ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 11, Issue, 06, pp.4935-4940, June, 2019

DOI: https://doi.org/10.24941/ijcr.35747.06.2019

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

CORRELATION OF INJURY OF ARCUATE FASCICULUS WITH APHASIA IN PATIENTS OF MILD TBI USING DIFFUSION TENSOR IMAGING

[1]Prof. Arumugam Thiruvalluvan and [2,*]Dr. Nihal Ahemad

[1]Director of Institute of Neurosurgery, MMC Chennai
[2]Resident in Neurosurgery, Institute of Neurosurgery, Madras Medical College, Chennai

ARTICLE INFO

Article History:
Received 09th March, 2019
Received in revised form
24th April, 2019
Accepted 25th May, 2019
Published online 30th June, 2019

Key Words:
DTI, TBI, Arcuatefasciculus,
Aphasia, FA Values, Correlation.

Corresponding author:

ABSTRACT

Background: The Arcuate fasciculus (AF) is an important neural tract for language function. Various language deficits including conduction aphasia can be caused by injury of the AF. Little is known about injury of the arcuate fasciculus (AF) in patients with mild traumatic brain injury (TBI). ***Objective:*** To investigate the injury of the AF in the dominant hemisphere in patients with mild TBI presenting with aphasia, using diffusion tensor tractography (DTT) and to find a correlation between them. ***Materials and Methods*****:** Study design was observational retrospective cross sectional study. We recruited 20 patients with injury of the left AF with mild TBI and evaluated the DTTs of the left AF ; decline in FA values of left AF compared to right AF using age matched controls using previous study data was used as an index of dominant AF injury. On WAB evaluation, aphasia quotient was calculated and correlated with the degree of aphasia and the severity of AF injury. ***Results:*** Based on the aphasia quotient patients were classified into mild, moderate and severe and this was correlated well with the level of arcuate fasciculus injury. A positive linear correlation between the decline of FA values in the language dominant hemisphere to the degree of aphasia in that patient was established. Hence it can be postulated that severity of injury to arcuate fasciculus is directly proportional to the degree of severity of aphasia. However, no such correlation could be established between the FA values to the specific type of aphasia. ***Conclusion*****:** DTT could provide useful information in detecting injury of the AF and evaluation of the AF using DTT would be necessary even in the case of a patient with mild TBI who complains of mild language deficit.

Citation: ***Dr. Nihal Ahemad and Prof. Arumugam Thiruvalluvan*****, 2018.** "Correlation of injury of arcuate fasciculus with aphasia in patients of mild tbi using diffusion tensor imaging", *International Journal of Current Research*, 11, (06), 4935-4940.

INTRODUCTION

Traumatic brain injury (TBI) is a major cause of neurological disability in adults worldwide (Maas, 2008). TBI is classified as mild, moderate, and severe according to the severity, and mild TBI has been reported in 75% to 85% of cases of TBI (Alexander, 1995; Cassidy, 2004; De Kruijk, 2001; Styrke, 2007). Patients with mild TBI frequently experience various neurological symptoms derived from neural injury (Bazarian, 2007; Kwon, 2014; Lipton et al., 2008; Rutgers, 2008). Previous studies have reported that 80% to 100% of patients with TBI had some forms of language deficit (Rabinowitz, 1980; Sarno, 1980). However, little is known about the incidence and the pathogenetic mechanisms of language deficits in mild TBI (Wesson Ashford, 2009). In addition, patients with mild TBI rarely show significant abnormality on standardized language assessment tools (Bernstein, 1999). As a result, language deficits in patients with mild TBI have been overlooked so far. The Arcuate fasciculus (AF) is an important neural tract for language function with the inferior fronto-occipital fasciculus (Dick, 2012; Makris, 2009; Bernal, 2009).Various language deficits including conduction aphasia can be caused by injury of the AF (Bernal, 2009; Kim et al., 2011; Mori et al., 1999; Jang, 2013). Therefore, precise estimation of the state of the AF in patients with language deficits following mild TBI is clinically important because it would be useful for clinicians in setting precise rehabilitative strategy and predicting prognosis of language deficits (Bernal, 2009; Kim, 2011; Jang, 2013). Diffusion tensor imaging has enabled 3-dimensional reconstruction of the architecture and integrity of the neural tracts at the sub cortical level (Mori, 1999). Injury of the neural tracts in patients with mild TBI, which is not detected on conventional MRI, has been demonstrated in many studies using DTI (Bazarian, 2007; Lipton, 2008; Rutgers, 2008; Jang, 2013). However, so far, little is known about injury of the AF (Wesson Ashford, 2009). In the present study, we attempted to investigate injury of the AF in the dominant hemisphere in patients with mild TBI presenting with various forms of aphasia using DTI.

MATERIALS AND METHODS

Twenty right-handed patients with mild TBI 16 men and 4 women, who were admitted to the Madras Medical College and Rajiv Gandhi Government General hospital, Chennai during a period of 2 yrs from March 2017 to Feb 2019,with a diagnosis of mild TBI presenting with aphasia ,were included in the study.

Further, the following inclusion criteria was considered:

- Loss of consciousness (LOC) for <30 min, post-traumatic amnesia (PTA) for <24 hours, and initial Glasgow Coma Scale score of 13 to 15 at admission or within 24hrs of injury-criteria for mild TBI
- No brain lesion on conventional CT or MRI,
- Age <18 years>50 yrs old,
- no symptoms related to injury of the corticobulbar tract or dysarthria
- No cognitive impairment to rule out the effect of cognition on the result of language evaluation as assessed by the Mini-Mental State Examination[21] (MMSE >25)
- No previous history of neurologic or psychiatric disease
- No oromotor dysfunction or language disorder before the head trauma

Language evaluation: Aphasia quotient was calculated using the Tamil version of Western Aphasia Battery with the following components being assessed:

- Spontaneous speech-20 POINTS
- Auditory verbal recognition-10 POINTS
- Naming and word finding-10 POINTS
- Repetition-10 POINTS

Using the above indices, the aphasia quotient was calculated out of a total 100 points and correlation with the level of arcuate faciculus injury was done using DTI. Based on the Aphasia quotient they were classified into mild, moderate and severe groups. (severity criteria—mild: 80–99, moderate: 50–79, severe <50). Also based on the above indices, patients were categorised to have a specific type of aphasia as depicted in table 1:

Diffusion tensor imaging: DTI scanning was performed at an average of 2 weeks after head trauma using a 6-channel head coil on a 1.5 T MRI with single-shot, spin echo-planar imaging. The values of fractional anisotropy (FA) of left Arcuate Fasciculus in comparison to the right AF were measured. Usually the left AF has higher FA values than in right AF as indicated by several previous studies. The patients were thus identified to have likely injury to the left arcuate fasciculus if the FA value of left AF was significantly decreased than that of the right AF for that same individual, as compared to FA values of age matched healthy persons determined by previous studies; or either on tractography there was documented narrowing of AF or apparent discontinuity.

Statistical analysis: All statistical analysis were performed using the Statistical Package for the Social Sciences for Windows (SPSS, Version 17.0; Chicago). The level of statistical significance was set at $P < 0.05$.The study design was observational retrospective cross sectional study.

RESULTS

Among 20 consecutive patients with the same inclusion criteria, the demographic data of the patients are summarized in Table 2. The causes of TBI were as follows: motor vehicle accidents, falls, and hit by falling objects. Figure 1(a) and (b) depicts one of the sample DTI values and DTT of one the patients. There is a significant decline in the FA value of superior longitudinal fasciculus including the arcuate fasciculus on the left side as compared to the right. The DTT depicting narrowing of the AF is seen in the adjacent figure. The most common symptom was par aphasia in 6(30%) patients. They confuse the words or replace 1 word with another real word or feel difficulty in word-finding. Two (10.0%) patients complained of deficits of comprehension when they communicate, and 4 (20.0%) patients felt difficulty in making sentences while speaking. Four(20.0%) patients complained of >2 language symptoms (par aphasia and deficits of comprehension);3(15.0%) deficits of comprehension and repetition;1 (5.0%) par aphasia and deficits of speech production.Table3 depicts these findings. Based on the aphasia quotient patients were classified into mild, moderate and severe and this was correlated well with the level of arcuate fasciculus injury as depicted in table 3. Of the 20 patients, 10 patients had moderate degree of aphasia and 7 patients had mild degree of aphasia. Only 3 patients were diagnosed to have severe degree of aphasia. This was confirmed by Pearsons correlation coefficient which was calculated at-0.8, indicating a strong negative linear correlation between the FA values of AF in the language dominant hemisphere to the severity of aphasia in that patient. Hence it can be postulated that severity of injury to arcuate fasciculus is directly proportional to the degree of severity of aphasia. Of the 20 patients, based on aphasia quotient they were sub classified into different types of aphasia as depicted in Table 4. However, no such correlation could be established between the FA values to the specific type of aphasia. Functional MRI will be better able to delineate definite areas responsible for the sameTable5 depicts the summary of FA values of 20 patients with left AF injury with corresponding Aphasia quotient and the type of Aphasia.

DISCUSSION

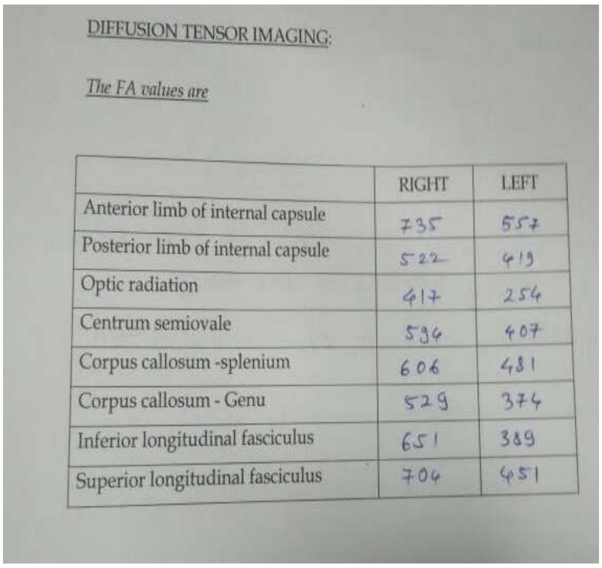
In this study, we investigated injury of the AF in the dominant hemisphere on DTT in patients with mild TBI presenting with various degrees of aphasia by comparing the FA (Fractional anisotropy) values of right and left AF tracts. FA, ADC (Apparent Diffusion Coefficient), and fiber number have been frequently used for evaluation of the state of a neural pathway in patients with brain injury (Mori, 1999; Assaf, 2008; Neil, 2008). The FA value indicates the degree of directionality of water diffusion, therefore, indicates the white matter organization. The ADC value means the degree of water diffusion, which increases in some pathology such as vasogenic edema or axonal damage. By contrast, the fiber number indicates the existing number of voxels in a neural tract[24].Therefore, the decreased FA value or fiber number with the increased ADC value confirms injury of the AF. In our study however only FA values were considered. Since the introduction of DTI, many studies have reported on the usefulness of DTT for evaluation of the AF in patients with brain injury; however, most studies focused on stroke (Wesson Ashford, 2009; Kim, 2011; Kim, 2013; Tak, 2014; Breier et al., 2008; Hosomi, 2009; Liegeois, 2013; Schlaug, 2009; Zhang, 2010). Regarding TBI, to the best of our knowledge, only 3 studies have reported on injury of the AF

Table 1.

Aphasia type	Fluency	Auditory verbal comprehension	Repetition	Naming and word finding
Global	<5	<4	<5	<7
Brocas	<5	>3	<8	<9
Isolation	<5	<4	>4	<7
Transcortical Motor	<5	>3	>7	<9
Wernickes	>4	<7	<8	<10
Transcortical Sensory	>4	<7	>7	<10
Conduction	>4	>6	<7	<10
Anomic	>4	>6	>6	<10

Table 2. Demographic Data of Patient Group

MEAN AGE	33YRS
MALE :FEMALE RATIO	16:4 OR 4:1
MODE OF INJURY	
RTA	17
ACCIDENTAL FALL	2
FALL OF HEAVY OBJECT	1
HANDEDNESS	ALL RIGHT HANDED


DIFFUSION TENSOR IMAGING:

The FA values are

	RIGHT	LEFT
Anterior limb of internal capsule	735	557
Posterior limb of internal capsule	522	419
Optic radiation	417	254
Centrum semiovale	594	407
Corpus callosum -splenium	606	481
Corpus callosum - Genu	529	374
Inferior longitudinal fasciculus	651	389
Superior longitudinal fasciculus	704	451

Figure 1(a)

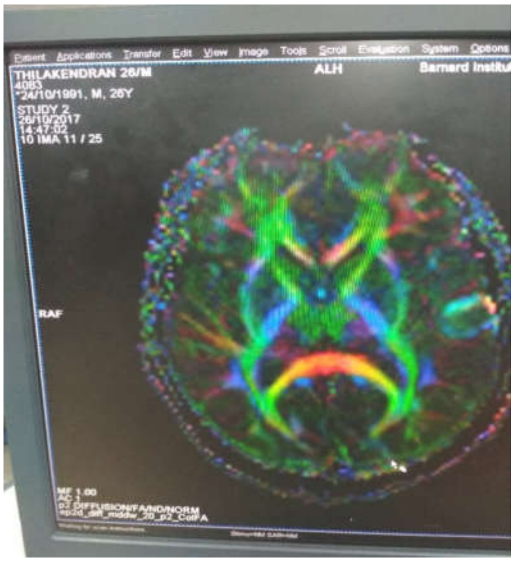


Figure 1(b)

Table 4.

Paraphasia	6(30%)
Comprehension deficits	2(10%)
Difficulty in making sentences	4(20%)
Paraphasia and comprehension deficits	3(15%)
Deficits of comprehension and repetition	4(20%)
Paraphasia and deficits of speech production	1(5%)

Table 5.

Sl no	Right Fa Value	left fa value	APHASIA QUOTIENT out of 100(DEGREE)	Type of APHASIA
1	547	441	62(moderate)	Transcortical motor
2	550	504	76(moderate)	Wernickes
3	600	552	78(moderate)	Transcortical sensory
4	580	480	76(moderate)	Conduction
5	631	526	42(severe)	Global
6	595	468	70(moderate)	Wernickes
7	580	490	44(severe)	Global
8	575	530	80(mild)	Conduction
9	480	392	68(moderate)	Wernickes
10	560	520	80(mild)	Wernickes
11	526	486	86(mild)	Brocas
12	560	540	84(mild)	Conduction
13	704	451	48(severe)	Global
14	608	530	78(moderate)	Wernickes
15	580	570	90(mild)	Brocas
16	520	434	76(moderate)	Conduction
17	560	518	68(moderate)	Transcortical sensory
18	540	532	88(mild)	Brocas
19	498	440	80(mild)	Brocas
20	460	420	76(moderate)	transcortical sensory

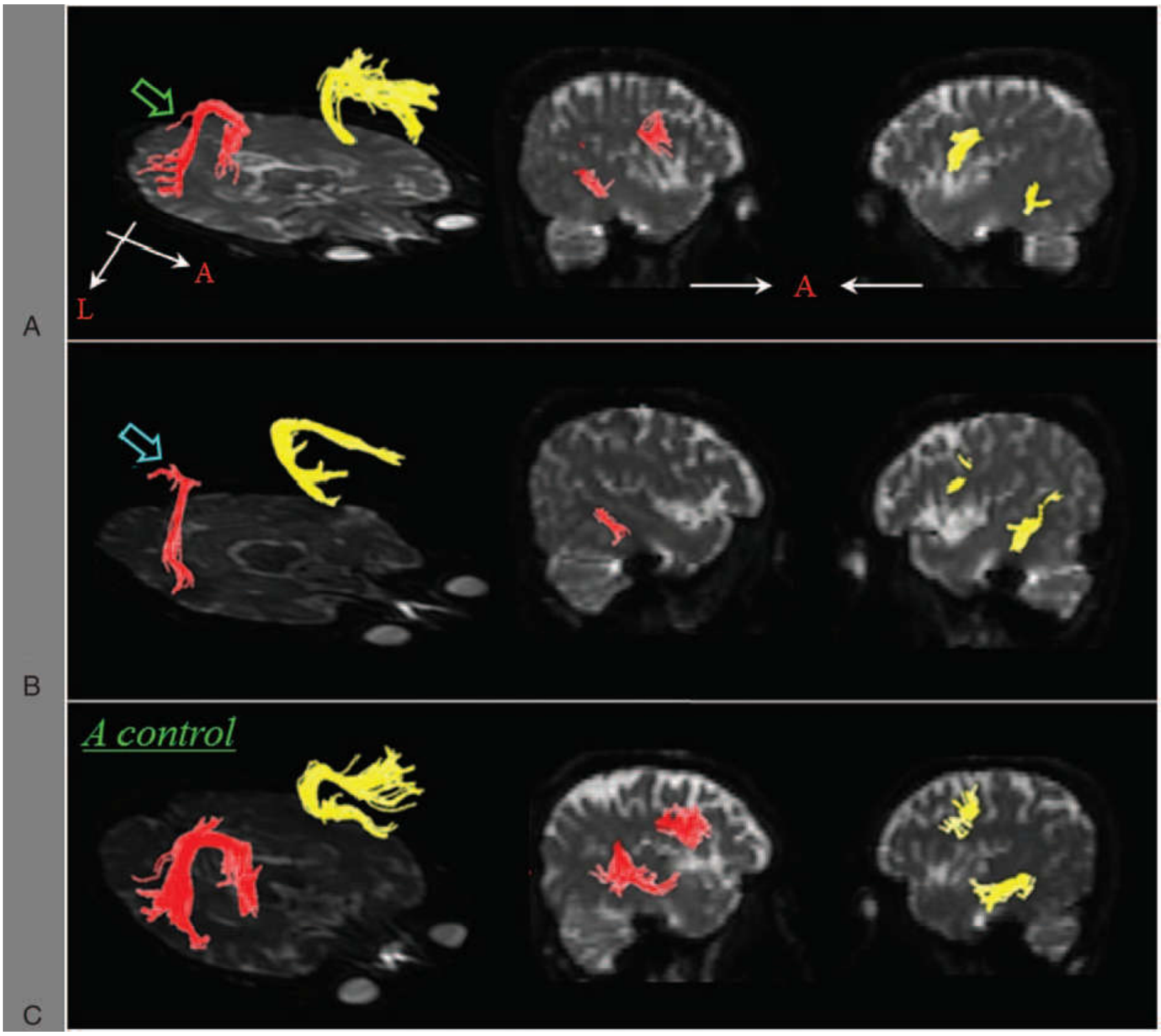


Figure 2. Diffusion tensor tractography for the arcuate fasciculus (right AF: yellow color, left AF: red color)—(A) a patient with decreased fiber number of the left AF (green arrow); (B) a patient with a discontinued left AF (blue arrow); (C) a normal subject. AF=arcuate fasciculus

(Wesson Ashford, 2009; Liegeois, 2013). In 2009, Wesson reported on a patient with mild TBI who showed conduction aphasia due to narrowing of the left AF on DTT following a blast injury. Recently, Liegeois et al investigated language function and DTT parameters of the AF, uncinate fasciculus, and the corpus callosum in 32 patients with mild to moderate-severe TBI and found that long-term outcome regarding poor language following TBI could be predicted by changes in tractography-derived properties of the 3 language neural tracts described above. In 2016, Sung ho Jang and colleagues published an article on injury to AF in mild TBI patients (Sung Ho Jang, 2016). They recruited 25 patients with injury of the left AF among 64 righthanded consecutive patients with mild TBI and 20 normal control subjects. DTTs of the left AF were reconstructed, and fractional anisotropy (FA), apparent diffusion coefficient (ADC), and fiber number of the AF were measured. Among 64 consecutive patients, 25 (39%) patients showed injury of the left AF. The patient group showed lower FA value and fiber number with higher ADC value than the control group ($P<0.05$). On Korean-WA Bevaluation, aphasia quotient and language quotient were 95.9and 95.0, respectively. However,23 (92.0%) of 25 patients complained of language-related symptoms after TBI; par aphasia in 12 (48.0%) patients, deficits of comprehension in 4 (16.0%) patients, deficits of speech production in 1 (4.0%) patient, and>2 language symptoms in 6 (24.0%) patients. They found that a significant number (39%) of patients with mild TBI had injury of the AF in the dominant hemisphere and these patients had mild language deficit. These results suggest that DTT could provide useful information in detecting injury of the AF and evaluation of the AF using DTT would be necessary even in the case of a patient with mild TBI who complains of mild language deficit. Hence this is one of the few the studies to investigate injury of the AF in patients with mild TBI.

Limitations of the study

However, several limitations of this study should be considered. First, this study included a relatively small number of patients and did not include long-term follow up DTI data. Therefore, further long-term follow-up studies including a larger number of patients and DTI data to elucidate natural course and prognosis should be encouraged. Secondly, although DTI is a powerful anatomic imaging tool which can visualize the gross fiber architecture, because regions of fiber complexity and crossing can prevent full reflection of the underlying fiber architecture by DTT, it may underestimate or overestimate the fibertracts (Lee, 2005; Parker, 2005). Finally, the fact that we did not analyze the other neural tracts which are involved in language function is another limitation in this study; hence injury correlation to the specific type of aphasia was not possible. FMRI may be better suited for this role, but this is cost ineffective, especially in developing countries.

Conclusion

In conclusion, we investigated injury of the AF in the dominant hemisphere on DTI in patients with mild TBI and found that a significant number of patients with mild TBI had injury of the AF in the dominant hemisphere and these patients had various degrees of language deficit. These results suggest that DTT could provide useful information in detecting injury of the AF, which could not be detected on conventional brain MRI in patients with mild TBI. Furthermore, evaluation of the AF using DTT would be necessary even in the case of a patient with mild TBI who complains of mild language deficit. Further studies on the other various neural tracts associated with language disturbances should be encouraged.

Acknowledgement

We would like to thank Prof Babu Peter, Professor of Radiology, Barnard Institute of radiology, Madras Medical College, Chennai and the other radiology staff for their kind assistance in carrying out DTI studies.

Disclosure: The authors have no conflicts of interest to disclose.

Funding: All expenses have been borne by the authors. No external funding obtained.

REFERENCES

Alexander MP. 1995. Mild traumatic brain injury: pathophysiology, natural history, and clinical management. *Neurology.*, 45:1253–1260.

Assaf Y., Pasternak O. 2008. Diffusion tensor imaging (DTI)-based whitematter mapping in brain research: a review. *J Mol Neurosci.,* 34:51–61

Bazarian JJ., Zhong J., Blyth B. et al., 2007. Diffusion tensor imagingdetects clinically important axonal damage after mild traumatic braininjury: a pilot study. *J Neurotrauma.,* 24:1447–1459.

Bernal B., Ardila A. 2009. The role of the arcuate fasciculus in conduction aphasia. Brain.132(pt 9):2309–2316.

Bernstein DM. 1999. Recovery from mild head injury. Brain Injury.13:151–172.

Breier JI., Hasan KM., Zhang W. et al., 2008. Language dysfunction afterstroke and damage to white matter tracts evaluated using diffusiontensor imaging. *Am J Neuroradiol.,* 29:483–487.

Cassidy JD., Carroll LJ., Peloso PM. et al. 2004. Incidence, risk factors andprevention of mild traumatic brain injury: results of the WHOCollaborating Centre Task Force on Mild Traumatic Brain Injury. *J Rehab Med.,* (43 suppl):28–60.

De Kruijk JR., Twijnstra A., Leffers P. 2001. Diagnostic criteria and differential diagnosis of mild traumatic brain injury. Brain Injury. 15:99–106.

Dick AS., Tremblay P. 2012. Beyond the arcuate fasciculus: consensus andcontroversy in the connectional anatomy of language. Brain. 135(pt 12):3529–3550.

Folstein MF., Folstein SE., McHugh PR. 1975. Mini-mental state. Apractical method for grading the cognitive state of patients for theclinician. *J Psychiatr Res*., 12:189–198.

Geschwind N. 1970. The organization of language and the brain. Science. 170:940–944.

Hosomi A., Nagakane Y., Yamada K. et al., 2009. Assessment of arcuatefasciculus with diffusion-tensor tractography may predict the prognosisof aphasia in patients with left middle cerebral artery infarcts. *Neuroradiology*.51:549–555.

Jang SH. 2013. Diffusion tensor imaging studies on arcuate fasciculus instroke patients: a review. *Front Hum Neurosci.,* 7:749.

Kim SH., Lee DG., You H. et al., 2011. The clinical application of thearcuate fasciculus for stroke patients with aphasia: a diffusion tensortractography study. *Neuro Rehab.*, 29:305–310.

Kim SHJS. 2013. Prediction of aphasia outcome using diffusion tensortractography for arcuate fasciculus in stroke. *Am J Neuroradiol*. 34:785–790.

Kwon HG., Jang SH. 2014. Delayed gait disturbance due to injury of thecorticoreticular pathway in a patient with mild traumatic braininjury. *Brain Injury*., 28:511–514.

Lee SK., Kim DI., Kim J. et al., 2005. Diffusion-tensor MR imaging andfibertractography:a new method of describing aberrant fiberconnections in developmental CNS anomalies. *Radiographics*. 25:53-65.

Liegeois FJ., Mahony K., Connelly A. et al. 2013. Pediatric traumatic brain injury: language outcomes and their relationship to the arcuatefasciculus. Brain Lang.;127:388–398.

Lipton ML., Gellella E., Lo C. et al., 2008. Multifocal white matterultrastructural abnormalities in mild traumatic brain injury withcognitive disability: a voxel-wise analysis of diffusion tensorimaging. *J Neurotrauma*., 25:1335–1342.

Maas Al SN., Bullock R. 2008. Moderate and severe traumatic brain injuryin adults. *Lancet Neurol*.7:728–741.

Makris N., Pandya DN. 2009. The extreme capsule in humans andrethinking of the language circuitry. *Brain Struct Funct*. 213:343–358.

Mori S., Crain BJ., Chacko VP. et al., 1999. Three-dimensional tracking ofaxonal projections in the brain by magnetic resonance imaging. *Ann Neurol.*, 45:265–269.

Neil JJ. 2008. Diffusion imaging concepts for clinicians. *J Magn Reson Imaging*., 27:1–7.

Pagani E., Agosta F., Rocca MA. et al. 2008. Voxel-based analysis derivedfrom fractional anisotropy images of white matter volume changeswith aging. Neuro Image. 41:657–667.

Parker GJ., Alexander DC. 2005. Probabilistic anatomical connectivityderived from the microscopic persistent angular structure ofcerebral tissue. *Philos Trans R Soc Lond B Biol Sci.,* 360:893–902

Rabinowitz AR., Levin HS. 2014. Cognitive sequelae of traumatic braininjury. *Psychiatr Clin N Am.,* 37:1–11.

Rutgers DR., Toulgoat F., Cazejust J. et al., 2008. White matter abnormalitiesin mild traumatic brain injury: a diffusion tensor imaging study. *Am J Neuroradiol*., 29:514–519.

Sarno MT. 1980. The nature of verbal impairment after closed head injury. *J Nerv Ment Dis*.168:685–692.

Schlaug G., Marchina S., Norton A. 2009. Evidence for plasticity in whitemattertracts of patients with chronic Broca's aphasia undergoingintense intonation-based speech therapy. *Ann N Y Acad Sci.,* 1169:385–394.

Styrke J., Stalnacke BM., Sojka P. et al., 2007. Traumatic brain injuries in a well-defined population: epidemiological aspects and severity. *J Neurotrauma*., 24:1425–1436.

Sung Ho Jang, Ah Young Lee, and So Min Shin. 2016. Injury of the Arcuate Fasciculus in the Dominant Hemisphere in Patients With Mild Traumatic Brain Injury. Medicine.95:9;March.

Tak HJ., Jang SH. 2014. Relation between aphasia and arcuate fasciculus inchronic stroke patients. *BMC Neurol*., 14:46.

Wesson Ashford J., Yu Zhang AR., Wang Han, et al. 2009. Mild traumaticbrain injury and conduction aphasia from a close proximity blastresulting in arcuate fasciculus damage diagnosed on DTI tractography. *Mil Med*., 174:v–vi.

Zhang Y., Wang C., Zhao X. et al., 2010. Diffusion tensor imaging depictingdamage to the arcuate fasciculus in patients with conduction aphasia:a study of the Wernicke–Geschwind model. *Neurol Res*., 32:775–778.

****