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Original Research Article

DIFFUSION-WEIGHTED IMAGING AS A PREDICTOR OF VISUAL OUTCOME IN ACUTE OPTIC NEURITIS

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Abstract

Background: Optic neuritis is an inflammatory optic nerve disease that affects young children and adults, primarily women. MRI helps evaluate the optic nerve, with diffusion-weighted MRI (DW-MRI) used to measure changes in optic nerve diameters and hyperintensities in patients with optic neuritis. **Aim:** This study aimed to determine whether diffusion-weighted imaging (DWI) can be used as a predictor of visual outcomes in patients with acute optic neuritis at a tertiary eye care centre in Southern India. **Material and Methods**: This prospective observational study was conducted on 31 eyes of 28 patients who were diagnosed with acute optic neuritis at the Neuroophthalmology Clinic at Aravind Eye Hospital, Madurai, for 15 months. The patients underwent ophthalmological and neurological examinations, neuroimaging, and a series of tests. Improvements in vision, colour vision, and central fields were assessed at 15 days, 1 month, and 3 months. The incidence of acute optic neuritis was calculated. **Results**: There was a significant difference in colour vision and contrast enhancement between the diffusion restrictions ($p < 0.05$). There was a significant difference in the fundus, central fields, and optic nerve diameter between diffusion restriction groups ($p < 0.05$) at 3 months. There was no significant difference in colour vision, red colour desaturation, brightness sensitivity, and ADC between the diffusion restriction groups ($p > 0.05$) at 3 months. There was a significant association between diffusion restriction and BCVA ($p < 0.05$). **Conclusion**: This study explored the use of DWI as a predictive tool for visual outcomes in patients with acute optic neuritis, highlighting its potential for enhancing diagnostic and prognostic capabilities.

INTRODUCTION

Optic neuritis is an inflammatory condition of the optic nerve frequently affecting young children and adults of which women are most commonly affected.[1] Typical Optic neuritis usually manifests as an inflammatory, demyelinating disease of the optic nerve commonly associated with multiple sclerosis. Atypical optic neuritis can occur in isolation or in conjunction with other autoimmune diseases.[2] In the anterior visual pathway, it is difficult to evaluate the optic nerve radiologically because of its size, mobility, and tortuosity. This shortcoming is overcome by MRI where it assesses the Optic nerve in terms of its structural changes, pathology localization and changes in diffusion pattern.[3]

Diffusion-weighted magnetic resonance imaging (DW-MRI) is a type of MRI that utilises diffusing properties of water molecules within tissues to obtain images. This technique is employed to calculate the Apparent Diffusion Coefficient (ADC) which quantifies the amount of diffusion in a particular imaged area.[4] In recent advances DWI is employed to understand its importance in diagnosing and prognosticating treatment outcomes of various diseases like ischemic optic neuropathy, optic neuritis etc. Studies have shown that DWI with

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ADC measurements shows changes in optic nerve diameters, and hyperintensities in patients with acute and chronic optic neuritis in comparison with normal subjects.[5]

Aim

This study aimed to determine whether DWI can be used as a predictor of visual outcomes in patients with acute optic neuritis at a tertiary eye care centre in Southern India.

MATERIALS AND METHODS

This prospective, observational study was conducted on 31 eyes of 28 patients who were diagnosed with acute optic neuritis at the Neuroophthalmology Clinic at Aravind Eye Hospital, Madurai, for 15 months. Approval was obtained from the Institutional Review Board (IRB Code No. IRB201500225 dated 12-12-2015). Informed consent was obtained from all the patients participating in the study.

Inclusion Criteria

Age 18-65 years, with loss of visual acuity or visual field, with or without pain for less than 1 month, relative afferent pupillary defect, fundus findings consistent with optic neuritis (disc may be oedematous or normal), and field defects consistent with optic neuritis-centrocaecal scotomacentral scotoma, altitudinal defect, hemi-anopic defect, or generalised constriction of the visual field were included.

Exclusion Criteria

Patients aged < 18 years with visual loss due to toxic, nutritional, metabolic, vascular, hereditary, glaucomatous, traumatic, and compressive neuropathies, and prior occurrence of optic neuritis in the affected or fellow eye were excluded from the study.

Clinical assessment included defective vision, pain in eye movements, headache, dyschromatopsia, relative afferent pupillary defects, disc changes, and a diagnosis of acute optic neuritis. All patients underwent a series of ophthalmological and neurological examinations and neuroimaging. In the pro forma, data on the patients' names, ages, sex, and address were noted. The complete history of each symptom was recorded.

Visual acuity testing using the Snellen chart. If the patient was not able to read any letter in the Snellen chart at 6m, then the chart was moved towards the patient and vision was tested at 5m, 4m, 3m, 2m, and 1 m. If the patient was not able to read any letter at 1m then the ability to count fingers close to the face, identify hand movements, and perceive light was assessed. Examination of the eyelids, conjunctiva, anterior segment, pupillary reaction with torchlight, and measurement of intraocular pressure by non-contact tonometry for more than 40 years.

Examination of the fundus by direct ophthalmoscopy and slit-lamp biomicroscopy using a +90 dpt lens. Ishihara's 21 plates were used to test colour vision; if one or more plates were not identified by the patient, the test was considered abnormal. A red desaturation test was performed, and the patient was asked to indicate the amount of red saturation of the red-coloured objects in terms of percentage; if less than 100%, it was noted as reduced.

A brightness sensitivity test was performed, and the patient was asked to indicate the amount of brightness of the bright torch shown in the eyes in terms of percentage; if it was less than 100%, it was noted as reduced. The central 30° of the visual field was tested using Bjerrum's screen, and any field defects were noted. If the visual acuity was ≤ 3/60 by Snellen chart perimetry, colour vision, brightness sensitivity, and red desaturation were not performed. Neuroimaging, especially DWI MRI, depends on the affordability of the patient.

Diffusion characteristics, contrast enhancement, and apparent ADC values were assessed. They were compared to the unaffected eye in unilateral cases, and to age-matched controls in eyes with bilateral involvement. The regions of interest were adjusted and placed at the centre of the optic nerve by increasing the size of the image. ADC values and optic nerve diameters were calculated.

All patients received 1 g of intravenous methylprednisolone for 3 days, followed by prednisolone 1 mg/kg/BW for 2-4 weeks. Improvements in the patients' visual acuity, colour vision, and central fields of the affected eyes were assessed at 15 days, 1 month, and 3 months. Data for comparison were obtained at baseline and at 3 months. The incidence of acute optic neuritis was calculated using hospital statistics from the total number of neuroophthalmology cases during the study period.

Statistical Analysis

The information collected regarding all selected cases was recorded on a Master Chart. Statistical analysis was performed using STATA 11.1 (College Station, TX, USA). Using this software range, frequencies, percentages, means, standard deviations, paired t-tests and 'p' values were calculated. The paired t-test and Wilcoxon signed-rank test were used to test the significance of differences between quantitative variables and the Cochran Q test for qualitative variables. A 'p' value less than 0.05 denotes a significant relationship. The correlation between ADC, optic nerve diameter, and visual acuity was determined by Pearson's chi-square test using SPSS software 17. A 'p' value < 0.05 denotes a significant relationship.

RESULTS

This study included 31 eyes of 28 patients who fulfilled the inclusion and exclusion criteria during the study period. The mean age at presentation was 34 years, with the youngest and oldest patients being

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aged 18 and 57 years, respectively. A female preponderance was noted, accounting for close to 2/3rd of the patients (n=18, 64.3%). The majority of the patients had unilateral involvement (n=25, 89%). The most common complaint was defective vision (100%), which was painful in 14 (45.2%) eyes. Another nine patients (32.1%) complained of headaches. RAPD was observed in 90.1% of the eyes, with the remaining three eyes (9.7%) showing a sluggish pupillary reaction. At presentation, fundus examination revealed disc oedema in 22 eyes (70.9%), temporal pallor in three eyes (9.7%), disc hyperaemia in three eyes (9.7%), and was normal in the remaining three eyes (9.7%).

There were no significant differences in age, sex, laterality, pain on eye movement, headache, pupil, red colour desaturation, brightness sensitivity, and fundus and central fields between the diffusion restriction groups ($p > 0.05$). There was a significant difference in colour vision and contrast enhancement between the diffusion restrictions ($p < 0.05$). [Table 1]

There was a significant difference in the fundus, central fields, and optic nerve diameter between diffusion restriction groups ($p < 0.05$) at 3 months. There was no significant difference in colour vision, red colour desaturation, brightness sensitivity, and ADC between diffusion restriction groups ($p > 0.05$) at 3 months. [Table 2]

There was a significant association between diffusion restriction and BCVA ($p < 0.05$). [Table 3]

Table 1: Association between diffusion restriction and other variables

Variables		Diffusion restriction		P-value
		Restricted	Not restricted	
Age (in years) (N=28):	18-27	8(33.3)	1(25.0)	0.747
	28-37	6(25.0)	2(50.0)	
	38-47	8(33.3)	1(25.0)	
	48-57	2(8.4)	0(0.0)	
Sex (N=28):	Male	8(33.3)	2(50.0)	0.601
	Female	16(66.7)	2(50.0)	
Laterality (N=28):	Unilateral	22(91.7)	3(75.0)	0.206
	Bilateral	2(8.3)	1(25.0)	
Pain on eye movement (N=31 Eyes):	Absent	14(53.8)	12(46.2)	1
	Present	12(46.2)	2(40.0)	
Headache (N=31 Eyes):	Absent	19(73.1)	3(60.0)	0.613
	Present	7(26.9)	2(40.0)	
Pupil (N=31 Eyes):	Normal	2(7.7)	1(20.0)	0.422
	RAPD	24(92.3)	4(80.0)	
Colour vision (N=31 Eyes):	Normal	2(7.7)	2(40.0)	0.026
	Defective	14(53.8)	0(0.0)	
	Cannot do	10(38.5)	3(60.0)	
Red colour desaturation (N=31 Eyes):	Normal	2(7.7)	1(20.0)	0.261
	Reduced	14(53.8)	1(20.0)	
	Cannot do	10(38.5)	3(60.0)	
Brightness sensitivity (N=31 Eyes):	Normal	2(7.7)	1(20.0)	0.261
	Reduced	14(53.9)	1(20.0)	
	Cannot do	10(38.5)	3(60.0)	
Contrast enhancement (N=31 Eyes):	Enhanced	26(100.0)	0(0.0)	<0.001
	Not Enhanced	0(0.0)	5(100.0)	
Fundus (N=31 Eyes):	Normal	2(7.7)	1(20.0)	0.845
	Disc oedema	18(69.3)	4(80.0)	
	Hyperemia	3(11.5)	0(0.0)	
	Temporal	3(11.5)	0(0.0)	
Central fields (N=31 Eyes):	Normal	3(11.5)	0(0.0)	0.602
	Generalised depression of visual field	5(19.2)	0(0.0)	
	Centrocecal scotoma	6(23.1)	1(20.0)	
	Altitudinal scotoma	1(3.9)	0(0.0)	
	Enlargement of blind spot	1(3.9)	1(20.0)	
	Not able to see	10(38.5)	3(60.0)	

Table 2: Association between diffusion restriction at 3 months

3 Months		Diffusion restriction		P-value
		Restricted	Not restricted	
Fundus (N=31 Eyes):	Normal	19(73.1)	1(20.0)	0.017
	Disc oedema	0(0.0)	1(20.0)	
	Temporal	7(26.9)	3(60.0)	
Central fields (N=31 Eyes):	Normal	25(96.2)	3(60.0)	0.06
	Generalised depression of visual field	0(0.0)	1(20.0)	
	Centrocecal scotoma	1(3.8)	1(20.0)	
Colour vision (N=31 Eyes):	Normal	24(92.3)	3(60.0)	0.112
	Defective	2(7.7)	2(40.0)	
Red colour Desaturation (N=31 Eyes):	Normal	24(92.3)	3(60.0)	0.112
	Reduced	2(7.7)	2(40.0)	

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Brightness sensitivity (N=31 Eyes):	Normal	24(92.3)	3(60.0)	0.112
	Reduced	2(7.7)	2(40.0)	
Optic never diameter (N=31 Eyes): Mean ± SD		4.61±0.90	3.46±0.97	0.0147[T]
ADC (N=31 Eyes): Mean ± SD		996.45±290.57	1079±373.82	0.5787[R]

Table 3: Association between diffusion restriction and BCVA in various time points

Diffusion restriction	BCVA Median (IQR) N=31 Eyes	BCVA in 3 Month Median (IQR) N=31 Eyes	P-value
Restricted {Snellen's VA}	1.00(0.8-1.8) {6/60(6/36-1/60)}	0.0(0.0-0.2) {6/6(6/6-6/9}	**<0.0001**
Not restricted {Snellen's VA}	1.3(0.3-1.8) {3/60(6/12-1/60)}	0.3(0.2-0.3) {6/12(6/9-6/12)}	0.2500
P-value	0.8976[T]	**0.0031[R]**	

DISCUSSION

The present study investigated the utility of diffusion-weighted imaging (DWI) as a predictive tool for visual outcomes in patients diagnosed with acute optic neuritis. This inflammatory condition affecting the optic nerve has been extensively associated with various demographic factors, and its diagnosis, particularly in the context of multiple sclerosis, often poses a challenge. The adoption of DWI in this study opens avenues for a more nuanced understanding of optic neuritis by examining the structural changes and diffusion patterns in the optic nerve.

This prospective study included a total of 28 patients. The mean age was 34 years; 18 were female (64%) and 10 were male (36%). Our study was similar to the ONTT, where 77% of the affected patients were females. This female preponderance was also observed in a similar study by Li et al.6 The most common complaints were defective vision (100%), eye movement pain (45.16%), and headache (29%). Our study results were similar to those of a study by Shatriah et al. In their study, swollen optic nerves were detected in 92.9% of eyes, while 60.7% of patients presented with a visual acuity of 6/60 or worse, including 20/200 vision or worse. Among the visual field defects observed, cecocentral scotoma was the most prevalent.[7]

In our study, the median logMAR at baseline was 1.32 ± 0.86 which improved after 3 months to 0.14 ± 0.24. According to the Snellen chart, 15 (48.4%) eyes had a visual acuity of < 6/60. Saxena et al. showed in their study a similar improvement in visual acuity from baseline logMAR of 1.6 ± 0.8 to 0.2 ± 0.6 after treatment.[8]

In our study, the pupillary reaction was normal in 3 eyes, and RAPD was found in 28 eyes. Fundus examination showed disc oedema or papillitis (70.9%), hyperaemia (9.7%), temporal pallor (9.7%), and normal fundus in (9.7%) eyes. Our study was similar to that of Saxena et al., in which papillitis was the most common fundus finding in optic neuritis. In their study, papillitis was found in 53.5% of patients, whereas in our study, papillitis was found in 70.9% of the eyes.[8]

In our study, colour vision was normal at baseline in 4 (12.9%) eyes, defective in 14 (45.2%) eyes, and could not be performed in 13 eyes (41.9%) because of low vision. In the following months, colour vision was normal in 28 eyes (90.3%), and this difference was statistically significant ($p < 0.001$). Central fields were normal in 3 (9.7%) eyes and defective in 28 (90.3%) eyes. Central fields could not be performed in 13 eyes because the visual acuity was very low. Central fields showed a caecal scotoma in 18 eyes (38.9%). The sequence of events that occur at the histopathological level in untreated acute optic neuritis includes inflammation, demyelination, gliosis, and optic atrophy. The chance of recovery depends on the extent and severity of the insult. DWI aids in evaluating the extent of damage and, thereby, the visual outcome. Zareen Fathima et al. in a study on DWI in optic neuritis concluded that ADC values were significantly decreased in patients with acute optic neuritis.[5]

In our study, there was a remarkable difference between the optic nerve diameters measured by imaging the affected and unaffected eyes. The diameter increased in the most affected optic nerves. On DWI, all 31 affected eyes showed hyperintensities in the intra-and intracanalicular portions of the optic nerve. The mean ADC values of the affected eyes at baseline was 1009.76 ± 299.90 (SD) × 10-6 mm 2 /sec, compared to the mean ADC values of the unaffected eyes, 1206.51 ± 425.64 × 10-6 mm2/sec. There was a statistically significant difference between the ADC values in eyes with acute optic neuritis and their controls (unaffected eyes), with a p-value of 0.002. ADC values were decreased in 26 eyes and increased in 5 eyes. The visual acuity of the 26 eyes with decreased ADC 17 had a visual acuity of 6/6(65.4%) and 7 had 6/9 (27%) at 3 months, except for two who had a visual acuity of 6/12 (7.6%). Of the five eyes that showed increased ADC, two had a visual acuity of 6/9(40%), two had a visual acuity of 6/12 (40%), and one had a visual acuity of 4/60 (20%).

In the present study, the optic nerve diameter increased in 27 eyes. Four eyes showed a reduced diameter compared to the control eyes. Two eyes had 6/12 vision, 1 eye had 6/9 vision, and 1 eye had 4/60 vision. Eyes with 4/60 vision had reduced optic nerve diameter, enhanced contrast enhancement, and increased ADC. The eye with 6/12 vision at 3 months follow-up had a reduced ADC and optic nerve diameter at baseline. Although the specificity was not 100%, DWI was found to have high specificity in identifying acute optic neuritis in our study, similar to previous studies conducted by Hickman et al. and Kupersmith et al.[3,9]

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CONCLUSION

This study provides valuable insights into the potential of DWI as a predictive tool for visual outcomes in patients with acute optic neuritis. The integration of neuroimaging with clinical parameters provides a multifaceted understanding of the disease and enhances its diagnostic and prognostic capabilities. While this study lays a foundation for the utility of DWI in optic neuritis, ongoing research with expanded cohorts and longer follow-up periods is necessary to consolidate and refine these findings for broader clinical applicability.

Limitations

The sample size of our study was small and the study was performed only at our institution. If many centres are included in the study, the number of patients will increase, which will increase the yield, and the results will be more accurate in our population. Only patients who could undergo MRI were included in our study. Thus, 15 patients who had acute optic neuritis and could not afford treatment were not included in our study. Post-treatment MRI could not be performed owing to the financial constraints of the patients.

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