

Role of Diffusion Weighted Magnetic Resonance Imaging in Cerebral Venous Thrombosis (CVT)

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Abstract: *Background:* Cerebral venous thrombosis (CVT) is a cause of stroke with diverse etiologies and varied clinical presentations. The Pathophysiology of CVT with associated venous stroke appears to differ from arterial strokes. Acute arterial strokes show cytotoxic edema, whereas venous strokes are thought to contain vasogenic and interstitial edema due to venous congestion. Conventional MRI cannot differentiate between vasogenic edema and cytotoxic edema.

Keywords: Diffusion-weighted imaging; Magnetic resonance imaging; Thrombosis, Cerebral venous

1. Introduction

Dural sinus thrombosis involves the thrombosis of deep or cortical cerebral venous system, results in venous stroke which is more common than once thought ⁽¹⁾. Cerebral venous thrombosis (CVT) is a cause of stroke with diverse etiologies and varied clinical presentations. Its Presentation may mimic acute arterial stroke or mass lesion ^(1, 2). The Pathophysiology of CVT with associated venous stroke appears to differ from arterial strokes. Acute arterial strokes show cytotoxic edema, whereas venous strokes are thought to contain vasogenic and interstitial edema due to venous congestion.

Conventional MRI cannot differentiate between vasogenic edema and cytotoxic edema ⁽³⁾. Diffusion-weighted imaging (DWI) is a relatively new MRI technique based on the molecular motion of water, sensitive in detecting strokes due to Cytotoxic and vasogenic edema. This new fast neuroimaging technique will give insight to the pathophysiological mechanism as well as the prognosis of CVT ⁽⁴⁾.

This study looks at the application of diffusion-weighted MRI technique in cerebral venous thrombosis.

2. Aims and Objectives

- 1) To study the pattern of diffusion-weighted images in patients with cerebral venous thrombosis.
- 2) To study the extent of venous sinus involvement.
- 3) To find out the correlation of cerebral parenchymal changes with involvement of sinuses.

3. Materials and Methods

This is a prospective observational study of 30 patients with cerebral venous thrombosis (CVT). Patients had undergone diffusion-weighted imaging along with conventional MRI and MR Venogram. The diagnosis of CVT was confirmed with MR Venogram and other conventional MR sequences in all the patients.

The study was undertaken in Department of Radiodiagnosis, Great Eastern Medical School & Hospital, Ragolu. Period of study- May 2018- April 2019 (period of 1 year)

The patients were examined with 1.5 T MRI GE (signa HDxt). Diffusion weighted images with echo planar imaging were obtained using two b values.

MR Venogram was done using TOF (time of flight) technique in oblique Sagittal and coronal planes. The follow-up MRI was done after 4 weeks of the initial presentations.

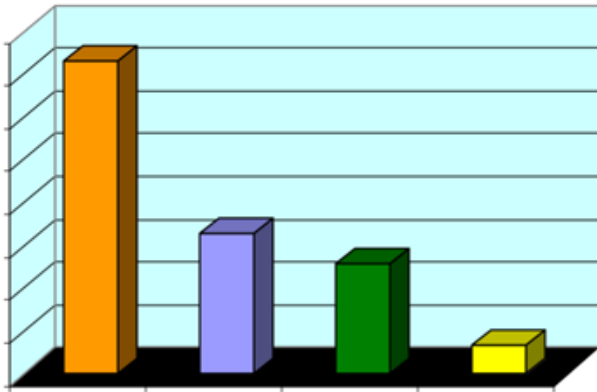
The region of interest (ROI) was chosen on the abnormal intensity area, avoiding hematoma on T2 weighted or diffusion-weighted images, in order to calculate ADC values. The areas with maximum and minimum ADC are taken as the representative lesions when multiple areas of abnormal intensity were observed. In follow up studies with diffusion-weighted imaging, an ROI was placed on the same areas used in the initial study

4. Results

Image analyses of 30 patients (22 females, 8 male patients; age range 19 to 73 years; mean age 33 years) were done in our study.

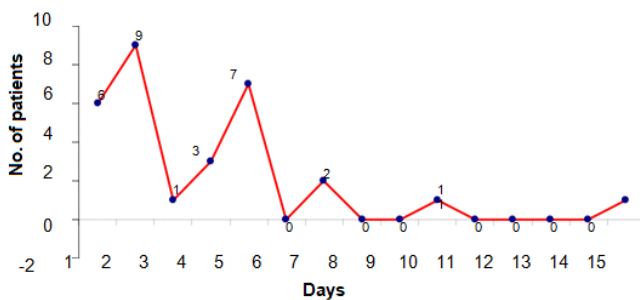
Most common associated condition in the study was postpartum status.

Common clinical presentations included headache, focal neurologic deficits, and seizures. Other clinical manifestations in decreasing order of frequency were vomiting, giddiness, blurring of vision, altered sensorium, loss of consciousness and fever.



Graph 1: Presenting symptoms of cerebral venous thrombosis

Delay between clinical onset and first MRI investigation ranged from 1 day to 15 days.



Graph 2: Time to diffusion weighted imaging in days

Image analysis was done using a structural assessment of the site of each occluded vein or sinus as detected on both MR venography and conventional MRI.

- 1) The presence (location) or absence of an increased signal in veins or sinuses by visual inspection on DWI.
- 2) The presence and location) or absence of signal abnormalities on conventional MR images.
- 3) Presence or absence of signal abnormalities within the brain parenchyma on conventional images and Diffusion weighted images with ADC values.

Table 1: Distribution of thrombosed cerebral venous structure in 30 patients

Location of thrombus	No. of patients
Superior Sagittal sinus	22 (73%)
Lateral sinus (LS)	
Bilateral LS	7 (23%)
Right LS	6 (20%)
Left LS	8 (26%)
Cortical Veins	3 (10%)
Deep Venous System	7 (23%)

Percentages total > 100%, because patients may have multiple sinus involved.

Twenty-three of the thirty patients had brain parenchymal lesions with hyperintensities on T2 / FLAIR images due to thrombosis of the superficial venous system. In the remaining seven patients combined superficial and deep venous system were involved.

Of the 30 patients, 13 patients had hemorrhagic infarction; four patients had focal intracerebral hematomas, 12 patients

had non-hemorrhagic infarcts and one patient had high signal intensity intravascular clot without parenchymal abnormality on diffusion-weighted images.

All the brain parenchymal abnormalities were supratentorial in location. Parenchymal changes in the parasagittal frontal and parietal lobes were the findings in patients with superior sagittal thrombosis.

Bilateral involvement of cerebral parenchyma, seen in seven patients with superior sagittal sinus occlusion. Hemorrhagic infarcts were seen irrespective of complete or partial thrombosis.

Parenchymal changes in the temporal or occipital lobes are the findings in lateral sinus occlusion.

Occlusion of deep venous system (internal cerebral vein, straight sinus and vein of Galen) was associated with involvement of thalami and deep white matter.

Hemorrhagic transformation in deep venous involvement was seen only in one patient.

In all cases, cerebral venous infarction were identified on conventional MR images, with no patient showing hyperintensity on diffusion weighted images in the absence of conventional MR findings.

The normal ADC values (+/- 2SD) of the control areas (unaffected side of brain) in 30 patients were 0.75- 0.80 x 10⁻³ mm²/sec. In the hemorrhagic infarcts patients, diffusion weighted images showed heterogeneous signal intensity with dark, thin rim and surrounding low signal intensity. The ADC maps depicted decreased values in the very bright signal intensity present near the hemorrhagic cavity and increased values (0.8 - 1.5 x 10⁻³ mm²/sec) in the surrounding low signal region on DWI.

Nonhemorrhagic infarcts were seen in thirteen patients. The findings were focal and multifocal high signal intensities in DWI. The ADC values of the lesions were variable. In 10 patients, the ADC values were low (ADC) as observed in arterial stroke. In other three patients, ADC values were high. Time interval from onset to DWI was variable

5. Discussion

Dural sinus thrombosis, combined with thrombosis of the deep or cortical cerebral venous system and resulting venous stroke is more common than once thought.

Cerebral venous thrombosis (CVT) is a cause of stroke with diverse etiologies and varied clinical presentations. Its presentation may mimic acute arterial strokes or a mass lesion, thus radiological examinations play an important role in the diagnosis of CVT and helps to determine the prognosis. MRI and MR Venography is a useful method to establish the diagnosis.

Conventional MR imaging (T2 and FLAIR) depicted similarly high signal intensities for the areas of venous congestion and infarct, and cannot distinguish between

Cytotoxic and vasogenic edema. Diffusion weighted imaging provides ADCs that can differentiate whether the associated cerebral edema is of cytotoxic origin or vasogenic edema. However, the findings on diffusion weighted imaging and the ADC value changes in relation to the disease progression in patients with dural sinus thrombosis remains to be elucidated.

A. Extent of venous sinus involvement and correlation of cerebral parenchymal abnormalities:

Multiple locations of thrombosis were identified, in majority of the cases contiguous transverse and sigmoid sinuses were found, the parenchymal involvement is ipsilateral parieto – temporal lobes. Superior Sagittal sinus involvement in 22 cases and the parenchymal involvement were unilateral or bilateral fronto–parietal lobes. The parenchymal abnormalities that occurred with deep venous occlusion were thalami and deep periventricular regions. Cortical venous involvements were seen in three cases. However, prediction of parenchymal changes with extent of involvement of venous sinuses was variable.

Isolated cortical venous thrombosis was not found in our study, and was always associated with superior sagittal sinus thrombosis. This represents, isolated cortical venous thrombosis has relatively rare entity. Fewer than 20 cases have been reported in the imaging literature ⁽⁵⁾.

In the current study, we describe the pattern of diffusion-weighted images at the onset of presentation and with different time course in patients with cerebral venous thrombosis.

B. Various patterns have been observed in the DWI findings

1) Heterogeneous SI of hemorrhagic venous infarct

Parenchymal hemorrhages were seen in 13 patients with cerebral venous thrombosis. The mechanism of hemorrhage is multifactorial. Hemorrhage may be precipitated by continued arterial perfusion in areas of cell death, as can be seen at reperfusion in arterial ischemia. Elevation of venous pressure beyond the limit of the venous wall was also believed as the cause ⁽⁶⁾.

Heterogeneous SI group on diffusion-weighted imaging included hemorrhagic venous infarctions. The Signal intensities were attributed to hemorrhage. The bright signal intensity of the hemorrhagic clot on DWI was due to the paramagnetic effect of the intracellular methemoglobin, and the surrounding low SI with high ADC values was due to vasogenic edema. Between these, a thin rim of low signal was observed, suggesting the occurrence of hemosiderin. These findings were similar to the findings reported by kon Chu et al ⁽⁷⁾.

Diffusion weighted imaging and ADC measurement of intracranial hematoma were recently reported by Atlas et al ⁽⁸⁾, however in our study ADC values of hematoma were avoided. The reason being, the determining factors of ADC values in hematoma may be due to paramagnetic effects of the methemoglobin rather than true restriction of water movement.

2) High SI of nonhemorrhagic venous stroke

These manifestations were seen in 13 patients. The findings were focal and multifocal high signal intensities in DWI. The ADC values of the lesions were variable. In 10 patients, the ADC values were low (ADC) as observed in arterial stroke. In other three patients, ADC values were high. Time interval from onset to DWI was variable (ranging from one to 5 days). DWI findings of this group may represent the acute stages. Forbes et al ⁽⁹⁾ reported the initial ADC decrease in patients with CVT and the ADC decrease returned to normal or increased within 4 days. Kon Chu et al ⁽⁷⁾ also reported similar finding, followed by which anticoagulation was immediately initiated the clinical symptoms disappeared completely after the anticoagulation therapy. However, the clinical relevance of this pattern is unclear. The pathophysiological process underlying this pattern may represent cytotoxic edema due to congestive ischemia in regions with adequate venous collaterals. According to kon Chu et al, clinical deficits in these patients did not match the lesions, suggesting that DWI may not be sensitive to the pathophysiological processes in these patients.

3) Signal intensity of clot in sinuses

Diffusion weighted imaging also showed high signal intensity of the intravascular clot, the finding that has been reported by kon Chu et al ⁽⁷⁾. The ADC values were observed to decrease in two patients. This finding was believed to be due to paramagnetic effect of the clot (intracellular methemoglobin) and due to T2 shine through effect. The T1, T2W SI was also high and these findings were similar to the early subacute stage thrombus. This represents that Diffusion weighted imaging is not required for direct imaging of clot within a cerebral sinus because conventional MR sequence and MR Venography can identify these lesions. However, Favrole et al ⁽¹⁰⁾ reported that the movements of water molecules are more or less restricted within the venous clot according to the stage of thrombus formation in CVT. The presence of High signal intensity in diffusion-weighted images in occluded veins at the time of diagnosis might be predictive of low rate of vessel recanalisation 2 or 3 months later; this suggests that the microstructure of the clot in CVT, as reflected by the signal changes on DWI, might influence the effectiveness of clot dissolution under heparin treatment. Some authors have suggested that the migration of fibroblasts into the clot and incorporation of collagen may render the fibrin less accessible to fibrinolytic enzymes ⁽¹¹⁾. Others argue that this resistance may be related mainly to an abnormal fibrin polymerization ⁽¹²⁾. High signal intravascular clot on diffusion-weighted images are not correlated to the risk of tissue lesion as seen in patient 30 of our study. However Follow up studies were not there in our cases to substantiate these findings and number of cases were also less larger. Follow up studies are warranted to confirm the predictive value of high signal intravascular clot on diffusion-weighted imaging for recanalisation and to assess its clinical value in CVT.

4) Detection of early venous infarct

In our study, all cases of cerebral venous infarct manifesting hyperintensity on diffusion weighted images also showed T2 signal changes. This is probably explained by image timing, because we did not image any subjects hyperacutely, when

diffusion restriction might have been present in the absence of T2 hyperintensity. This also explains the time from onset of disease to DWI was variable and non homogeneous. This can be attributed to diverse clinical manifestations of CVT.

5) Time course of diffusion lesion evolution

In the current study, we demonstrated the ADC changes and its correlation with the time course in patients with dural sinus thrombosis. The results indicated that vasogenic edema develops more frequently and earlier in dural sinus thrombosis, though both vasogenic and cytotoxic edema are associated with the pathological condition in the early phase of the disease.

The contribution of vasogenic edema is prominent in the early phase of dural sinus thrombosis. One case report on straight sinus and deep cerebral venous thrombosis described a local augmentation of ADC, which correlated our results (13).

Other reports showed coexistence of increased and decreased ADCs with that of disease progression. Increase in ADC suggests predominance of vasogenic edema in the early phase of the CVT. It was reported that the reduction in ADC persisted upto 6 days, on average after stroke, due to arterial ischemia and that a significant reduction of ADC was detected for at least 4 days. ADC changes in the early phase of dural sinus thrombosis differ from those of arterial ischemia, in which cytotoxic edema is predominant in the intravascular coagulants.

hyperacute or acute phase (1).

6. Conclusion

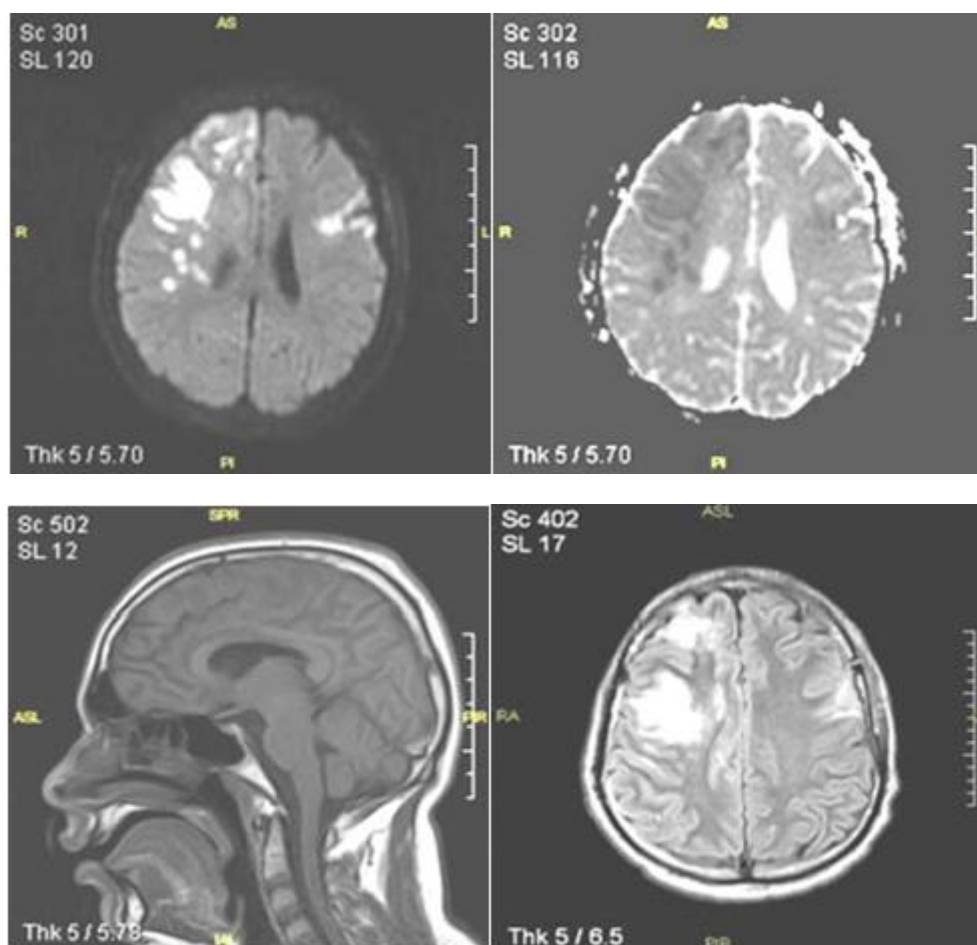
In the current study, we demonstrated the initial diffusion weighted patterns with ADC changes and its correlation with the time course of diffusion lesion evolution in cerebral venous thrombosis.

The results indicate, though both vasogenic and cytotoxic edema are associated with the pathological condition in the early phase of CVT, Vasogenic edema develops more frequently.

Our report showed coexistence of increased and decreased ADCs in hemorrhagic infarcts. Increase in ADC suggests predominance of vasogenic edema and decrease in ADC suggests cytotoxic edema.

Based on our results, decrease of ADC, presumed to represent more severe pathological conditions and residual neurologic deficit and they are the last areas where signal intensity reverse to normal values.

High signal intensity clot on DWI represents abnormal polymerization of fibrin, which is unlikely to undergo lyses with anticoagulants. These patients probably need



DWI performed 2 days after clinical onset in 22-year-old man (Patient 9)

- A) DWI shows multiple high signal intensities in the right fronto- parietal lobe.
- B) Apparent diffusion coefficient(ADC) map indicates decreased ADC values ($0.4 \times 10^{-3} \text{mm}^2/\text{s}$)
- C) Initial FLAIR image show high SI in the right fronto-parietal lobe.
- D) Sagittal T1 W image show high signal intensity in SSS.

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