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Six-Month Visual Outcomes in Pediatric Optic Neuritis: A Multicenter Study From South Korea

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Background: Current knowledge regarding the causes, clinical course, treatment response, and long-term outcomes of pediatric optic neuritis remains largely derived from case reports and retrospective series. Considering the ethnic variability in its presentation and the critical role of antibody-based differential diagnoses in guiding treatment strategies, further research is necessary. The aim of this study was to provide insights into the etiology and clinical findings of pediatric optic neuritis, thereby improving our knowledge of the condition in the era of antibody-based approaches.

Methods: This prospective multicenter cohort study was conducted at 31 referral medical centers. Patients younger than 18 years with first-episode optic neuritis were included. All patients underwent comprehensive neuro-ophthalmic examinations, including aquaporin-4–IgG and myelin oligodendrocyte glycoprotein–IgG testing and brain/orbit MRI. The primary outcome measure was best-corrected visual acuity (BCVA) at 6 months. Best-corrected visual acuity was further categorized into high vision (BCVA $\geq$ 20/40), moderate vision (20/200 $<$ BCVA $<$ 20/40), and low vision (BCVA $\leq$ 20/200).

Results: Overall, 44 pediatric patients were enrolled, with a mean age at onset of 10.7 ± 3.5 years. Bilateral optic neuritis and optic disc swelling were observed in 56.8% and 81.8% of patients, respectively. The mean BCVA at enrolment was 0.99 ± 0.89 logMAR, which improved significantly to 0.24 ± 0.52 logMAR at 6 months. The final 6-month diagnoses included myelin oligodendrocyte glycoprotein antibody–associated disease (n = 30 [68.2%]), isolated optic neuritis (n = 11 [25.0%]), acute disseminated encephalomyelitis (n = 2 [4.5%]), multiple sclerosis (n = 1 [2.3%]). No patients had neuromyelitis optica. At the 6-month follow-up, 50.0% showed improvement in the visual category, 50.0% maintained their visual category, and none experienced deterioration. There were no significant predictors related to poor BCVA at enrolment and at 6 months.

Conclusion: Pediatric optic neuritis exhibits severe visual deficits but shows good recovery. Myelin oligodendrocyte glycoprotein antibody–associated disease is the most common etiology. These findings reflect the distinct characteristics of pediatric optic neuritis and provide important baseline data for developing tailored treatment strategies.

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The Optic Neuritis Treatment Trial (ONTT) significantly enhanced our understanding of the etiology, management, and prognosis of optic neuritis (ON).[1] How-

ever, the implications of these findings are limited by the study's focus on adults with unilateral acute ON and the absence of specific antibody (Ab) profiles. Therefore, these findings and treatment recommendations are not directly applicable to pediatric patients with ON. Thus, current knowledge regarding the causes, clinical course, treatment response, and long-term outcomes of this condition remains largely derived from case reports and retrospective series.[2–7]

Recently, cohort studies conducted by the Pediatric Eye Disease Investigator Group (PEDIG) have provided valuable insights into pediatric patients with ON.[7,8] However, more than 50% of the participants were Caucasians, with Asians representing only 9%. Moreover, Ab testing was only conducted in less than 40% of the participants. Considering the ethnic variability in the presentation of ON and the critical role of Ab-based differential diagnoses in guiding treatment strategies, further research is necessary.

Therefore, the aim of this prospective multicenter cohort study was to describe the etiology, clinical findings, and early treatment outcomes of pediatric ON, thereby improving our knowledge of the condition.

METHODS

The Korea-Pediatric Optic Neuritis Study (K-PONS) is a nationwide multicenter research initiative involving 31 referral medical centers in South Korea with expertise in pediatrics and neuro-ophthalmology. In the K-PONS study, a prospective cohort design (January 2023 to December 2024) and a retrospective cohort design spanning the past 10 years (January 2010 to December 2020) were used. This report exclusively presents findings from the prospective research component. The full protocol of this prospective study is provided in the **Supplemental Digital Content** (see **Supplement 1**, http://links.lww.com/WNO/B12).

The study was conducted following the Declaration of Helsinki. The Institutional Review Boards (IRBs) of all participating medical centers approved the study. Ethical approval was granted by the Institutional Review Board of Seoul National University Hospital (IRB No. 2301-018-1391), and written informed consent was obtained from the patients and their legal guardians after an explanation of the purpose and procedures of the study.

PARTICIPANTS

This study included patients younger than 18 years (at the time of enrolment) who presented with a first episode of ON in one or both eyes within 2 weeks of visual symptom onset. ON was diagnosed following the Optic Neuritis Treatment Trial guidelines, and contrast-enhanced orbital MRI was performed for confirmation.[9] Optic neuritis was classified as bilateral if both eyes were affected at the time of enrolment; in such cases, the eye with worse visual function was selected for analysis.

Exclusion criteria included (1) history of ON; (2) systemic, congenital, or other ophthalmological diseases affecting optic nerve function; (3) optic neuropathy due to other identifiable causes, such as trauma, compression, infiltration, drug, or infection; (4) history of ocular surgery potentially affecting visual acuity; and (5) insufficient data evaluating for visual function.

Demographic and clinical data were collected at the time of enrolment. A detailed history was obtained, and comprehensive neuro-ophthalmic examinations were performed, including best-corrected visual acuity (BCVA) using the Snellen chart, color vision testing, and fundus examination. If the patient cooperated, optical coherence tomography (OCT) and visual field assessments were performed at the initial visit. Brain/orbit MRI with gadolinium was performed at the initial visit. Optic nerve segments with gadolinium contrast enhancement on fat-suppressed T1 imaging or a high signal on T2 imaging were regarded as acute ON lesions.[10] Serum samples were obtained at the time of the acute attack and tested for the presence of aquaporin-4 (AQP4)–IgG and myelin oligodendrocyte glycoprotein (MOG)-IgG. Each Ab test was performed using a cell-based assay.[11] In addition, complete blood count, serum C-reactive protein levels, erythrocyte sedimentation rates, and albumin and IgG levels were assessed. A cerebrospinal fluid assessment, including the levels of albumin, IgG, and white blood cells, as well as the presence of oligoclonal bands, was performed in available cases.

Patients were further classified into one of the following categories based on clinical findings, presence of antibodies, and MRI findings: isolated ON, acute disseminated encephalomyelitis (ADEM), multiple sclerosis (MS), neuromyelitis optica spectrum disorder (NMOSD), or myelin oligodendrocyte antibody–associated disease (MOGAD).

Follow-up visits were scheduled at 1, 3, and 6 months after enrolment. Monocular BCVA measurements, fundus examination, OCT, and visual field testing were repeated at each visit. We also collected data on acute treatment strategies and followed each patient's management.

STATISTICAL ANALYSES

Continuous data are presented as mean ± SD, while categorical data are presented as numbers and percentages. Logistic regression analysis was performed to investigate factors associated with positive MOG-Ab positivity. Multiple linear regression analysis was performed to investigate the factors associated with BCVA. Statistical significance was set at $P < 0.05$ for all analyses. All statistical analyses were performed using SPSS (version 23.0; SPSS Inc., Chicago, IL).

Visual acuity data throughout the disease course were converted to logMAR values for analysis. Poor vision was measured by counting fingers, hand motion, light perception, and no light perception, which were converted to logMAR 1.7, 2.0, 2.3, and 3.0, respectively.[12]

RESULTS

Baseline Characteristics

Overall, 44 children experiencing first-time ON attacks were enrolled in this study. The sex distribution was 21 male and 23 female, with a mean age at onset of 10.7 ± 3.5 years (range: 5.0–17.0 years). Among them, 19 (43.2%) had unilateral ON, with a mean age at onset of 11.2 ± 3.5 years (range: 4.8–16.0 years). Meanwhile, 25 (56.8%) had bilateral ON, with a mean age at onset of 8.6 ± 2.9 years (range: 3.9–13.5 years). A history of recent systemic infection was assessed based on parental report and was reported in 23 cases (52.3%), with an interval of 23.0 ± 17.7 days (range: 3.0–73.0 days) between the infection and ON diagnosis. None of the patients had a recent vaccination history before the ON diagnosis.

Two patients had a history of central nervous system (CNS) demyelination (ADEM and autoimmune cerebellitis). At the time of diagnosis, neither patient showed evidence of visual dysfunction on ophthalmic examination. Both were treated with intravenous steroid pulse therapy and achieved favorable clinical outcomes.

Among the participants, 20 (45.5%) experienced ocular pain along with visual symptoms. Ten participants experienced ocular pain before visual symptoms occurred, whereas in the remaining 10, ocular pain simultaneously appeared with the onset of visual symptoms. At the initial examination, 36 patients (81.8%) showed optic disc swelling and 8 patients (18.2%) exhibited normal optic disc features. Three patients (6.8%) presented with peripapillary hemorrhages. The mean BCVA at enrolment in the 44 eyes of those with ON was 0.97 ± 0.90 logMAR (range: 0.00–3.00). MRI revealed perineural enhancement in 5 of 44 patients (11.4%) and cerebral white matter lesions (WML; aside from optic nerve enhancement) in 14 patients (31.8%).

The AQP4-Ab test was conducted in 43 of 44 patients, with no positive results in any patient. The MOG-Ab test was performed for all 44 patients, and the antibodies were detected in 31 participants. Among the MOG-Ab–positive cases, one patient exhibited a low-positive Ab titer, presented with unilateral ON without systemic symptoms or abnormal brain lesions, and was diagnosed with isolated ON.

By combining clinical findings, MRI review, and serological testing, the final diagnoses at 6 months were MOGAD (n = 30 [68.2%]), isolated ON (n = 11 [25.0%]), ADEM (n = 2 [4.5%]), and multiple sclerosis (n = 1 [2.3%]). No patients had NMOSD. The demographic information is summarized in Table 1.

We also performed further analysis to investigate the associated baseline factors with the presence of MOG-Ab positivity; however, no statistically significant factors were identified (Table 2).

All 44 patients were initially treated with high-dose intravenous methylprednisolone (IVMP) followed by oral steroid tapering. The average duration of IVMP usage was 3.5 ± 0.9 days (range: 3.0–5.0), the average IVMP dose per kg was 68.7 ± 26.4 (mg/kg) (range: 27.4–156.3), and the average oral prednisolone dose per kg was 27.7 ± 36.0 (mg/kg) (range: 4.0–189.4), with significant variability in the dosage across medical centers. Four patients received additional intravenous immunoglobulin, and azathioprine was administered to one patient. There was no recurrence within the 6-month follow-up period, but among the 16 patients followed up for 1 year, 4 patients showed recurrence. Interferon beta therapy was started for the patient with MS 1 year after the first episode due to ON recurrence. The other 3 patients (one with idiopathic ON and 2 with MOGAD) also experienced ON recurrence within 1 year and were all retreated with IVMP.

Distance Best-Corrected Visual Acuity at Enrolment and 6 Months

The mean distance BCVA at enrolment in the 44 eyes of patients with ON was 0.99 ± 0.89 logMAR (0.00–3.00); 21 eyes (47.7%) had a distance BCVA of 20/200 or less (low vision); the distance BCVA was between 20/200 and 20/40 (moderate vision) in 7 eyes (15.9%), while it was 20/40 or above (high vision) in 16 eyes. Of the 44 patients who underwent the initial examination, 38 participated in the 6-month follow-up period. The mean distance BCVA at the 6-month follow-up was 0.24 ± 0.52 logMAR (0.00–1.70); 4 eyes (10.3%) had a distance BCVA of 20/200 or less, 3 eyes (7.7%) had a distance BCVA between 20/200 and 20/40 or worse, and 32 eyes (82.1%) had a distance BCVA of 20/40 or above.

The distribution of vision outcomes across baseline visual acuity groups, as visualized in the Sankey diagram (Fig. 1), is summarized as follows: 100% of patients with high vision maintained their status (12/12), 57.1% of those with moderate vision showed improvement (4/7), and 42.9% remained stable (3/7). Among the patients with low vision, 78.9% improved (15/19) to high vision, whereas 21.1% maintained their vision (4/19). Overall, 50.0% (19 patients) showed improvement, 50.0% (19 patients) maintained their vision, and no patients (0%) experienced deterioration.

Associations With Poor Best-Corrected Visual Acuity at Enrolment and 6 Months

Poor BCVA at the initial visit was not significantly associated with sex, age, recent history of systemic infection, laterality, presence of pain, disc swelling, peripapillary hemorrhage, positive MOG antibodies, or abnormalities in brain parenchyma on brain MRI (all $P > 0.05$) (Table 3).

TABLE 1. Baseline demographics and clinical characteristics of enrolled subjects (N = 44)

Characteristics	
Sex (male: female)	21 (47.7%): 23 (52.3%)
Age at onset (y)	10.7 ± 3.5 (5–17)
Laterality of ON presentation (unilateral: bilateral)	19 (43.2%): 25 (56.8%)
History of recent systemic infection	23 (52.3%)
Interval between recent systemic infection and ON (d)	23.0 ± 17.7 (3–73)
History of CNS demyelination	
Chief complaints of patients	
Decreased vision	40/44
Visual blurring with normal visual acuity	4/44
Diminished color vision	8
Pain on eye movement	20 (45.5%)
Pain precedes the visual symptoms	10 (50%)
Pain and visual symptoms occur simultaneously	10 (50%)
Optic disc feature (swelling: normal)	36 (81.8%): 8 (18.2%)
Peripapillary hemorrhage	3 (6.8%)
BCVA at presentation (logMAR)	0.99 ± 0.89 (0.00–3.00)
Brain parenchyma lesion(s) on MRI	14 (31.8%)
AQP4 test result	
Negative	43 (97.7%)
Positive	0 (0.0%)
Not done/unknown	1 (2.3%)
MOG test result	
Negative	13 (29.5%)
Positive	31 (70.5%)
Not done/unknown	0 (0.0%)
Final diagnosis at the 6-month FU	
Isolated ON	11 (25.0%)
MOGAD	30 (68.2%)
ADEM	2 (4.5%)
MS	1 (2.3%)
NMOSD	0 (0.0%)

ON, optic neuritis; BCVA, best-corrected visual acuity; IVMP, intravenous methylprednisolone; AQP4, aquaporin-4; MOG, myelin oligodendrocyte glycoprotein; FU, follow-up; MOGAD, myelin oligodendrocyte antibody–associated disease; ADEM, acute disseminated encephalomyelitis; MS, multiple sclerosis; NMOSD, neuromyelitis optica spectrum disorder.

The final BCVA outcome at 6 months was not associated with poor BCVA at the initial visit. Other factors, such as sex, age, recent infection history, laterality, pain, disc swelling, peripapillary hemorrhage, positive MOG antibodies, and brain MRI findings, also did not show significant correlations with the 6-month visual outcomes (all $P > 0.05$) (Table 3).

DISCUSSION

This study provides meaningful information regarding pediatric ON based on the antibody approach. Forty-four children were enrolled with a mean age of 10.7 ± 3.5 years; 56.8% of them presented with bilateral ON. Visual symptoms were accompanied by ocular pain in 45.5% of the patients, and optic disc swelling was observed in 81.8% of them. At the initial visit, the mean BCVA was 0.99 ± 0.89 logMAR, while it improved significantly to 0.24 ± 0.52 logMAR after 6 months. Among the 39 patients who completed the 6-month follow-up, all patients either showed improvement or maintained their visual category, with no patients experiencing visual deterioration. MOG antibodies were positive in 70.5% of the patients, with 65.9% diagnosed with MOGAD at the 6-month follow-up.

TABLE 2. Baseline factors associated with positive MOG-antibody

	*P**
Sex	0.609
Age	0.621
Recent systemic infection	0.551
Laterality	0.300
Pain	0.700
Disc swelling	0.211
Peripapillary hemorrhage	0.900
Perineural enhancement on MRI	0.353
Brain parenchyma lesion(s) on MRI	0.170
Initial BCVA	0.906

*Logistic regression analysis.
BCVA, best-corrected visual acuity.

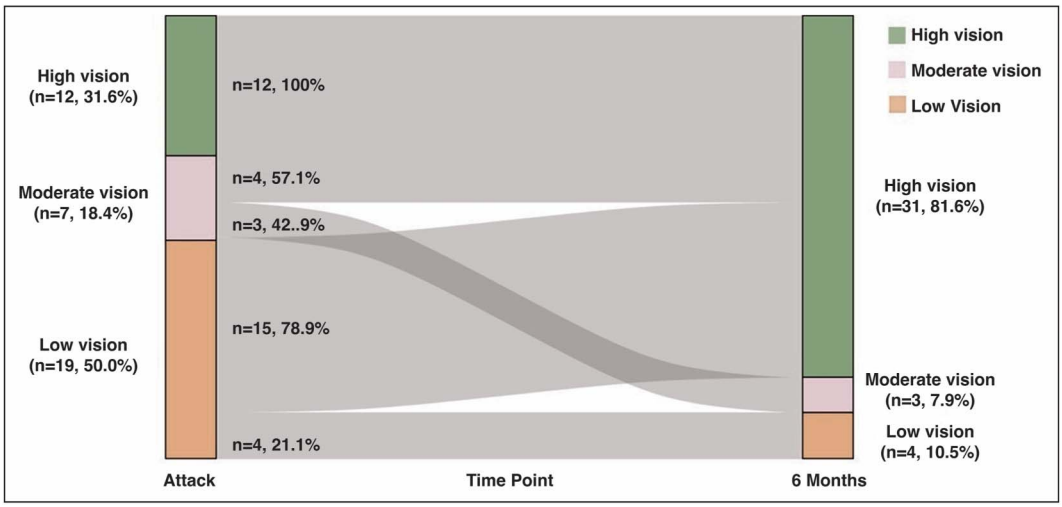

FIG. 1. Sankey diagram of visual acuity recovery pattern. Best-corrected visual acuity (BCVA) was categorized into high vision (BCVA ≥20/40), moderate vision (20/200 < BCVA <20/40), and low vision (BCVA ≤20/200). All patients with high vision maintained their status (12/12), 57.1% of those with moderate vision showed improvement (4/7), and 42.9% remained stable (3/7). Among the patients with low vision, 78.9% improved (15/19) to high vision, whereas 21.1% maintained their vision (4/19). Overall, 50.0% (19 patients) showed improvement, 50.0% (19 patients) maintained their vision, and no patients (0%) experienced deterioration.

This study revealed several meaningful findings when compared with the PEDIG study conducted in the United States and Canada.[7] Both studies included 44 children with similar average ages (K-PONS: 10.7 ± 3.5 years vs PEDIG: 10.2 ± 3.5 years). Regarding visual outcomes, both studies showed a substantial improvement in BCVA over the follow-up period. In the PEDIG study, an improvement from 0.95 logMAR to 0.12 logMAR was reported at 6 months,[7] with the improved vision being maintained up to 2 years of follow-up.[8] Regarding Ab test results in the PEDIG study, the proportion of MOG-Ab–positive cases was the highest, with 54% (7/13) and 7% (1/15) testing positive for MOG and AQP4 antibodies, respectively. In our study, we conducted Ab testing for most patients, demonstrating 70.5% MOG-Ab positivity (31/44) and 0% AQP4-Ab positivity (0/43). Both studies showed that MOG antibodies are the primary causative agents in pediatric ON.

In contrast to children, adults with demyelinating ON tend to have similar rates of AQP4 and MOG Ab positivity.[13] However, epidemiological research has shown that pediatric-onset NMOSD is extremely rare.[14,15] In our study, none of the 43 patients tested positive for AQP4 Ab, and no cases of NMOSD were detected. This finding suggests that the underlying etiology of acute ON in children differs from that in adults.

An analysis was performed to identify risk factors for MOG-Ab positivity based on the initial clinical presentation, but no significant associations were found. Similar to our study, a previous study showed no significant

TABLE 3. Factors associated with poor BCVA at enrolment and at 6 months

	At enrolment		At 6 months	
	Coefficient beta	*P**	Coefficient beta	*P**
Sex	0.045	0.896	−0.073	0.694
Age	−0.097	0.087	0.050	0.171
Recent systemic infection	0.030	0.934	0.325	0.108
Prior CNS demyelinating disease	0.653	0.557	0.690	0.239
Laterality	0.009	0.567	0.096	0.305
Pain	−0.744	0.059	0.031	0.900
Disc swelling	−0.331	0.437	−0.322	0.213
Peripapillary hemorrhage	−0.509	0.420	0.149	0.692
MOG antibody	−0.090	0.797	−0.110	0.572
Brain MRI abnormality	−0.090	0.901	−0.054	0.776
Initial BCVA			0.099	0.318

*Multiple regression analysis.
CNS, central nervous system; MOG, myelin oligodendrocyte glycoprotein; BCVA, best-corrected visual acuity.

demographic differences between MOG-Ab–positive and MOG-Ab–negative cases.[16] Another study on ADEM showed that the frequency of thalamic lesions on brain MRI was the only significant difference between MOG-Ab–positive and MOG-Ab–negative cases.[17]

According to previous studies, the high prevalence of MOG-Ab positivity raises concerns about subsequent CNS demyelinating disorders or ON recurrence in pediatric patients. Our previous investigation of pediatric ON showed a 5-year cumulative risk of CNS demyelinating events or recurrent ON attacks of approximately 26% in the MOG-IgG group.[18] In this study, no ON recurrence or subsequent CNS demyelinating disorders were observed during the 6-month follow-up; however, among the 16 patients monitored for 1 year, 4 experienced ON recurrence. Long-term follow-up is required in pediatric patients with ON.

Before the antibody era, pediatric ON was characterized by bilateral involvement, frequent optic disc swelling, and poor vision at initial presentation; however, it had a favorable response to IVMP. These clinical features closely resemble those of typical MOGAD-ON known in adult and pediatric patients.[10,19,20] In our study, antibody testing revealed a high prevalence of MOG-Ab positivity in pediatric patients, suggesting that the previously reported similarities between pediatric ON (before antibody era) and MOGAD may be attributable to underlying MOG-Ab predominance.

This study had some limitations. First, the relatively small sample size may limit statistical power. However, the findings align with those of the PEDIG study,[7] particularly in favorable visual outcomes and the predominance of MOG-Ab positivity. Second, the study exclusively included Korean patients, which may restrict its generalizability. Nonetheless, it is valuable in highlighting features of East Asian patients, who were underrepresented in the PEDIG study (9%). Third, while the follow-up period was sufficient for assessing acute outcomes, it may be insufficient to capture long-term relapses or the development of demyelinating CNS diseases. Further research using long-term data is needed to investigate relapses and CNS disease comorbidities. Fourth, treatment protocols varied across centers. High-dose IVMP remains the first-line treatment for acute ON in adults. Moreover, various immunomodulatory strategies, such as immunosuppressive agents, intravenous immunoglobulins, and plasmapheresis are being used for relapse prevention. However, the lack of pediatric-specific clinical trials has led to notable gaps in evidence-based treatment guidelines for children. Therefore, future studies focusing on treatment in pediatric patients are necessary. Finally, we acknowledge that diagnostic classifications may evolve over time as additional disease processes become apparent, potentially resulting in diagnostic reclassification.

In conclusion, this prospective study offers comprehensive data on pediatric ON through systematic antibody testing, establishing key baseline features of this population.

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