Abstract:
Diffusion weighted imaging is now routine sequence in the MR imaging of the brain and is now the important sequence in evaluating acute ischemic brain injury patients. However high signal intensity on diffusion MR and hypointensity on apparent diffusion coefficient images (ADC), have been reported in other conditions like abscess / tumor. Differentiating between these conditions is required for determination of appropriate diagnosis and treatment. We are presenting a systematic review of our study of hyperintense lesions on diffusion weighted MR imaging in 100 patients and their potential in clinical imaging and application.

Key words: Diffusion weighted MRI

Introduction
This technique is based on microscopic motion of water within the brain cell. First described by two physical chemists, STEJSKL and TANNER in 1965. Diffusion weighted images are obtained by having two sequential gradient pulses to a 90 - 180 - degree spin-echo sequence. Phase shifts acquired in mobile molecules led to failure of such molecules to rephase completely resulting in substantial signal loss.

The degree of signal drop is proportional to the exponent of the diffusion co-efficient (D) and the duration and strength of the encoding gradient (b).

This means for spins that are less freely diffusible (those with low diffusion co-efficient) application of the additional gradient pulses results in less signal loss than for spins that are more freely diffusible.

The signal intensity of a voxel of tissue is calculated as:

\[ SI = SI_0 \exp (- bD) \]

where \( SI_0 \) is signal intensity on T2W imaging (or \( b=0 \)), diffusion factor \( b = \frac{2 \times 10^{-3}}{Gd^2} \) (?-
d/3) and $D = \text{diffusion co-efficient}$, $\gamma$ is gyromagnetic ratio, $G$ is magnitude of, $d$ is the width of and $\Delta$ is the time between two balanced DW gradient pulses.

In the normal adult brain ADC of grey and white matter are very similar such that diffusion weighted imaging (DWI) has very little intrinsic contrast.

Any contrast observed is primarily due to underlying differences in T2 that is the contrast of the So component of the image [1,2].

At low diffusion weighting (small b values) there is minimal sensitivity to diffusion motion and images will show predominant T2 contrast. At high "b" values the contrast is produced by the diffusion properties. Even at higher "b" values a T2W component is still present in all DW images producing T2 shine through. Hence all DW images should be compared with ADC maps. Lesions with diffusion restriction appear bright on DW images and appear dark on ADC maps. Structures with diffusion like CSF will appear dark on DW images and bright on ADC maps.

**EVALUATION OF ACUTE INFARCT ON DIFFUSION WEIGHTED IMAGING:**

Diffusion weighted imaging and ADC maps show changes in ischemic brain within minutes to few hours after symptoms onset when no abnormalities are typically seen on conventional MR and CT [3-5]. The marked increase in diffusion weighted signal with areas of acute ischemia relative to unaffected brain is typically so striking that the finding as been referred to as the "light bulb sign" of acute stroke. This hyperintense signal increases during 1st week after symptom onset and decreases thereafter, but signal remains hyperintense for a long period (upto 72 days) [6].

ADC values decreased rapidly after the onset of ischemia and subsequently increases from dark to bright in 7 to 10 days [7-9]. This finding can be used to differentiate from older to more acute lesions.

![Figure 2](image-url)

*Figure 2*
*Patient with acute onset of left sided weakness. FLAIR image demonstrates multiple white matter lesions where acute and chronic lesions can't be differentiated. DW image clearly demonstrates acute infarct in right corona radiata.*

ADC passes back through the normal range after 7 to 10 days resulting in pseudonormalisation or fogging of the infarct on ADC maps. Although not visible on ADC maps the infarct remains typically hyperintense on diffusion weighted imaging because of T2 shine through effect.

Chronic infarcts are characterized by elevated diffusion and appear hypo, iso or hyperintense on DW and hyperintense on ADC.

All the lesions with restriction on diffusion weighted imaging may not progress to complete infarction [10].

There are few reports of normalisation of initial diffusion restriction [11-13]. In our study we have not come across any reversal of diffusion bright lesions.

**EVALUATION OF TUMORS ON DIFFUSION WEIGHTED IMAGING:**

*Figure 1*
*Patient with acute onset of right side weakness. T2W MR image shows flow voids in insular cortex without any significant signal change in the cortex. Diffusion weighted imaging clearly depicts acute infarction in left MCA territory.*
High cellular tumors like malignant meningiomas / lymphoma / medulloblastoma and other tumors like epidermoid show restriction on diffusion weighted imaging with increased ADC values [14,15].

Gliomas show variable diffusion weighted signal (hyper, iso or hypointense). Several are shown that diffusion weighted imaging can be used to grade the gliomas [17-20].

Glioma grade correlates inversely with minimum ADC values that can be explained on the basis of increasing tumor cellularity with grade.

Lymphomas when compared with gliomas are having lower ADC because of their high cellularity [20-22].

Figure 3
The lesions appear mildly hyperintense on T2W and shows diffusion restriction in brainstem. (Patient is biopsy proven brainstem lymphoma).

Necrotic component of brain tumors (GBM and metastases) show marked hypointensity on DW and increased ADC values due to increased free water and less cellularity. This finding is used to differentiate necrotic tumors from cerebral abscess which demonstrates marked diffusion restriction [13].

Figure 4
Contrast MR of TIW image shows ring enhancing mass. DW image, ADC map shows that the lesion as increased diffusion (Patient with biopsy proven glioblastoma multiforme).

Epidermoid tumors demonstrate ADC's similar to grey matter and lower than those of CSF [14] and appear markedly hyperintense compared with CSF and brain tissue on diffusion weighted images.

Figure 5
Post operative epidermoid tumor on TIW imaging shows no differentiation of the residual mass from the resected cavity. Diffusion weighted imaging clearly depicts the residual mass (hyperintense on diffusion weighted imaging) from the residual cavity.

EVALUATION OF INFECTION ON DIFFUSION WEIGHTED IMAGING:

Hyperintensity on DW MR images noted in herpes encephalitis. This restriction is due to cytotoxic edema in the tissue undergoing necrosis.

Figure 6
FLAIR imaging showing T2 hyperintensities within the right temporo-polar and temporo-mesial regions (Arrow). Diffusion weighted imaging showing restriction (Arrow).

Diffusion weighted imaging helps in distinguishing herpes lesions from infiltrative temporal lobe tumors because of low ADC values in herpes while ADC of tumors are elevated or in the normal range.

Restriction diffusion in pyogenic abscesses is believed to be due to high viscosity, cellularity and protein content of the pus [13].
SUMMARY:
Diffusion weighted imaging has a major role in the evaluation of acute stroke from chronic stroke and to differentiate between tumor infection and infarction.

CONCLUSION:
Clinical diffusion neuro-imaging introduced in the early 90's and is quickly adopted for clinical imaging.

Diffusion weighted imaging is unique and indispensable sequence providing information about the physiological state of the brain tissue. It is an important tool in the evaluation and treatment of acute ischemic stroke. It provides valuable information in the evaluation of infarct / tumor / infection as described in this review.

Further investigations are needed to optimise the possible contribution of diffusion weighted imaging and its clinical application with new technologies such as parallel imaging and diffusion tensor imaging, leading to even more potential applications, the future of diffusion imaging is bright and its potential unrestricted.

References:


