Yonago Acta medica 2004;47:71–79

Assessment of Macular Function by Multifocal Electroretinography and Optical Coherence Tomography before and after Panretinal Photocoagulation in Diabetic Retinopathy

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We evaluated macular function before and after panretinal photocoagulation (PRP) in diabetic retinopathy using a multifocal electroretinogram (mfERG) and optical coherence tomogram (OCT). In mfERGs, the 1st positive wave (P1) minus the 1st negative wave (N1) amplitude (P1 – N1 amplitude), the P1 peak latency and the response density were measured in 7, 19, 37 and 103 hexagonal areas or elements (Areas 1, 2, 3 and 4) within a central radius of 5, 7, 10 and 20 degrees, respectively. The mean retinal thickness was estimated from 9 calculation points at the foveal region within 5 degrees; the central and each of the other 4 points at a distance of 250 μm and 500 μm from the central portion on horizontal and vertical sections on OCT. The P1 peak latencies from the 4 areas were remarkably prolonged in 14 eyes of 9 patients with preproliferative or early proliferative diabetic retinopathy showing no clinically significant macular edema before PRP as compared with those in 15 normal control eyes, without a tendency of recovery throughout the course after PRP except for area 1. The P1-N1 amplitudes and the mean response density levels from the 4 areas were remarkably decreased in the diabetic eyes before PRP as compared with those in the control eyes, followed by a maximum decrease in both parameters at 3 months after PRP. However, remarkable recoveries were detected in both decreased parameters from the 4 areas at 6 months after PRP. The mean foveal retinal thickness on OCT was remarkably increased in the diabetic eyes before PRP as compared with the thickness in 16 normal control eyes. Most remarkably, a transient increase in thickness was detected in diabetic eyes 1 month after PRP, followed by a tendency of recovery 3 to 6 months after PRP. These results indicate that mfERG and OCT examinations are useful in the assessment of macular function before and after PRP in diabetic retinopathy, especially within 5 degrees of the central portion, and that the effects of PRP on macular function in this entity seem to be reversible at the foveal region, although we need to do further investigation in relation to the outcome of visual acuity.

Key words: diabetic retinopathy; macular function; multifocal electroretinogram; optical coherence tomogram; panretinal photocoagulation

List of Abbreviations, p. 72.

Panretinal photocoagulation (PRP) is a beneficial procedure for the treatment of preproliferative or early proliferative diabetic retinopathy (Diabetic Retinopathy Study Research Group, 1981; Early Treatment Diabetic Retinopathy Study Research Group, 1991), even though vitrectomy has been performed in many patients with severe and complicated diabetic lesions (Lewis et al., 1992; Massin et al., 2003). On that occasion, the assessment of macular function is very important for predicting the patients' quality of vision after PRP. Several reports showed various changes in retinal sensitivity after PRP in this entity, using mostly the Goldmann kinetic perimeter (Frank, 1975), the computed static perimeter (Chee and Flanagan, 1993; Yoon et al., 1996) and the electroretinogram (ERG) (Frank, 1975; Bresnick and Palta, 1987).

Using an optical coherence tomogram (OCT), Hee and his co-workers (1995, 1998) and Kang and others (2004) quantified foveal retinal thickness correlated with visual acuity in patients with clinically significant diabetic macular edema. Recently, Palmowski and others (1997) and Fortune and others (1999) revealed local retinal dysfunction in the macular area in diabetic patients, with and without retinopathy, using a multifocal electroretinogram (mfERG) (Sutter and Tran, 1992). In general, morphological changes in the retina are assessed by OCT examination because optical coherence tomography offers high-resolution, cross-sectional images of the retina and quantitative measurement of retinal thickness (Hee et al., 1995, 1998; Kang et al., 2004), while topical functional changes in the retinal layer are assessed with mfERG examination, using a multifocal technique (Sutter and Tran, 1992; Palmowski et al., 1997; Fortune et al., 1999).

These tests allow a relatively fast, objective evaluation of retinal function in their images and patterns in contrast to subjective perimetric examinations such as the Goldmann kinetic perimeter (Frank, 1975) and the computed static perimeter (Chee and Flanagan, 1993; Yoon et al., 1996). However, little attention has been paid to the assessment of macular function by mfERG and OCT examinations before and after PRP in diabetic patients with retinopathy. We therefore evaluated macular function before and after PRP in diabetic retinopathy by multifocal electroretinography and optical coherence tomography in this survey.

Subjects and Methods

Nine patients (14 eyes) with preproliferative or early proliferative diabetic retinopathy showing no clinically significant macular edema were referred to us for this study. Their ages ranged from 51 to 77 years averaging 61.2 ± 8.6 years (SD). The mean corrected visual acuity of the 14 diabetic eyes before PRP was 0.87 ± 0.37 (SD), followed by 0.80 ± 0.37, 0.76 ± 0.33 and 0.84 ± 0.38 at 1, 3 and 6 months after PRP, respectively. They were examined using a VERIS Science System for the mfERG (Mayo Corp., Nagoya, Japan) and a Humphrey OCT scanner (Carl Zeiss Co., Ltd., Tokyo, Japan) before PRP and at 1, 3 and 6 months after the procedure, as described later.

Fourteen healthy volunteers (15 normal eyes) aged 51.1 ± 13.1 years (SD) on the average served as controls for the VERIS study, and 12 healthy volunteers (16 normal eyes) aged 66.1 ± 12.5 years (SD) on an average served as controls for the OCT study in the present estimation. These healthy volunteers were randomly divided into either study group.

The diabetic patients were randomly chosen for the present survey over the past 4 years (August 1996 to September 2000) at the Department of Ophthalmology, Tottori University Hospital. The tenets of the Declaration of Helsinki were followed. Upon giving informed consent, all subjects including volunteers participated in the present study. Error of refraction did not exceed ± 3 diopters in the diabetics or normal controls. Eyes with clouding of the media or subjected to previous surgery were excluded from the analysis.

Abbreviations: ERG, electroretinogram; ETDRS, Early Treatment Diabetic Retinopathy Study; mfERG, multifocal electroretinogram; N1, 1st negative wave; OCT, optical coherence tomogram; P1, 1st positive wave; PRP, panretinal photocoagulation

PRP procedure

Treatment with PRP on the diabetic patients was performed according to the Early Treatment Diabetic Retinopathy Study (ETDRS) protocol (Diabetic Retinopathy Study Research Group, 1981; Early Treatment Diabetic Retinopathy Study Research Group, 1991). All patients underwent PRP in 2 sittings 1 week apart, lower hemifield followed by upper hemifield. Photocoagulation covered the entire mid periphery beyond the equator, and posteriorly to the area bordered by the temporal vascular arcades, nasal disc border and 2-disc diameter temporal to the fovea. All eyes were treated with either a green argon laser (Coherent Inc., Palo Alto, CA) or a dye laser (Biophysic Medical Ins., Clermont-Ferrand, Cedex, France). Approximately 1,000 to 2,000 burns of a 200 to 500 μm spot size were made 1 to 2 burn spaces apart through a 3-mirror universal lens (Ocular Instruments Inc., Bellevne, WA) or a double aspheric lens Trans Equator or Quadr Aspheric (Volk Optical Inc., Mentor, OH).

mfERG examination

The VERIS Science System, which is a visual evoked response imaging system originally developed by Sutter and Tran (1992), was used for the mfERG recording. The mfERG stimulus matrix consisted of 103 concentrically scaled hexagons, which covered the fundus area within a central radius of 20 degrees (Fig. 1). Alternated color changes were set in each hexagon between black and white in binary m-sequences at a rate of 75 Hz. Luminance levels ranged from 5 to 200 cd/m^2. A Burian-Allen bipolar contact lens electrode was used for signal derivation. A grounding electrode was attached to either earlobe, a routine procedure. The pupil of one eye was fully dilated with 2.5% phenylephrine hydrochloride, and the other eye was occluded. The net recording time for each eye was 4 min. The entire procedure was divided into eight 30-s segments. The signals were amplified using the VERIS Science System with bandpass filters (10–300 Hz).

As demonstrated in Fig. 2, in the response arrays of the mfERG consisting of the mean focal flash response (Fig. 2a), the 1st positive wave of each mean focal flash response (P1) minus the 1st negative wave of each response (N1) amplitude (P1 – N1 amplitude) in μV and the P1 peak latency in ms were measured as mfERG parameters in 7, 19, 37 and 103 hexagonal areas or elements (Areas 1, 2, 3 and 4; 4 mfERG areas) within a central radius of 5, 7, 10 and 20 degrees, respectively (Fig. 1). Three-dimensional topography revealed the re-

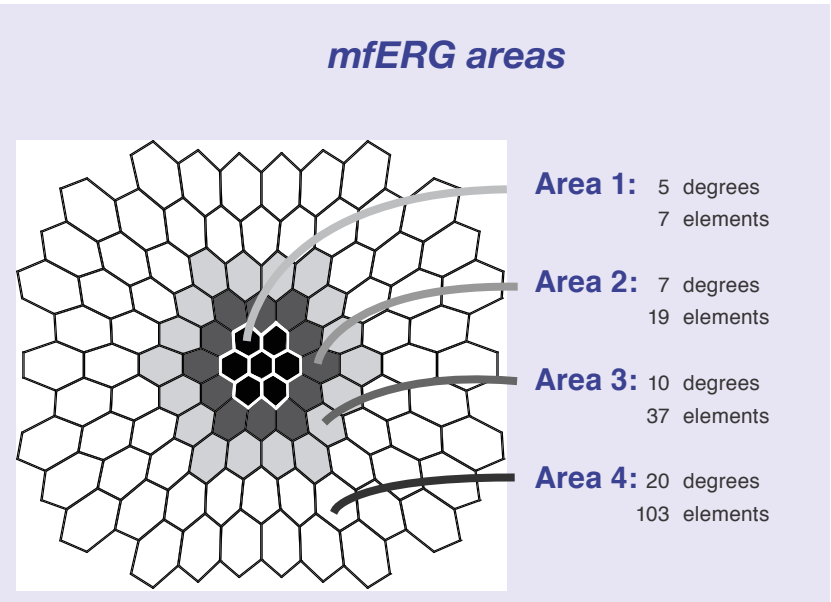

Fig. 1. The multifocal electroretinogram (mfERG) stimulus matrix consisting of 103 concentrically scaled hexagons. The matrix was divided into 7, 19, 37 and 103 hexagonal areas or elements (Areas 1, 2, 3 and 4; 4 mfERG areas) within a central radius of 5, 7, 10 and 20 degrees, respectively.