Correlation of Electroretinographic Changes with Visual Prognosis in Central Retinal Artery Occlusion

Key Words
Central retinal artery occlusion
Electroretinogram b/a amplitude ratio
Visual prognosis

Abstract
Recent advances in the treatment of central retinal artery occlusion (CRAO) have resulted in a relatively good prognosis, but few studies have been reported. In the present study, electroretinography (ERG) was used to evaluate visual function recovery in 15 cases of CRAO. All patients were treated with ocular massage, intravenous urokinase and hyperbaric oxygenation. Of 15 cases, 8 had improved vision after treatment. A single flash ERG of 40 J from a xenon lamp was recorded before and during treatment. For ERG evaluation, the a- and b-wave amplitudes and the b/a wave amplitude ratio were analyzed. As control, the nonaffected eye of each patient was used. Before treatment, no significant difference was found in the a-wave amplitude between the two eyes, while a significant attenuation was found in the b-wave of the affected eye (p < 0.01). The b/a ratio was 0.73 ± 0.04 (mean ± SE) in the affected eye group and 1.08 ± 0.03 in the nonaffected eye group. It was significantly higher (p < 0.01) in eyes with improved visual acuity (0.83 ± 0.03) than in those with unimproved visual acuity (0.62 ± 0.05). The b-wave amplitude increased in accordance with visual improvement. We could thus demonstrate the temporal changes of ERG before and after treatment and show their correlation with the visual prognosis in patients with CRAO.
Introduction

Some methods of treating central retinal artery occlusion (CRAO) have yielded unsatisfactory results. Recent advances in the treatment of CRAO with the intravenous injection of urokinase and hyperbaric oxygenation, however, have brought relatively good visual prognoses. To date, only a few studies using these new techniques have been reported. On the other hand, the electroretinogram (ERG) in patients with CRAO is of known diagnostic value because the waveform has a characteristic negative form. The negative ERG, which is a small b-wave with a large or pronounced a-wave, was first named by Karpe [1] in his 1946 study of several patients with CRAO. Negative ERGs in cases of CRAO have been confirmed since then by several authors, [2–7], although the terminology is infrequently used. The concept of the negative ERG, however, is still considered a typical sign of severe inner retinal disorder. In 1979, Sole and Alfieri [8] demonstrated CRAO quantitatively by measuring the ratio of the b- to a-wave amplitudes.

In the present study, we evaluated the recovery of visual function in patients with CRAO based on the b-wave/a-wave amplitude ratio of the ERG and subjective visual acuity.

Subjects and Methods

Fifteen patients suffering from CRAO treated at Chiba University Hospital between 1980 and 1991 were the subjects for this study. The 9 men and 6 women ranged in age from 36 to 78 years (mean, 61.9 years). Ten cases involved the right eye and 5 affected the left eye. All patients were treated with ocular massage, the intravenous injection of urokinase (12 × 10^6 to 24 × 10^6 IU/day) and hyperbaric oxygenation. Two patients were treated further with an intravenous injection of prostaglandin. The treatment was started between 6 h and 6 days after the onset of CRAO.

A single flash ERG to a flash stimulus of 40 J of energy from a xenon lamp held 10 cm above the corneal plane was recorded after 20 min of dark adaptation before and during treatment. The ERG was recorded from a corneal contact electrode that was referred to the electrode placed at the earlobe. The response was amplified with a preamplifier which had an electric filter that was set between 1.5 and 300 Hz (Nihon Kohden VC-9, Tokyo), and was registered with an X-Y recorder (Rikadenki, Tokyo). For ERG evaluation, the a- and b-wave amplitudes and the b-wave/a-wave amplitude ratio were analyzed. The b-wave amplitude was calculated from the a-wave trough to the b-wave peak, and the a-wave amplitude was measured from the baseline to the a-wave trough. As a control, the unaffected fellow eye of each patient was used. Informed consent was obtained from all patients before their admittance to the study.

Results

Visual Acuity

The relationship between visual acuity before and after treatment is shown in figure 1. Of 15 patients, 9 patients (60%) showed improved visual acuity after treatment, 4 were unchanged and 2 had decreased vision.

Figure 2 shows the relationship between visual acuity after treatment and the duration from the onset of the disease to the start of treatment. The earlier the treatment began the more improved was the visual acuity. One exception was a patient who had a visual acuity before treatment of hand movement. His visual acuity dropped to no light perception even though treatment was started within 3 h after the onset of CRAO.

ERGs

Before treatment, no significant difference was found in the a-wave amplitude between affected eyes and unaffected fellow eyes, although significant attenuation was found in the b-waves of the affected eyes (p < 0.01) (fig. 3a, b). The b-wave/a-wave ratio was 0.73 ± 0.04 (mean ± SE) in the affected eye.
Fig. 1. Relationship between visual acuity before and after treatment in patients with CRAO. NLP = No light perception; LP = light perception; HM = hand movement; CF = counting fingers.

Fig. 2. Relationship between visual acuity after treatment and time from onset to treatment. Abbreviations as defined for figure 1.

Fig. 3. The mean ± SE of a-wave (a) and b-wave (b) amplitudes in eyes with CRAO and nonaffected fellow eyes from 15 patients (n = 15).
Fig. 4. The mean ± SE of b-wave/a-wave amplitude ratios of the ERG in the eyes with CRAO and fellow eyes from 15 patients (n = 15).

Fig. 5. The mean ± SE of b-wave/a-wave amplitude ratios in patients with CRAO whose visual acuity had not improved or had worsened and in those who had improved visual acuity (n = 15).

Fig. 6. Relationship between the b-wave/a-wave amplitude ratio and visual acuity before treatment in patients with improved visual acuity ( devised as described for figure 1.

The b-wave/a-wave ratio was plotted against visual acuity before treatment in patients with improved visual acuity and in those with unimproved or worse visual acuity (fig. 6).
Discussion

Karpe's report [1] of a highly attenuated b-wave of the ERG in a few patients with CRAO was further confirmed by Henkes [2] in 21 patients with CRAO. Since the ERG recordings were evoked with a low stimulus intensity that could elicit only extremely small a-waves, the quantitative evaluation was done only in the b-wave amplitude. When compared with the a-wave amplitude, the b-wave amplitude was expressed as "high", "super", or "small". Consequently, the characteristic waveform changes were referred to as negative ERG, that is, a small b-wave with a large or pronounced a-wave. Henkes further termed the ERG as a negative minus response to differentiate it from the negative plus response, which is a large b-wave with a large a-wave. Later studies [6, 7] with the use of a much higher stimulus intensity showed a clearly measurable a-wave. The term negative has been used in other ways, characterizing the ERG with the b-wave lower than baseline value as being obviously smaller than the a-wave amplitude. Such a negative ERG is found not only in patients with CRAO, but also in patients with retinoschisis [9, 10], congenital nightblindness, [11, 12] and Oguchi's disease [13, 14]. On the other hand, in patients with central retinal vein occlusion, several authors [8, 15–18] have tried to evaluate the attenuation of the b-wave amplitude/a-wave amplitude ratio. The negative ERGs recently demonstrated may mean that the ratio is less than 1.0.

All of our 15 patients with CRAO had a b-wave/a-wave amplitude ratio that was less than 1.0 where the a-wave was no different from the control eye. Only the attenuation of the b-wave was significant. The reduced ratio before treatment was significantly lower in patients with improved visual acuity after treatment. Patients' recovery on ERG correspond-

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**Fig. 7.** The mean b-wave/a-wave amplitude ratios in patients with CRAO who had improved visual acuity (n = 5) (a) and in those with unimproved or worse visual acuity (n = 4) (b) before and after treatment.

The mean b-wave/a-wave ratio increased significantly (p < 0.05) after treatment in the patients with improved visual acuity, while no significant changes were found in those with unimproved visual acuity (fig. 7a, b).
ed well with subjective visual acuity after
treatment, although the ratio remained less
than 1.0. It was thus speculated that damage to
the inner retinal layer, where the b-wave is
predominant, is reversible to some extent,
even when the inner retinal circulation has
been found by ophthalmoscopy and fluores-
ccein angiography to be disturbed.

It is noteworthy that the prognosis for
CRAO is better than it has been. When our
patients were treated within 12 h after the on-
set of CRAO, the outcome of visual recovery
was excellent for all, except the 1 patient
whose visual acuity was hand movement at the
onset.

The degree of pathological changes of
CRAO cannot be assured with clinical exami-
nations. Therefore, ERG findings based on
the b-wave/a-wave amplitude ratio currently
may be the only way to demonstrate the sever-
ity of the circulatory disturbance of the inner
retinal layers.

Acknowledgment

The editing assistance of Ms. Maxine Gere is grate-
fully acknowledged.

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