarcts involving subcortical and cortical areas.

REFERENCES

- Donnan GA, Fisher M, Macleod M, Davis SM. Stroke. *Lancet* 2008 May;371(9624):1612-1623.
- Park K. Textbook of preventive and social medicine. 21st ed. Jabalpur: Banarsidas Bhanot; 2011.
- Harvey RL, Eliot JR. Rehabilitation in stroke syndromes. In: Braddom RL, editor. Physical medicine and rehabilitation. 3rd ed. New Delhi: Elsevier; 2008. pp. 1175-1212.
- Stein J, Brandstater ME. Stroke rehabilitation. In: Frontera WR, Delisa JA, Gans BM, Walsh NE, Robinson LR, editors. Delisa's physical medicine & rehabilitation principles and practice. 5th ed. Philadelphia, PA: Lippincott Williams and Wilkins; 2010. pp. 551-574.
- Roth EJ. Heart disease in patients with stroke: incidence, impact and implications for rehabilitation. Part 1: classification and prevalence. *Arch Phys Med Rehabil* 1993 Jul;74(7):752-760.
- Weir CJ, Murray GD, Adams FG, Muir KW, Grosset DG, Lees KR. Poor accuracy of stroke scoring systems for differential clinical diagnosis of intracranial haemorrhage and infarction. *Lancet* 1994 Oct;344(8928):999-1002.
- Fiebach JB, Schellinger PD, Jansen O, Meyer M, Wilde P, Bender J, Schramm P, Jüttler E, Oehler J, Hartmann M, et al. CT and diffusion-weighted MR imaging in randomized order: diffusion-weighted imaging results in higher accuracy and lower interrater variability in the diagnosis of hyperacute ischemic stroke. *Stroke* 2002 Sep;33(9):2206-2210.
- Lynch JR, Blessing R, White WD, Grocott HP, Newman MF, Laskowitz DT. Novel diagnostic test for acute stroke. *Stroke* 2004 Jan;35(1):57-63.
- Thomson A, Skinner A, Piercy J, editors. Tidy's physiotherapy. 12th ed. Oxford: Butterworth Heinemann; 1991.
- Patel AT, Duncan PW, Lai SM, Studenski S. The relation between impairments and functional outcomes post stroke. *Arch Phys Med Rehabil* 2005 Oct;81(10):1357-1363.
- Foulkes MA, Wolf PA, Price TR, Mohr JP, Hier DB. The stroke data bank: design, methods, and baseline characteristics. *Stroke* 1988 May;19(5):547-554.
- Jorgensen HS, Nakayama H, Raaschou HO, Vive-Larsen J, Stoier M, Olsen TS. Outcome and time course of recovery in stroke. Part II: time course of recovery. The Copenhagen stroke study. *Arch Phys Med Rehabil* 1995 May;76(5):406-412.
- Warabi T, Inoue K, Noda H, Murakami S. Recovery of voluntary movement in hemiplegic patients. *Brain* 1990 Feb;113(Pt 1): 177-189.
- Kunesch E, Binkofski F, Steinmetz H, Freund HJ. The pattern of motor deficit in relation to the site of stroke lesions. *Eur Neurol* 1995;35(1):20-36.
- Beloosesky Y, Streifler JY, Burstin A, Grinblat J. The importance of brain infarct size and location in predicting outcome after stroke. *Age Ageing* 1995 Nov;24(6):515-518.
- Everdingen KJ, Grond J, Kappelle LJ, Ramos LM, Mali WP. Diffusion-weighted magnetic resonance imaging in acute stroke. *Stroke* 1998;29(9):1783-1790.
- Saunders DE, Clifton AG, Brown MM. Measurement of infarct size using MRI predicts prognosis in middle cerebral artery infarction. *Stroke* 1995 Dec;26(12):2272-2276.
- Allen CM. Predicting outcome after acute stroke: role of computerised tomography. *Lancet* 1984 Aug;2(8400):464-465.
- Pantano P, Formisano R, Ricci M, di Piero V, Sabatini U, Pofi BD. Motor recovery after stroke: morphological and functional brain alterations. *Brain* 1996 Dec;119(Pt 6):1849-1857.
- Miyai I, Blau AD, Reding MJ, Volpe BT. Patients with stroke confined to basal ganglia have diminished response to rehabilitation efforts. *Neurology* 1997 Jan;48(1):95-101.
- Granger CV, Gresham GE. New developments in functional assessment. *Phys Med Rehabil Clin N Am* 1993;4(3):417-499.
- Brott T, Adams HP, Olinger CP, Marler JR, Barsan WG, Biller J, Spilker J, Holleran R, Eberle R, Hertzberg V, et al. Measurements of acute cerebral infarction: a clinical examination scale. *Stroke* 1989 Jul;20(7):864-870.
- Morgenstern LB, Hemphill JC, Anderson C, Becker K, Broderick JP. Guidelines for the management of spontaneous intracerebral hemorrhage: a guideline for healthcare professionals from the American heart association/American stroke association. *Stroke* 2010 Aug;41(9):2108-2129.
- Lyden P, Lu M, Jackson C, Marler J, Kothari R, Brott T, Zivin J. Underlying structure of the national institutes of health stroke scale: results of a factor analysis. *Stroke* 1999 Nov;30(11): 2347-2354.
- Sridharan SE, Unnikrishnan JP, Sukumaran S, Sylaja PN, Nayak SD, Sarma PS, Radhakrishnan K. Incidence, types,

- risk factors, and outcome of stroke in a developing country. *Stroke* 2009 Apr;40(4):1212-1218.
26. Carvalho JJ, Alves MB, Viana GA, Machado CB, Santos BF, Kanamura AH, Lottenberg CL, Neto MC, Silva GS. Stroke epidemiology, patterns of management, and outcomes in Fortaleza, Brazil: a hospital-based multicenter prospective study. *Stroke* 2011 Dec;42(12):3341-3346.
 27. Dhamija RK, Arora S, Gaba P, Jais M, Kaintura A, Kumar M, Bhattacharjee J. Study of genetic, metabolic and inflammatory risk factors in patients of acute ischemic stroke. *Indian J Clin Biochem* 2008 Apr;23(2):136-143.
 28. Chen CL, Tang FT, Chen HC, Chung CY, Wong MK. Brain lesion size and location: effects on motor recovery and functional outcome in stroke patients. *Arch Phys Med Rehabil* 2000 Apr;81(4):447-452.
 29. Sivakumar R, Meenakshisundaram U, Shankar V, Rajeswaran R, Maiya A. Effect of location of cerebral infarction on functional recovery following stroke. *Sri Ramachandra J Med* 2014 Jan-Jun;7(1):7-13.
 30. Miyai I, Suzuki T, Kang J, Volpe BT. Improved functional outcome in patients with hemorrhagic stroke in putamen and thalamus compared with those with stroke restricted to the putamen or thalamus. *Stroke* 2000 Jun;31(6):1365-1369.
 31. Miyai I, Suzuki T, Kang J, Kubota K, Volpe BT. Middle cerebral artery stroke that includes the premotor cortex reduces mobility outcome. *Stroke* 1999 Jul;30(7):1380-1383.
 32. Fu Y, Zhang Q, Yu C, Zhang J, Wang N, Zuo S, Zhang N. Longitudinal assessment of motor recovery of contralateral hand after basal ganglia infarction using functional magnetic resonance imaging. *Biomed Res Int* 2016;304(2):1-9.