Near-infrared Spectroscopy of the Visual Cortex in Unilateral Optic Neuritis

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Near-infrared spectroscopy (NIRS) is an optical method to assess dynamic changes in the hemoglobin concentration evoked by brain activity [1-4]. We applied this technique to five patients with unilateral optic neuritis and investigated whether or not NIRS could detect visual dysfunction objectively in clinically affected eyes.

Six healthy volunteers (one man and five women, age 25-39 years) with normal vision and five patients with acute unilateral optic neuritis (two men and three women, age 13-56 years) were examined. Informed consent was obtained from each subject or patient. This study was carried out with approval from the Institutional Review Board of the National Saigata Hospital. In Patient 1, NIRS was measured twice--when the visual acuity in the right eye was 20/200 and 20/40. In Patient 2, NIRS was measured three times--when the visual acuity in the right eye was 20/200, 20/40, and 20/20. The other three patients were tested only once.

We used an OM-100A (Shimadzu Corporation, Kyoto, Japan) near-infrared spectroscopy system, with wavelengths at 780, 805, and 830 nm, to monitor changes in the oxyhemoglobin (oxy-Hb), deoxyhemoglobin (deoxy-Hb), and total hemoglobin (total-Hb) concentrations in the occipital lobe, respectively. The inter-optode distance

was approximately 3 cm. The algorithm for calculating the hemoglobin concentration has been described elsewhere [5].

Light-proof goggles (S10VS, Grass Instruments, Quincy, MA), flashing at a frequency of 8 Hz, were placed over the subjects' eyes to provide monocular visual stimulation. Each condition lasted for 30 seconds, and a pair of two conditions was repeated six times for each experiment. A Macintosh-based program, Macstim (David Darby, West Melbourne, Australia), was used to turn the visual stimulation on or off.

For statistical analysis, t-tests were performed on each subject between the mean values during the two conditions (the right-eye stimulation versus the resting condition, for instance) using SigmaStat (SPSS, Inc., Chicago, IL). $P<0.05$ was considered to be statistically significant.

In all six normal subjects, an increase in [oxy-Hb], a decrease in [deoxy-Hb], and an increase in [total-Hb] were observed following monocular visual stimulation. In these control subjects, there were no significant differences in activation between the right and left eyes (data not shown). Figure 1 shows representative NIRS time course plots of a normal subject.

In all the studies of the patients with unilateral optic neuritis, a significant reduction in activation during the stimulation of the affected eye was observed as compared with the response measured from the fellow eye (Figure 2A). A significant activation of the visual cortex was detected when the fellow eyes were stimulated in all patients (data not shown). The reduced response from the affected eye was also observed even when the subject's visual acuity in the affected eye recovered to 20/20 (Figure 2B).

The prominent advantage of NIRS over other methods to assess visual function objectively is that it can easily be performed at the bedside, making it especially useful for patients with limited mobility. In addition, NIRS requires little cooperation from the subjects. There is no known health risk from NIRS.

Our results demonstrate that a decreased activation of the visual cortex in patients with optic neuritis can be demonstrated when NIRS is used. We are unaware of any previous reports of NIRS in the field of ophthalmology. Although the sensitivity of this method remains to be studied, NIRS may well be a promising method by which to detect visual dysfunction in patients with visual deficits both objectively and noninvasively.

References

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Figure Legends

Figure 1. A normal subject. Changes in the hemoglobin concentrations ([oxy-Hb], [deoxy-Hb], and [total-Hb]) of the visual cortex in response to the stimulation of the right eye ("R") are given in arbitrary units. The horizontal axis indicates the time (seconds). "O" indicates the resting period. A consistent response, consisting of an increase in [oxy-Hb], a decrease in [deoxy-Hb], and a small increase in [total-Hb] during monocular visual stimulation of the right eye, delayed by around 10 seconds, is observed throughout the experiment.

Figure 2A. Patient 1 (optic neuritis OD). This 23-year-old woman was found to have decreased visual acuity, a relative afferent papillary defect, a central scotoma and a superior altitudinal field defect, and disk swelling in the right eye. "R" and "L" denote the periods of the stimulation of the right and left eyes, respectively. The response was substantially decreased with the stimulation of the affected right eye. At the time of the study, the visual acuity was 20/200 in the right eye.

Figure 2B. Patient 2 (optic neuritis OD). This 38-year-old man was found to have decreased visual acuity in the right eye with a central scotoma. A diagnosis of

optic neuritis was confirmed by the presence of a right relative afferent papillary defect and a slightly swollen right optic disk. Even after recovery (the visual acuity OD was 20/20 at the time of this study), there remains a significant difference in the monocular activation of the visual cortex between the two eyes (i.e., there is a reduced response during the stimulation of the affected right eye).