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PREDICTION OF MOTOR OUTCOME USING DTI, IN PATIENTS WITH HAEMORRHAGIC STROKE IN BASAL GANGLIA, CAUSED BY HYPERTENSION

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Abstract:

***Background and Purpose**: Predicting motor outcome in patients with hemorrhagic stroke due to hypertension can be a challenging task. Purpose of this research is to seek out whether using combination of clinical evaluation (using Brunnstrom scale, functional walking scale and modified Rankin Scale) and DTI-based assessment of coricospinal tract damage caused by hemorrhagic stroke can be promising or not to predict motor outcome in patients with hemorrhagic stroke in basal ganglia caused by hypertension. DTI was performed at 12 hours of symptoms onset after hemorrhagic stroke in basal ganglia to predict motor outcome at 3 months.*

***Materials and Methods:** In this study, 45 patients with hemorrhagic stroke in the basal ganglia caused by hypertension admitted in Qinghai University Affiliated Hospital from August 2019 to September 2019 were enrolled. Selected patients were diagnosed with hemorrhagic stroke by head CT scan. DTI was performed at 12 hours of symptom onset in selected patients with motor deficits secondary to hemorrhagic stroke. The evaluation index was based on Brunnstrom scale, functional walking scale and modified Rankin Scale to predict motor outcome clinically. Patients were divided into 4 groups based on the level of damage to CST. Subsequently, the assessment of hemorrhage in basal ganglia, perihematomal edema (edema location and volume) and corticospinal tract involvement was done. Corticospinal tract ratios for mean diffusivity and fractional anisotropy were also calculated.*

***Results:** In this study we found that for patients with hemorrhagic stroke in the basal ganglia caused by hypertension, the DTI can be used as an effective technique to predict the prognosis of motor function, as it is capable to evaluate the damage to CST. Furthermore, it can also be used as a guide to select a suitable plan for an effective physiotherapy for such patients.*

***Conclusions:** Combination of clinical evaluation of motor function and DTI-based assessment of damage to CST from hemorrhagic stroke in basal ganglia caused by hypertension, can accurately predict motor outcome.*

Keywords: *DTI , Hemorrhagic Stroke, Motor Outcome Prediction, Basal Ganglia, corticospinal tract, Hypertension*

***Abbreviations:** DTI_diffusion tensor imaging; CST _ corticospinal tract; FA _ fractional anisotropy; ICH _ intracerebral hemorrhage; PHE _ perihematomal edema; rFA _ FA ratio ; HICH_Hypertensive intracerebral hemorrhage;PLIC_Posterior limb of internal capsule*

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INTRODUCTION:

Hemorrhagic stroke in basal ganglia caused by hypertension and the role of DTI in prediction of motor outcome:

One of the most common causes of morbidity and death in developing countries is stroke [1,2] . There are two major types of stroke including ischemic and hemorrhagic stroke [3]. Hemorrhagic stroke is one of the major causes of brain parenchymal injury which often causes severe motor weakness and functional disability resulting in disastrous physical dependence. Motor outcome prediction is crucial to accelerate and attain optimal and most effective therapeutic and rehabilitation purpose. Subtypes of hemorrhagic stroke include subarachnoid hemorrhage (SAH), intraventricular hemorrhage (IVH) and intracerebral hemorrhage (ICH) [4,5,6,7]. Incidence of ICH is approximately 13% and SAH is 25-30% amongst the different types of stroke. While more and more nonhuman primate models are being built to elaborate the underlying pathophysiology of non-hemorrhagic stroke, brain MRI and CT imaging is being used to establish biomarkers to visualize such neuronal injury mechanisms[8,9]. The Standard brain's MRI describes superficial and deeper parenchymal brain structure in great detail. Then there are more evolved unique sequences that have not yet reached the medical routine domain. These specialized sequences can shed light on the neuronal and axonal function's normal physiology. Diffusion tensor imaging or "tractography" is one of such sequences that specifically examines the directionality and integrity of the brain's axonal fibers. DTI is also capable to visualize the white fiber bundles' integrity or damage and how they get affected following a neuronal injury caused by hemorrhagic stroke due to different etiologies.

In several cases it was observed that hypertension causing intracerebral hemorrhage, tends to affect specific brain regions. According to a study which was carried out on 100 patients having ICH caused by hypertension, the most common bleeding sites were as mentioned below: the basal ganglia (55%), thalamus (26%), cerebral hemispheres (11%), brainstem (8%), and cerebellum (7%) [10]. Similar figures were reported in another older case series [11]. The sites of ICH caused by hypertension in their sequence were 65% in the basal ganglia, followed by 15% in the subcortical white matter, 10% in the cerebellum, and 10% in the pons.

Studies indicate that incidences of hemorrhagic stroke account for 20-30 % of total strokes cases reported in China and the rest of Asia. Patients arriving in emergency department with intracerebral hemorrhage (ICH) are usually more critical with worse outcomes than patients with ischemic stroke [12]. In causing hemorrhagic strokes, hypertension has been consistently found as a major risk factor. Ariesen MJ et al reviewed that, there were 14 separate studies (11 case-control studies and 3 cohort studies) carried out in order to check the association between hypertension and hemorrhagic strokes. All studies showed a positive correlation between hypertension and hemorrhagic strokes [13]. Between hypertension and patients with hemorrhagic strokes, the overall odds ratio was 3.68. As hypertension becomes more severe, the risk of developing ICH rises. An adjusted relative risk ($RR_{adjusted}$) of 2.20 for systolic BP of 140 to 159 mm Hg and 3.78 for ≥160 mm Hg compared with ≤139 mm Hg was found by Leppälä et al [14]. Suh et al in a different study observed an RR of 2.2 for high normal BP, 5.3 for hypertension in stage 1, 10.4 for stage 2 hypertension, and 33 in stage 3 hypertension [15]. It is clearly showed by both of these cohort studies that the higher the degree of hypertension, the greater the risk of ICH development. In a more recent study, 439 patients were prospectively investigated for possible etiologies of ICH [16]. In about 80 percent of the patients, hypertension was observed as an etiology (definite, probable, or possible) of ICH. Hypertension incidence increases with age; thus, hypertension is more common in older people as a risk factor for ICH. Above discussion clearly suggests that hypertension is one of the major risk factors of hemorrhagic strokes.

In hemorrhagic stroke mechanism of white matter tract injuries are now better understood. One of the most common neuronal injury mechanisms following an ICH is caused by Wallerian degeneration in the corticospinal tract in the immediate surroundings and away from the hematoma site. In addition to the mechanical mass effect, inflammation, and edema around the hematoma periphery that occurs during the acute period, neuronal injury is caused by a direct damage to the deep white and gray matter[17,18]. There are other mechanisms that mediate injury to the white matter's neural structures. [19, 20]. In the early phase, blood components and the hemoxygenase enzymes that cleave heme, cause neuronal damage. Heme degradation products then spread to tissues that cause cell toxicity [20,21]. Secondary brain damage in the periphery of hematoma following brain hemorrhage, is caused by both the mass effect of the new hemorrhage and the toxicity associated with the deterioration of structure of the hematoma, the consequent release of inflammatory mediators and free radicals. Iron has been demonstrated to be responsible for cerebral toxicity in all cerebral hemorrhage types including SAH [21]. Deferoxamine, an iron chelator, for example, reduces brain damage caused by ICH [19].

The explanation, why deeper structures especially the basal ganglia are more affected by hypertensive ICH is due to hemodynamic damage to the perforating arteries. These arteries originate directly from the larger arteries and enter the brain at right angles. Cortical vessels get protection from hypertension effects from a thicker smooth muscle layer in the tunica media [11]. On the other hand, due to having thinner walls, perforating arteries are more susceptible to high BP effects. The arteries which get affected from high blood pressure include thalamoperforate arteries, lenticulostriate arteries, upper and lower cerebellar arteries and paramedian branches of basilar artery. Thalamus, basal ganglia, cerebellum and pons are supplied by these arteries respectively, thereby illustrating the tendency of these brain areas particularly the basal ganglia to be more affected by extreme hypertension.

Currently, our ability in case of a hemorrhagic stroke to predict neuronal functional outcome is suboptimal. DTI is one of the non-invasive techniques that can predict functional results. DTI is now reaching a point where it is very reliable to have resolution and the ability to track fibers optimally. The Standard brain's MRI describes superficial and deeper parenchymal brain structure in great detail but it is not capable to visualize integrity or damage to white fiber bundles. Recording of a tissue volume signal by repeated dephasing and rephasing of processing protons in the specific valumed imaged is the method on which conventional MRI techniques are based on. Corticopspinal tract (CST) being the most important white fiber bundle can not be visualized by a conventional MRI scan of brain. DTI on the other hand is based on different properties the tissues possess. In most tissues, water molecules disperse similarly in all directions (isotropic diffusion), but in white matter tracts diffusion is along the tract's direction (anisotropic). The main parameter measured in DTI is essentially the degree of fractional anisotropy (FA) in the processing proton's given voxel and its Eigen vector in an ellipsoid domain. In each DTI-imaged voxel, the 3-dimensional Eigen vector path must be acquired in at least nine matrix elements to reflect the directionality of the elaborate dataset or "tensor." To build color maps of white fiber tracts, at least 6 directions of DTI datasets are required. Mathematical calculations and data processing are then used to present color coded maps of various white matter fiber tracts in the brain known as fiber tractography [44]. This ability of DTI to show damage or integrity of white fiber bundles particularly CST makes it a reliable and unique sequence to predict motor outcome in patients with hemorrhagic stroke. Studies regarding hemorrhagic stroke have been a prime example for the researchers to explore in past few decades, however the association between hypertension and hemorrhagic stroke with focus on exploration of the role of DTI is not fully studied yet. Hence, in this research our main focus will be on the role of DTI in predicting motor outcome in patients having hemorrhagic stroke in basal ganglia due to hypertension.

Clinical application of DTI:
Over 2000 published studies have been exploring the role of DTI tractography in the brain since its inception in the 1990s, although most of them were done during the last 5 years**.**[8]. DTI's role was explored in patients with traumatic brain injury, ICH, and surgical guidance to optimize glioma resection [21,22,23]. The other medical contexts in which DTI was examined are in the diagnosis of Alzheimer's disease dementia and in the discovery of subtle lesions that could explain epilepsy etiology [24,25].

Evidence gained from the review of previous literature indicates the role of DTI in human subjects is reliable [26]. Before studying human modules of DTI, the animals pilot researches were conducted in order to assess the role of DTI to visualize the damage or integrity of white fiber tracts. The purpose is to be able to predict the motor outcome in case of an ICH in order to allow for targeted therapy or early development of a rehabilitation strategy.

ICH is the most common type of hemorrhagic stroke in which DTI's function has been most discussed. In cases of stroke-induced damage, the ipsilateral corticospinal tract (CST) including the pyramid tract (PY) has been increasingly studied. The CST is an important white matter tract consisting of PY, internal capsule, and the cerebral peduncle. It has been demonstrated that the asymmetry produced from DTI maps in the CST in fractional anisotropy (FA) values correlates with clinical signs and can predict functional results[26,27,28,29,30,31]. In addition, a recent study showing a decrease in FA values at 7 to 28 days after ICH in the contralateral CST suggests that FA asymmetry may not be a robust assessment of secondary injury motor pathway [32]. Different studies suggest that the misunderstanding of contralateral PY and substantia nigra (SN) changes after ICH as shown in several other ICH animal model studies may be due to the use of various ICH sites and different time points of imaging in those studies[23,26,27,32].

Wang et al. investigated the association between DTI and the outcome of motor function 6 months after an ICH[33]. Evaluation of the performance of DTI in 36 patients at 3 days and 2 weeks after ICH was done by them. Measured at the anterior cerebral peduncle, the parameters selected for evaluation were FA, rFA and MD. Results show that the rFA assessed in the cerebral peduncle at 2 weeks was significantly correlated at 6 months with the mRS.

In the existing literature, the aspect of variations in FA and the correlation with the outcome of motor function was not well addressed. Following a different study, Ma et al. explored the dynamic variations of the affected CST DTI measurements in ICH patients over a 90-day period[34]. The series of MRI used on all research patients was diffusion weighted echo planar imaging with gradients in 6 directions. The researchers observed that day 0 FA was significantly correlated with day 90 with MFS. It is further proved by study that DTI technology is robust and that fiber tracking in the basal ganglia region can quantify the recovery of white matter after a spontaneous ICH. At least two more studies were done that examined the role of DTI in detecting post-ICH recovery of white matter fibers and hematoma evacuation treatment [35,36]. Similarly, in 27 patients treated with minimally invasive methods to evacuate the hematoma, Wu et al. show similar significant correlation between improved FA and CST fiber density and motor function outcome [36].

In their study of 22 SAH patients, Sang Seok Yeo et al. discussed this dimension of DTI. The measurement of DTI parameters was done in the 22 patients (24 years old) in the brain regions including posterior limb of the internal capsule,corona radiata, midbrain, mid-pons and medulla [37]. In contrast to the controls, they demonstrated significantly low FA values in ROI within CST in the midbrain in SAH patients. In other anatomical positions there was no significant difference in the measurements. In addition, in ADC values or between FA values and the motor function scores, no correlation was observed. Such findings support the hypothesis that early hydrocephalus may cause injury to CST in the midbrain during SAH [38]. It is dully understood that hypertension remains a major etiology of hemorrhagic stroke which is a leading cause of morbidity and mortality world wide. CT and conventional MRI scan can help to visualize superficial and deep parenchymal structures of brain but are not capable to show damage or integrity of white fiber bundle in patients having hemorrhagic stroke. Whereas, DTI is a special technique which can visualize white fiber bundles' integrity or damage in helping physicians to better understand the phenomenon of predicting motor outcome after hemorrhage stroke. Therefore, in this research, we attempted to explore the role of DTI in predicting motor outcome.

MATERIALS AND METHODS:

Patients:

In this study 45 patients with hypertensive cerebral hemorrhage in the basal ganglia diagnosed by head CT admitted in Qinghai University Affiliated Hospital were enrolled. Patients were selected from August 2019 to September 2019 including 36 males and 9 females. The age ranged from 39 to 86 years old, with an average age of (64 ± 14) years. Six patients were excluded because of early death whereas,3 patients were excluded from research group due to incompatibility with MRI suggested procedures (because 2 patients were with external orthopedic fixation and 1 with aneurysm clip in history) . In other instance, four patients' DTI dataset was not usable due to motion artifacts. Our institutional ethics committee approved the study, and all patients or their relatives provided written informed consent. Inclusion criteria for this study were (1) age > 39 years; (2) cerebral hemorrhage in the basal ganglia must be because of hypertension;(3) cerebral hemorrhage in the basal ganglia must be unilateral;(3) patients who only had conservative treatment;(4) patients with no history of neurosurgical treatment;(5)patients with normal limb movement before the onset of the disease;(6) patients with no history of unconscious disorders;(7)imaging studies were done within first 2 weeks of hypertensive hemorrhage. Patients with hematoma involving bilateral basal ganglia, patients with previous history of neurological diseases leading to limb dysfunction, patients with poor clinical condition (GCS 3), pregnant women, patients with renal insufficiency and patients with any contraindications to perform magnetic resonance imaging were excluded.

In remaining 32 patients DTI was performed 2 weeks after acute onset of the disease. The motor function was evaluated using Brunnstrom exercise evaluation form, Functional walking scale and modified Rankin rating scale, at 48 hours and 2 weeks after onset. After that the relationship between corticospinal tract damage by hematoma, perihematomal edema and changes in corticospinal tract integrity were observed. In addition, the degree of corticospinal tract injury was classified and analyzed for their correlation with motor function outcome in patients with hypertensive cerebral hemorrhage in basal ganglia.

Initial clinical measures taken to stabilize the selected patients:

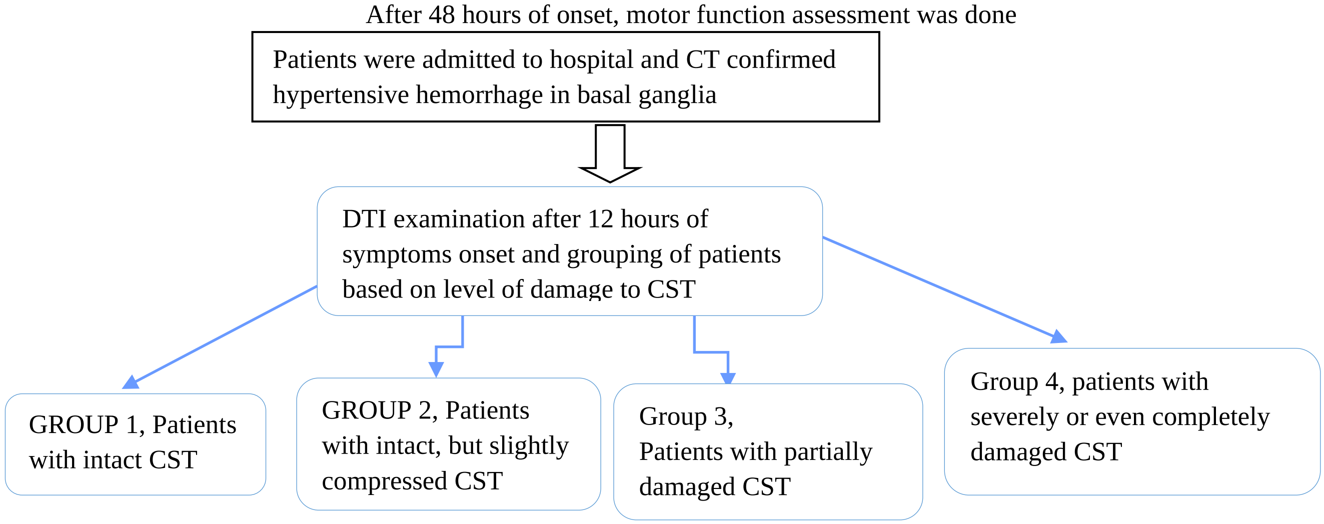
Following effective treatment measures were taken for such patients to stabilize them and to prevent further neurological damage and to improve the functional recovery rate.

1. Measures were taken to control blood pressure according to the patients' basic blood pressure level and fluctuations. Treatment with an appropriate anti-hypertensive agent helped to reduce the blood pressure by 10% - 20%. To control blood pressure a conventionally used combination of an angiotensin converting enzyme inhibitor or an angiotensin II receptor antagonist or a calcium channel blocker was used. For some patients, intravenous administration of the anti-hypertensive drug sodium nitroprusside was done to lower the blood pressure.
2. Short-term use of haemostatic drugs in conventional small doses was done to prevent further cerebral hemorrhage.
3. A diuretic agent in the early stage (6 hours) was used to decrease perihematomal edema. Gradually as the hematoma started to dissolve and the cerebral edema developed, 20% mannitol IV was given which is a routine way of its administration. In most of the patients dose of mannitol administration was 125ml, 2-4 times / day or adjustment of the dose was done according to the patient's condition. To prevent renal failure, renal function tests were done regularly to detect any changes in renal functions in elderly patients, as mannitol may cause renal failure in this age.
4. Patients' position was changed on regular intervals to prevent bed sores. Special attention was given to the patients who were diagnosed with diabetes in past, as healing of a bed sore is difficult in diabetics, once developed. Proper positioning of neck and suction was done in case of vomiting to prevent aspiration pneumonia. When necessary PPIs were used to prevent gastric ulcer and patients with GIT upsets were closely monitored.
5. Careful monitoring of parenteral nutrition and waters and electrolyte balance was done. In elderly patients special attention to the speed and quantity of infusion was given to prevent the incidence of acute heart failure.
6. Neurological rehabilitation program in the form of physiotherapy was planned to be started as soon as possible according to the patient's condition to prevent any physical dependence in future.

DTI based Assessment of CST damage:

In this study, DTI was performed after 2 weeks of onset and patients were divided into 4 groups based on the level of damage to CST on the affected side on the DTT map including Group 1 with CST intact; group 2, CST intact, but mildly compressed to opposite side; group 3, CST partially damaged; group 4, CST severely or even completely damaged. At the same time, the differences in FA values between the affected side and the contralateral cerebral peduncle were compared. Analysis of r FA values in Grade 1, grade 2, grade 3 and grade 4(affected side FA value / contralateral FA value), and assessment of motor function at the corresponding time point (evaluation index for Brunnstrom exercise evaluation form, functional walk, modified Rankin rating scale) were done.

After 48 hours of onset, motor function assessment was done



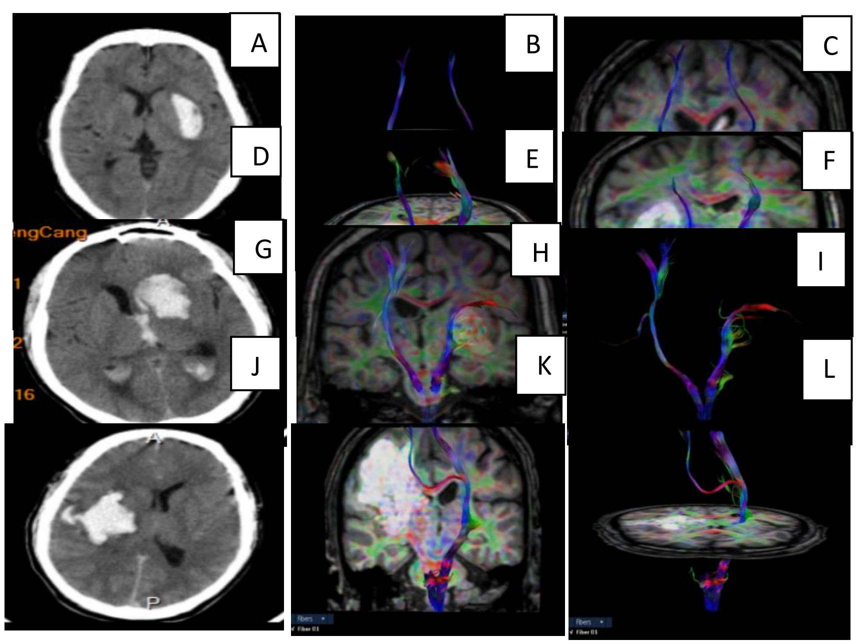
Note: Graphical layout for methodology

MR Imaging Protocol and DTI acquisition:

All scans were performed with a whole-body 3.0T MR imaging system (Philips Achieva 3.0T MR, Philips Healthcare, the Netherlands) with a sensitivity encoding head coil. DTI was performed using a singleshot SE-EPI sequence after contrast agent administration for angiography. A single diffusion-weighted B0 acquisition was obtained and diffusion-sensitized gradients were applied along 15 noncollinear directions with a b-value of 800.0s/mm2. Other acquisition parameters were the following: TR/TE, 6724.0/77.0 ms; FOV, 224 × 224 mm; matrix size, 112.0mm × 112.0mm. DTI voxel size was 2.05×2.0 × 3 mm. Sixty sections covering the brain were obtained parallel to the bicommissural line without intersection gaps. DTI acquisition took 4 minutes and 14seconds. The three-dimensional images of bilateral corticospinal tract were reconstructed on the basis of color anisotropic pattern.

Diffusion Tensor Tractography Processing and Assessment of CST damage by hemorrhagic stroke in basal ganglia:

Philips Research Integrated Development Environment (PRIDE; Philips Healthcare) software was used to perform deterministic diffusion tensor tractography. Using orientation-independent FA, anisotropy maps were obtained and color FA maps were created according the standard convention (red, left-right; green, anteroposterior; and blue, superoinferior). Tractography was based on a diffusion tensor deflection algorithm [39]. The threshold to prevent fiber propagation was FA < 0.2 and angle < 70. ROIs were placed around the corona radiata and at the level of the cerebral peduncle in the direction-coded color axial sections to reconstruct the CST. Designated tracts of interest were the fiber tracts passing through both ROIs. To exclude fibers to the cerebellum and to exclude interhemispheric fibers, exclusion ROIs were drawn around the superior and middle cerebellar peduncles and around a midline sagittal section (covering the brain stem and corpus callosum) respectively[40,41]. The CST depicted was validated using landmarks from neuroanatomy atlases[42]. The CST was considered affected only when the tractogram passed through the intracerebral hemorrhage or/and perihematomal edema. In those patients in whom the tractogram was bent over or displaced by the ICH, the CST was considered not affected. Image distortions and head motion effects caused by eddy currents were corrected using affine multiscale two-dimensional (2D) registration. Following are the images taken during standard DTI protocols. Fig.A, CT scan describes left sided hemorrhage in basal ganglia while in fig.B and C, DTI images demonstrate intact CST in group 1 patients. Fig.D, CT scan showing right sided hemorrhage in basal ganglia and in fig.E and F, DTI images showing intact but mildly displaced CST in group 2 patients.Fig.G showing a brain CT in which left sided hemorrhage in basal ganglia can be seen whereas in fig.H and I, DTI showing mildly damaged CST in group 3 patients. In fig.J, CT scan shows right sided hemorrhage in basal ganglia and in fig.K and L, DTI shows complete interruption in the continuity of CST.



Clinical evaluation of patients' neurological status:

Demographic and clinical data were collected from the medical records of patients. A senior certified staff neurologist evaluated the limb motor performance. In all Patients motor function evaluation was done by using Brunnstrom exercise score and functional walking scale score on the 48 hours and 14th day of onset.

Estimation of Hematoma Size and Volume:

Hematoma size (cm) was defined as the largest intraparenchymal diameter observed on the initial CT scan, and hematoma volumes were calculated using the conventional method [43] using initial CT scans. In addition, largest diameters of hematomas (value A), largest hematoma diameters perpendicular to A (value B) and heights of hemorrhages were measured in centimeters (value C). The formula used to estimate hematoma volume (mL) was as follows: hematoma volume = $4\pi/3 \times (A/2) \times (B/2) \times (C/2)$.

Statistical analysis:

Statistical analysis of case data was done by analyzing the images by parallel IPP software v 1.66. Correlative analysis between motor function prognosis and DTI findings in patients with cerebral hemorrhage was done to predict the motor outcome in selected patients. The mean FA value (FA) of the affected side and the contralateral cerebral hemisphere was measured based on the region of interest (ROI). According to the DTT map, the degree of CST damage on the affected side is divided into grade1,where CST is complete; grade 2, where CST is intact, but mildly compressed to opposite side; grade 3, in which CST has partial interruption and grade 4, where severe or even complete interruption of CST is witnessed. According to the original DTI images obtained by MRI scanning, the three-dimensional reconstruction was successfully performed, and the obtained DTT images were divided into one-level, two-level, three-level, and four-level cases. At the same time, the region of interest was placed on the bilateral cerebral peduncles on the FA map. The two sides were equal in size and symmetric in position. The average FA value of the cerebral peduncles on both sides was measured. All values were measured by the same physician and were measured three times and averaged. FA value ratio (FAratio, rFA value) = affected side FA value / contralateral FA value was compared.

RESULTS:

In this study total 45 patients were enrolled from which 13 were excluded on the basis of exclusion criteria. The research population was subjected to analyse after DTI assessment. Figure 01 and supplementary table 01 suggest that the recovery of limb function in patients with hypertensive cerebral hemorrhage in basal ganglia was significantly better in group 1st and 2nd patients (with shifting or partial interruption of CST), than 3rd 4th group patients (with severe or even complete interruption of CST). Severity index (damage to CST) shows that 4th group patients had severe damage caused by ICH which is significantly higher than all other groups, while on other hand a minimum of damage in CST was observed in 1st group of the patients assessed by tractography after 14 days. Among all 32 patients in the study, 14-day DTI showed that the motor function scores of 3rd and 4th patients were significantly worse than those of group 1st and 2nd patients ($P<0.05$); the FA values of 1st patients were significantly higher than those of 4th group patients. After 2 weeks of symptoms onset, the FA value of the affected cerebral peduncle was significantly lower (0.45±0.07) than the normal side FA value (0.52±0.04, $P<0.01$). (see supplementary table 01).

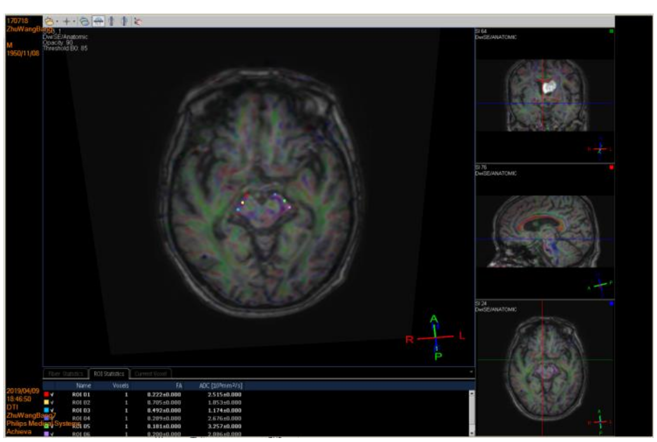


Fig.01 showing Graphical measurement of FA value in patients with cerebral hemorrhage

Groups of patients	**1st Group**	**2nd Group**	**3rd Group**	**4th Group**	**P value**
Age	57.14±13.36	58.7±13.82	55±11.35	57.4±11.31	0.918
FA on affected side	0.548±0.22	0.666±0.142	0.529±0.133	0.5±0.095	0.044
FA on normal side	0.634±0.21	0.71±0.182	0.68±0.12	0.675±0.13	0.804

Table 1: Comparison of FA values in patients with hypertensive cerebral hemorrhage

In Comparing the four groups of patients, there were no differences in age, sex and vascular risk factors, and laboratory parameters between the four groups , however the differences in the cerebral hemorrhage in the four groups were statistically significant. Table 02 indicates the comparison between research group and Brunnstrom exercise scale score. According to the Brunnstrom exercise scale score, if the values for Brunnstrom exercise scale score are lower, means that degree of injury in CST is heavier and the chances of recovery rates for the patients are minimal. Similarly, the FAC scale shows the same performance. In explaining FAC values , it is obvious that if injury is massive in basal ganglia the scale score will be lower, while the normal side FA scores has no significant difference. In table 2 it is clear that mean Brunnstrom exercise scale score was better in the patients with age ranging from 55±11.35 from all other patients.

Age	57.14±13.36	58.7±13.82	55±11.35	57.4±11.31	0.918
Bru2 day	4.43±1.13	3.3±1.49	3±1.67	1.73±1.1	0.001
Bru4 day	5.14±0.9	3.8±1.14	3.91±1.51	2.07±1.22	<0.001
ΔBru	0.71±0.488	0.5±0.707	0.91±0.831	0.33±0.724	0.235
FAC 2day	3.57±0.98	1±1.05	1.27±1.62	0.27±0.59	<0.001
FAC 14day	4.43±0.79	2.1±1.1	2.91±1.7	0.67±0.98	<0.001
ΔFAC	0.86±0.378	1.1±0.568	1.64±1.206	0.4±0.737	0.005

Table 2: Comparison of exercise scores in patients with hypertensive hemorrhage

According to the correlation analysis between grading and FA value and exercise ability evaluation, we can see that the grading is negatively correlated with FA side value and exercise ability score, that is, the higher the grading, the lower the FA value, the lower the exercise ability evaluation score.

	Correlation coefficient	**P value**
FA affected side	-0.32	0.036
Bru 2 days	-0.58	<0.001
Bru 14 days	-0.632	<0.001
FAC 2 days	-0.606	<0.001
FAC 14 days	-0.655	<0.001

Table 3: Correlative analysis between CST classification and FA value and Brunnstrom exercise scale

In table 3, we concluded that there was negative correlation between Brunnstrom exercise scale score, both with FA values and FAC values statistically. The score was taken at 2nd and 14th day of symptoms onset for both FA and FAC values. Brunnstrom exercise scale score recorded at 14th day was highly negative as compared to score taken at 2nd day. Similar correlation was found for FAC values.

DISCUSSION:

Spontaneous cerebral hemorrhage is one of the most common neurosurgical emergencies, caused by hypertension. It is categorized into basal ganglia hemorrhage, prefrontal brain hemorrhage, thalamic hemorrhage, cerebellar hemorrhage, and brain stem hemorrhage, according to the different bleeding sites. The incidence of cerebral hemorrhage in the basal ganglia is highest, accounting for 70%-80% of the total number of spontaneous cerebral hemorrhage with significantly higher rate of disability and mortality than other types of stroke. In above mentioned results, we assembled a conclusion that DTI can help in prediction of motor outcome in patients having hypertensive ICH. In our study, we did clinical evaluation of patients' neurological status by using Brunnstrom exercise scale after 48 hours of symptoms onset. We subsequently performed DTI to asses the damage to the CST caused by hematoma formation in basal ganglia. We divided patients into four separate groups, based on level of damage to CST. In primary results we came to know that the group 1st and 2nd patients had lesser damage in the CST as compared to 3rd and 4th group patients. The primary results were then compared with Brunstorm score. The patients with severely damaged CST had lower Brunnstrom exercise scale scores. Hence, DTI played a major role to visualize the white fiber bundles particularly in the assessment of the integrity or damage to CST. This assessment ultimately helped us to select a suitable future rehabilitation program in order to avoid possible threatening physical dependence. Our results are in line with Puig et al 2018, who studied similar role of DTI in prediction of motor outcome in patients having acute ICH. Fractional Anisotropy (FA) values were calculated where we determined that after 2 weeks of symptoms onset, the FA value of the affected cerebral peduncle was significantly lower (0.45±0.07) than the normal side FA value. These findings are correlated with Cheng et al 2015 who found similar FA values ratios correlated positively and negatively.

In our study FA and FAC values were taken and analyzed statistically at the (<0.01 and <0.005) significance. It was observed that both FA and FAC values were negatively correlated. The score was taken at 2nd and 14th day of symptoms onset for both FA and FAC values. Brunnstrom exercise scale score recorded at 14th day was highly negative as compared to score taken at 2nd day. Similar correlation was found for FAC values. In DTI the FA ans FAC values are compared with clinical scores which indicate the estimated damage caused to CST by hemorrhagic stroke. Similar evaluations were investigated by Wang et al, 2012 who studied role of DTI in prediction of long-term motor functional outcome in patients with acute supratentorial intracranial hemorrhage.

Above discussion discloses following information. DTI is predominant technique among conventional imaging techniques such as conventional MRI and CT. Conventional imaging techniques have certain limitations when it comes to the prediction of motor outcome and estimation of damage to white fiber bundles particularly CST caused by different types of strokes. In this study we mainly focused on the hypertension which is a major risk factor leading to hemorrhagic stroke with text to role of DTI. Several previous studies elaborated the role of conventional imaging techniques to visualize the precise site of brain damage caused by hemorrhagic strokes. However, extent of damage to white fiber bundles particularly CST following a hemorrhagic stroke in basal ganglia caused by hypertension was not elaborated sufficiently. Hence, our study presents a unique preview in a prospect that we explored the role of DTI in prediction of motor outcome in patients with hemorrhagic stroke in basal ganglia with hypertension as triggering factor. The special geographical environment especially hypoxia, hypothermia, diet and lifestyle increase the incidence of hypertensive intracerebral hemorrhage. The average altitude of Qinghai province is more than 3,000 meters. Therefore the instances of haemorrhagic strokes are common in this area. Explaining the mechanism we can also state that after cerebral hemorrhage, the cerebral edema caused by cerebral microcirculation disorder and hypoxia caused by oxygen imbalance in the brain is more obvious than that in the plain area. Therefore, it seriously affects motor dysfunction. Timely and appropriate rehabilitation after brain hemorrhage has a certain effect on the recovery of patients' motor function. The prediction of motor outcome after cerebral hemorrhage in the basal ganglia is very crucial. Conventional MRI, CT and motor function scores do not accurately determine and differentiate CST lesions, hence are not helpful in prediction of motor outcome in patients with hemorrhagic stoke.

Whereas, DTI is a water-dispersion imaging technique developed in recent years. It detects the microstructure of tissue by detecting the anisotropy and diffusion intensity of the diffusion direction of water molecules in tissues. In this study we assessed the role of DTI by calculating FA values of different groups of patients. FA values represent the degree of directionality of microstructures such as axons, myelin and microtubules. Numbers of tract were determined by counting the number of voxels contained within a neural tract. Reduction in FA values indicates the deterioration of neuronal microstructures resulting in poor motor outcome [45].

In our research we observed fluctuation in FA values of cerebral peduncles among research groups, indicating different degree of damage to CST. At present, with the increasing incidence of cerebral hemorrhage, DTI being a non-invasive and low cost imaging technique, provides an objective scientific basis for prediction of the prognosis in such patients. Furthermore, DTI provides assistance to select an appropriate future rehabilitation program in such patients to prevent disastrous physical dependence. There are still some limitations for this study especially the localization of the corticospinal tract as targeted ROI to perform DTI, requires a certain basic knowledge of neuroradiology and experience. Furthermore, all Patients selected for this study were with hemorrhagic stroke in the basal ganglia but in clinical practice, hemorrhage in the frontal lobe, pons and temporal lobe are also common. The use of DTI alone as an imaging technique in patients having motor dysfunction after hemorrhagic stroke has its limitations. Studies have shown that the recovery of motor function is not only related to the degree of damage to CST. It is also related to nerve cross fibers and may be related to the reconstruction of neural networks and the remodeling of functional areas. Our research gives future prospect that if population size and geographical regions are enhanced, the role of DTI to predict motor outcome in patients having hemorrhagic stroke, can be better understood. If tract lengths and numbers of axonal structures are taken into account along with FA and FAC values, it is possible to make correct assessment of CST damage by diffusion tensor imaging. This research is an encouraging phenomenon for the other medical investigators working in the disciplines of neurosurgery and neuroradiology. These findings could be helpful in finding resounding resources and solutions for the victims of hypertensive intracerebral hemorrhage in high altitude areas by exploiting the better role of DTI.

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