Diffusion Weighted Imaging a Predictor of Visual outcome in Acute Optic Neuritis

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Diffusion-weighted (DW) imaging refers to any MR imaging technique that has been made sensitive to the properties of molecular motion. Diffusion of water molecules is affected by the structure of the tissue. White matter tracts are made up of bundles of tightly packed axons. Diffusion of water occurs preferentially along the orientation of the axons because cell membranes act as barriers to diffusion. For DW imaging, a spin-echo-based pulse sequence is usually applied both with and without extra magnetic-field-gradient pulses for diffusion encoding. The applied gradients do not affect stationary molecules but cause an unfocused phase shift to molecules that move during the measurement period and hence loss of signal intensity relative to that acquired when no diffusion gradient is applied. The amount of signal intensity loss that can be measured in each voxel is determined by the apparent diffusion coefficient (ADC) in that voxel (so called to acknowledge the effect of hindered or restricted diffusion on the value measured). If white matter tracts are disrupted or the permeability of axonal membranes is increased, the ADC and mean diffusivity (MD), a measure of the average molecular motion, will increase, and the fractional anisotropy (FA), a measure of the directional dependence of the ADC, will decrease. In Demyelinating disorders like Multiple sclerosis, increased apparent diffusion coefficient value (ADC) from diffusion-weighted (DW) imaging is a well documented entity. It usually occurs due to axonal disruption and damage. In this retrospective study we measured ADC in optic neuritis patients by using zonal oblique multi section echoplanar imaging.

MATERIALS AND METHODS

In this study 16 patients presenting with acute optic neuritis were evaluated at our institution. The patients age ranged from 13 to 50 years. All of them presented within 2 days to 3 weeks duration from onset of symptoms. The diagnosis of optic neuritis was based on their clinical features of acute painful sudden vision loss with or without disc edema. But all patients had all signs of optic nerve dysfunction. 9 patients had bilateral optic neuritis and 7 patients had unilateral optic neuritis. All patients had undergone MRI Brain and orbit and DW imaging. All patients showed T2 hyperintense signal in the involved optic nerve(s), 9 patients showed restricted
diffusion and reduced ADC (110 x 10-6) compared to the ADC of 10 normal healthy volunteers. Ethical approval was obtained for the study and informed consent in writing was obtained from all patients.

Imaging was performed on a 1.5T Signa imager (General Electric, Milwaukee, WI). The optic nerve diffusion protocol consisted of three series of four interleaved sections each, acquired by using the ZOOM-EPI sequence with a spectral-spatial 90° pulse for fat saturation and an inversion recovery prepulse for CSF signal intensity suppression. The 12 x 4 mm contiguous sections were combined into a single data set after reconstruction. The imaging parameters were TR 3400 ms, TE 96.7ms, TI 1160 ms, matrix size 64 x 32, FOV 80 x 40 mm, in-plane resolution 1.25 x 1.25 mm2 with four different diffusion weightings (i.e., b0 = 0, plus bmax = 600 s/mm2 applied sequentially along the three orthogonal axes). A minimum of 40 signal intensity averages were collected for off-line averaging; during imaging, subjects were asked to close their eyes and to avoid any deliberate eye movements. Each individual magnitude image at low signal-to-noise ratio is characterized by Rayleigh noise distribution, with a nonzero mean, which would introduce a bias in the measured signal intensity after simple magnitude averaging. By using a further series of images, acquired with the same sequence but with the excitation pulse turned off, it was possible to estimate the absolute noise level and correct for this signal intensity bias. The total acquisition time for the above was 28 minutes. The resultant magnitude images were averaged off line after reconstruction with Rayleigh noise correction. A noise-reduction algorithm that preserved structure was also applied to improve the signal-to-noise ratio before calculating the ADC. The data were then processed to determine the ADC on a pixel-by-pixel basis for each of the 12 sections. All patients also had their optic nerves imaged with a dual echo fast spin-echo (FSE) sequence (coronal-oblique, TR, 2300 ms; TE, 58/145 ms; echo-train length, 8; NEX, 2; matrix size, 512 x 384; FOV, 24 x 18 cm; in-plane resolution, 0.5 x 0.5 mm; 16 x 3 mm interleaved contiguous sections; 11-minute acquisition time) and a fat-saturated short echo time fast fluid-attenuated inversion recovery (sTE fFLAIR) sequence (coronal-oblique, TR, 2740 ms; TE, 16 ms; TI, 1072 ms; NEX, 6; echo train length, 6; matrix size, 512 x 384; 24 x 18 cm FOV; in-plane resolution, 0.47 x 0.47 mm; 3-mm interleaved contiguous sections; acquisition time, 13.5 minutes).

Best visual acuity with appropriate spectacle or pinhole correction was measured by using a retroilluminated ETDRS chart and recorded as the 4-m logMAR acuity. The central 30° of the visual field was analyzed by using the 30-2 program on the Humphrey field analyzer (Allergan-Humphrey, San Leandro, CA). Color vision was measured by Ishihara pseudoisochromatic plates. Flash and pattern-reversal VEPs was done for patients with normal optic nerve head appearance.
RESULTS
16 patients (25 eyes) who presented with acute optic neuritis, to a Tertiary care eye centre in South India were analysed prospectively. Male female ratio was 7:9 (male-43.75%, female-56.25%) with age range between 9-62 yrs and the mean age being 35 years. All patients presented with sudden drop in vision with a mean duration of 6 days among which 10 patients (62.5%) had associated pain. 9 patients had bilateral involvement and unilateral in 7 patients. Vision loss varied between No perception of light to profound loss in 92% of the eyes(23 eyes) and mild to moderate vision loss in 8%(2 eyes). 68.75% of the patients had disc edema (11 pts.). All patients underwent MRI Brain and Orbit with Diffusion weighted imaging and all had T2 hyperintense signals (100%) and 9 patients had restricted diffusion in DWI with reduced ADC (56.25%). All 9 patients with restricted diffusion had good visual recovery after treatment unlike the remaining 7 patients with negative DWI did not improve much after treatment except for 1 patient with absent DWI had good improvement after treatment.

DISCUSSION
By using the zoom-EPI sequence, it has been possible to apply DW imaging to the optic nerves in a patient population. The protocol is time consuming, requiring three acquisitions of four sections each and a separate noise acquisition. Off-line averaging of the data in the image domain, including Rayleigh noise correction, is also needed to compensate for optic nerve motion between successive single-shot acquisitions. The total acquisition time is about 28 minutes per subject. The resulting b = 0 images allowed the optic nerve to be identified and segmented from four 4-mm sections in the orbit in most subjects. The intracanalicular optic nerve could not be identified in many of the subjects because of susceptibility artifacts, and it was not possible to segment the intracranial optic nerve reliably from the brain because of the relatively low resolution. DWI can add valuable information in assessment of damage to nerve and neuronal barriers and thus in predicting recovery in cases of ON. We performed a retrospective study using records of 14 patients with clinically suspected acute ON. Affected nerves were evaluated for sizes, signal characteristics on DWI and T2-weighted imaging (T2WI), contrast enhancement, and apparent diffusion coefficient values.

Conclusion
This study has shown that it is possible to apply DW imaging in optic neuritis to give quantitative measures of ADC and the mean ADC correlated with clinical and electrophysiologic parameters. This suggests that the ADC is a useful measure of functionally relevant axonal pathway disruption in the postinflammatory chronic nerve lesions following optic neuritis. At present, the long acquisition time of the DW imaging sequence will limit its use in
clinical practice, but DW imaging may be of use in the study of novel treatments that aim to prevent axonal damage in patients with optic neuritis.

REFERENCES

