Original Article

Automated grating contrast-sensitivity: The easy test for hidden visual loss in recovered optic neuritis patient

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Abstract:

PURPOSE: Residual visual loss is an important predictor of optic neuritis relapse and progression. This study aimed to investigate the hidden residual visual loss in patients with optic neuritis using automated contrast-sensitivity (CS) function testing.

MATERIALS AND METHODS: This cross-sectional study investigated 29 recovered optic neuritis patients (age: 27.69 ± 13.32 years, range: 13–51). Twenty age-matched controls with normal visual acuity (VA, in LogMAR) were recruited, for comparison with patients' VA and CS function after stable recovery from optic neuritis (6 months of follow-up). CS tests used a novel software that displays a single set of Gabor patches (2 cycles per degree at 10° ×10° of visual angle) with contrasts grating from 100% to 0.1%.

RESULTS: There were 13 adolescent patients (63.6%: retrobulbar neuritis [RN]; 36.4%: papillitis), 14 adult patients (50%: RN; 42.9%: papillitis), and only 2 older patients (all with neuroretinitis). There was improvement of VA in the patient group at first diagnosis and follow-up (VA initial vs. final: 1.438 ± 1.134 vs. 0.235 ± 0.272, $P < 0.001$). This VA improvement was similar to control group ($P = 0.052$). In CS, there were significant differences in patient versus control groups (69.069% ± 70.235% vs. 27.215% ± 25.27%, $P = 0.025$). Linear regression showed that initial VA and CS function could not predict final VA ($P = 0.183$ and $P = 0.138$, respectively).

CONCLUSIONS: Patients with optic neuritis showed decreased CS compared to control group which indicated the residual visual loss. Automated CS testing is useful in detecting residual visual loss in patients who recovered from optic neuritis.

Keywords:

Contrast-sensitivity function, Gabor patch, neuro-ophthalmology, optic neuritis

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Introduction

Individuals with normal visual acuity (VA) might still complain about a slight disturbance in sight.[1] Standard visual examinations such as using the Snellen chart are known to not depict the complete visual function. The Snellen chart uses low luminance letters (black letters) to be seen within a high luminance background (white background).[2,3] Therefore, there are other visual functions that need to be assessed to determine the complete visual function of an individual.[4] Contrast-sensitivity (CS) loss may sometimes be called as hidden visual loss because the visual loss is often undetected by the clinician. This might be due to the lack of CS measurement as the standard visual examination.[5]

CS indicates the visual sensitivity of an individual to identify objects in the background with various contrasts and is measured as CS function. CS implies the ability of an individual to differentiate an object from its background.[5] The size of the objects could be specified as the spatial frequency (cycle per degree [cpd]) of a sine wave pattern[3] [Figure 1]. An individual

may visually identify an object better when the size is bigger and the contrast is higher.[2]

Factors that may contribute to the change of CS are optical and neural factors. Neural changes include the optic neuritis condition. Optic neuritis is an inflammation of the optic nerve due to many causes. It is indicated by unilateral painful visual loss and mostly occurs in young healthy females.[6] After excluding glaucoma, optic neuritis is the most common optic neuropathy in persons under 50 years old who seek treatment in general ophthalmic practice. It is the earliest clinical symptom in about 20% of cases of multiple sclerosis.[7]

Optic neuritis can be divided into anterior neuritis (papillitis) and retrobulbar neuritis (RN). Papillitis is indicated when the optic disc appears swollen. It is an anterior form of optic neuritis. Funduscopic features of the swollen optic disc include elevation of optic nerve head, disc hyperemia, disc margins blurring, and nerve fiber layer edema.[6] Meanwhile, RN is when the disc appears normal. Other clinical features are similar in both papillitis and RN.[8]

As demonstrated in previous study, the strongest predictor of recovery from optic neuritis is attack severity. Given this relationship, predictors of both attack severity and attack recovery can provide valuable information about the clinical course of patients with optic neuritis.[9] Residual visual loss is an important predictor of optic neuritis relapse and progression. The present study aimed to investigate the hidden residual visual loss in patients with optic neuritis using automated CS testing.

Methods

Design and subjects

This cross-sectional study investigated 29 recovered neuritis patients (age: 27.69 ± 13.32 years, range: 13–51). The subjects were recruited using consecutive sampling method, taken randomly, and voluntarily participated in this study after giving informed consent. Patients with confirmed optic neuritis (RN, papillitis, and neuroretinitis) were included as the case group. The inclusion criteria of patients diagnosed with optic neuritis were age 18–50, unilaterality, pain on eye movement, subsequent improvement, and no evidence of any systemic disease other than multiple sclerosis.[10] The exclusion criteria were subjects diagnosed as atypical optic neuritis, diabetic papillopathy, and anterior optic ischemic neuropathy. Twenty age-matched controls with normal VA were recruited, for comparison with patients VA after stable recovery from optic neuritis (in LogMAR) and CS function (in percent). Control subjects were excluded if subjects have current eye disorder on clinical examination, have previous history of eye disorder that

Figure 1: Gabor patch in each trial: the contrast-sensitivity patch was adjusted according to subjects' performance using the staircase thresholding method

might affect visual function, and have previous history of eye surgery and there was family history of glaucoma or diabetes. This study was approved by the Medical and Health Research Ethics Committee Faculty of Medicine, Universitas Gadjah Mada and Dr. Sardjito General Hospital (ID: KE/FK/0749/EC/2017).

Preliminary validity study

The subjects were 66 eyes from individuals aged 20–49 years with normal corrected VA (6/8 or better) in each eye. The subjects were excluded if the subjects have eye disorder on the day of the examination, have history of related eye disorders, or have systemic illnesses that affect visual function. The VA measurements were done using the Snellen chart measured at standard 6 m while the CS was measured using two methods; Pelli Robson Chart measured at 1 m and the computer-based Gabor Patch (1 cpd, 10°). The number of subjects with CS measurement using Gabor Patch better than Pelli Robson were 56 data. The number of subjects with CS measurement using Gabor Patch worse than Pelli Robson was 6 data. The comparison result showed $P = 0.00$ ($P < 0.05$). Thus, it was concluded that there was significant difference in CS testing measured using Pelli Robson and Gabor Patch. The subjects tended to have better CS when tested using Gabor Patch than when measured using the Pelli Robson method.

Automated contrast-sensitivity testing

Before measurement, standard ophthalmic examinations (Snellen VA, anterior and posterior segment examination) were done to examine the eye conditions. CS tests were done using novel CS software that displays a single set of Gabor patches (10° × 10° of visual angle) with contrasts grating from 100% to 0.1%. Two-dimensional Sine Wave Luminance Gratings were the basis for describing visual stimuli and probing the visual system's sensitivity [Figure 1].[4] Stimuli were

displayed on an LED color monitor in a laptop with resolution of 1366 × 768 and a frame rate of 120 Hz. The trials started with a fixation point at the central of the monitor for 0.7 s; then Gabor grating was shown with 2 cpd spatial frequency and with variable CS. It followed by a question mark sign at the central of the monitor and displayed until the subject pressed the respond key. The Gabor patches would appear at the center of the monitor for 400 ms. The participants then chose whether they saw the grating or not by pressing one of two buttons using a two-alternative forced-choice staircase procedure. Throughout the trials, no change was done at the cpd, but there was only the change of the luminance of the grating foreground versus background. This change was then set as the threshold according to their performance. The final CS value was revealed at the end of the trials (approximately after 50 trials) of thresholding using the staircase method. The staircase steps were as follows: stimulus contrast was raised by 25% following one incorrect response and lowered by 12.5% following two consecutive correct responses. The final contrast threshold was shown in percentage with lower percentage indicating a better performance.

Statistical analyses

Subject characteristics such as age and VA were tested using Kolmogorov–Smirnov for the normality test, followed by independent sample t-test if normally distributed. Nominal variables such as sex distribution and eyes laterality were analyzed using Chi-square test. For the CS function analysis, Kolmogorov–Smirnov was done for the normality test, followed by Mann–Whitney test if the data were not normally distributed.

Results

We found that the distribution of the optic neuritis subtypes was RN 30.6%, neuroretinitis 14.3%, and papillitis 10.2%. There were 13 adolescent patients (63.6%: RN; 36.4%: papillitis), 14 adult patients (50%: RN; 42.9% papillitis), and only 2 older patients (all with neuroretinitis, and not related to *Bartonella* infection). There was no difference between case versus control group in sex and eyes laterality distribution [Table 1]. Initial VA of patients with optic neuritis was significantly worse than the control group. However, there was improvement of VA in the case group at the follow-up [VA initial vs. final: 1.438 ± 1.134 vs. 0.235 ± 0.272, P < 0.001, Figure 2]. This VA improvement was similar to the control group (P = 0.052).

For the CS parameters, we calculated the number of trials for CS threshold (trial threshold), CS, accuracy, and reaction time (RT). No difference in trial threshold, accuracy, and RT indicated the similarity of cognitive state of the patients as well as control. In CS, there

Table 1: Subject's characteristics

Variables	Optic neuritis, *n* (%)	Normal, *n* (%)	*P*
Age (mean±SD)	27.79±13.62	30.05±13.26	0.122
Sex			
Male	11 (37.9)	9 (45.0)	0.621
Female	18 (62.1)	11 (55.0)	
Eyes			
Right eye	13 (46.4)	9 (45)	0.922
Left eye	15 (53.6)	11 (55)	
VA initial (logMAR)	1.3825±1.14240	0.08±0.10954	0.04*

*Statistically significant (<0.05). VA=Visual acuity, SD=Standard deviation

Table 2: Contrast-sensitivity parameters

Variables	Optic neuritis	Normal	*P*
Trial threshold (*n*)	56.28±24.26	53.55±31.82	0.331
Accuracy (%)	74.83±23.06	84.94±0.09	0.319
RT (s)	1.29±0.77	0.96±0.32	0.179
CS (%)	69.07±70.24	27.7±42.31	0.025*

Note: Pairwise comparisons were done using Mann-Whitney test (Kolmogorov-Smirnov > 0.05). *Statistically significant (<.05); CS=Contrast-sensitivity; RT=Reaction time
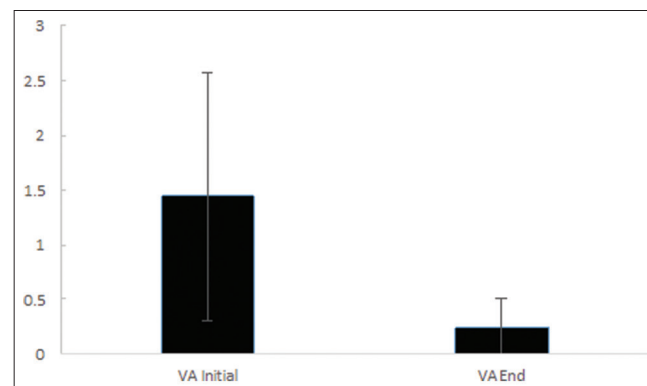

Figure 2: The visual acuity improvement after 6 months follow-up (initial vs. end) of the case group (*P* < 0.001)

were significant differences in patient versus control groups (69.069% ± 70.235% vs. 27.215% ± 25.27%, P = 0.025) [Table 2]. This result showed that although there was VA improvement of patient with optic neuritis, there still was residual vision loss. There was no significant difference between RN versus papillitis (33.725 ± 33.63 vs. 34.335 ± 34.037, P = 0.755). Further analysis with linear regression showed that initial VA and CS could not predict final VA (P = 0.183 and P = 0.138, respectively).

Discussion

We revealed that automated CS testing was able to detect hidden visual loss in visually recovered patients with optic neuritis. The automated computer-based method was objective and effective to be implemented in the clinical setting. Giving the clear instructions to the patients was an important factor to gain the most objective and accurate results.[11] There are only a few

recent studies that investigated CS and optic neuritis;[12,13] however, they used a manual chart when compared to the automatic chart used in this present study. In our experiment, there was no significant difference in trial threshold, accuracy, nor RT between optic neuritis patients and control groups, which showed that there was no difference in cognitive ability between the two. However, we found that although patients who recovered from optic neuritis had improved VA (until nearly 6/6), they still continued having subtle visual disturbances that were explained by the loss of low spatial CS. This condition might be caused by damage (unrecovered from inflammation) of small fractions of optic nerve myelin that might produce subtle visual loss. A study by Al-Hashmi *et al.* found that parvocellular function contributes to mid-high spatial frequencies in which the parvocellular respond to chromatic contrast.[14]

Patients with optic neuritis have reduced CS function at lower spatial frequency and commonly show normal VA.[3] In the present study, we used 2 cpd grating to overcome the low spatial frequency in optic neuritis. Generally, optic neuritis is accompanied with decreased vision, optic nerve dysfunction, decreased peripheral vision, decreased color vision, decreased contrast/brightness sense, and relative afferent papillary defect and tends to be associated with periorbital pain.[6] The severity of visual loss varies from a mild visual field defect to severe loss of central acuity. Severe loss of VA is more common in children. Color vision and CS are impaired in almost all cases, often out of proportion to VA. Visual field loss, which may be diffuse or focal (i.e., nerve fiber bundle defects, central or ceco-central scotomas, and hemianopic defects), is also common in acute optic neuritis. Altitudinal defects (focal visual field loss above or below the horizontal meridian) are less common.[8] Previous study found that the severity of optic neuritis was similar between the pediatric and adult subjects, but recovery was significantly better in pediatric subjects.[9]

In daily life, although recovered patients with optic neuritis might have normal VA, patients with decreased CS at middle-to-low spatial frequencies are likely to have decreased ability to see faces, road signs, and common place objects.[1,14] Limitations of the study were the length of follow-up time to observe the improving vision being only 6 months, limited number of patients, and no control of patients' eye movements using an eye tracker device.

Conclusions

The present study showed that patients with optic neuritis had statistically lower contrast threshold when compared to normal subjects which indicated the residual visual loss condition. Therefore, automated computer-based CS testing is important in detecting subtle visual changes and is promising to be used for eye diseases involving CS ranging from refractive anomalies to neural diseases. Further study is needed to employ eye tracker device to validate the responses from the subjects.

Conflicts of interest

The authors declare that there are no conflicts of interests of this paper.

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