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Variation of temporal stimulus characteristics to evaluate visual function prior to pars plana vitrectomy

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Abstract. Electrophysiological examinations were carried out prior to pars plana vitrectomy in a series of consecutive patients with complicated diabetic retinopathy, proliferative vitreoretinopathy, and perforating injuries. In 141 eyes electroretinograms were evaluated. The amplitude of the a- and b-waves at dark and light adaptation and of the 30-Hz flicker response correlated with the postoperative visual acuity and the retinal morphology. Due to the variability of these parameters, however, the preoperative electroretinogram has no predictive value. In 245 eyes, flash and flicker (5, 10, 20, 30 Hz) visual evoked cortical potentials (VECP) were recorded. The flash VECP was of no value. The presence of a response to a flicker stimulus of 10 Hz or higher frequencies, however, indicated a better functional recovery ($P<0.02$). More eyes with an attached central retina showed a 30-Hz flicker response as compared to eyes with central retinal detachment ($P<0.01$). The flicker VECP, therefore, has a predictive value prior to vitrectomy.

Zusammenfassung. In einer konsekutiven Serie von Patienten mit komplizierter diabetischer Retinopathie, proliferativer Vitreoretinopathie und perforierenden Verletzungen wurden elektrophysiologische Untersuchungen vor einer Pars-plana Vitrektomie durchgeführt. Von 141 Augen wurde das Elektroretinogramm ausgewertet. Die Amplituden der A- und B-Wellen bei Dunkel- und Helladaptation sowie die 30-Hz-Flimmerlichtantwort korrelierten mit dem postoperativen Visus und der Netzhautsituation. Aufgrund der hohen Variabilität dieser Parameter hatte das präoperative Elektroretinogramm jedoch keinen Vorhersagewert für die postoperative Funktion. Bei 245 Augen wurden mit Einzelblitz und Flimmerlicht (5, 10, 20, 30 Hz) visuell evozierte kortikale Potentiale (VECP) abgeleitet. Das Einzelblitz-VECP war ohne Aussagekraft. Das Vorhandensein einer 10-Hz-Flimmerlichtantwort wies auf eine bessere Funktionserholung hin ($P<0{,}02$). Verglichen mit Augen mit zentraler Netzhautablösung hatten Augen mit zentral anliegender Netzhaut häufiger eine nachweisbare 30 Hz Flimmerlichtantwort ($P<0{,}01$). Das Flimmerlicht-VECP ist daher für die Funktionsbeurteilung vor einer Vitrektomie hilfreich.

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Introduction

Progress of microsurgical techniques in vitreoretinal surgery recently led to an increased number of successful operations, even in very difficult cases of proliferative vitreoretinopathy, perforating injuries, and diabetic tractional detachments. These sophisticated techniques are time-consuming, and in most cases, more than one operation is needed for final anatomical success. The anatomical success, however, is not always paralleled by the functional recovery. Especially diabetic patients with longstanding disease and, e.g., renal dysfunction or other generalized diseases have an increased risk for complications after surgery. Confronted with the necessity of several operations, the patient and the surgeon are interested in knowing to which extent functional recovery may be expected after successful surgery.

Subjective methods such as determination of visual acuity, light projection, and entoptic phenomena are not contributory factors [13]. There are several papers concerning the usefulness of electrophysiological examinations [1, 3–6, 8–10, 16–21], but the predictive value of these examinations in a given patient are discussed controversially. Except for our laboratory [3, 11], flicker stimuli for the determination of visual evoked cortical potentials (VECP) are used only by a few investigators [4, 8, 9, 22, 23], and larger series have been reported only by Fuller and Hutton [4, 9]. In the present study we evaluated the functional outcome in a large number of consecutive vitrectomy patients as compared with either bright-flash and flicker electroretinograms (ERGs) or flash and flicker visual evoked cortical potentials (VECP) or both.

Patients and methods

Electrophysiological methods

Our electrophysiological methods have been described elsewhere [11, 12]. They were carried out according to international standards [15]. In short, they are described as follows. After 40 min dark adaptation and with maximal possible dilation of the pupil (2.5% phenylephrine and 0.5% tropicamide), the ERGs were recorded in a dark environment. The stimulus duration was 10 ms. Six different light intensities (1–6) increasing by 1 logarithmic unit from the b-wave threshold of the normal eye were used for the dark-adapted recordings. The maximal light intensity was 7.8 cd s m^{-2}. The light-adapted recordings were performed under white light adaptation with 4.5 cd/m^2 and with the light stimuli 4–6. The 30-Hz flicker stimulus had the light intensity 5. White light from a filtered xenon light source served as the stimulus in all examinations. The potentials were displayed on an oscilloscope, recorded on a paper writer, and stored digitally for later workup on a computer disc. No computer averaging was used. In our evaluation we measured the a- and b-wave amplitudes in the dark- and light-adapted states at maximal stimulus intensity and the amplitude of the 30-Hz flicker response. The normal values are given in Table 1.

The VECP examinations were performed on individuals with dilated pupils. The electrodes were placed at the vertex position (Cz) and 2 cm above the inion (Oz). The ear served as the reference ground. A 100-D contact lens gave uniform retinal illumination. The light stimuli were of 10 ms duration and the light intensity was 7.8 cd s m^{-2}. Single flash stimuli were used first, followed by flicker stimuli with the frequencies of 5, 10, 20, and 30 Hz (Fig. 1). In all, 64 responses were averaged at every frequency.

We measured the amplitude of the flash evoked cortical potential and the implicit time of the P100 component. The amplitudes of the flicker evoked cortical potentials were determined, and we estimated the highest positive frequency response. Our normal amplitude values for flash and flicker evoked cortical potentials are shown in Table 2. The high interindividual variance of the amplitudes of the flicker evoked cortical potentials results in a wide normal range. Stimulus frequencies above 30 Hz were not analyzed because the normal responses have a mean amplitude of less than 5 μV.

Patients

Included in the study were patients undergoing vitrectomy between January 1, 1984, and December 31, 1989. Inclusion criteria were vitrectomy in complicated cases of proliferative diabetic retinopathy, proliferative vitreoretinopathy, and perforating injuries; e.g., patients with proliferative diabetic retinopathy and a hemorrhage of short duration with echographically clearly attached retina were not considered as complicated. The electrophysiological examination was done in most cases within 1 week before surgery and not longer than 2 months before surgery. The follow-up period was at least 6 months. Exclusion criteria were no anatomical success on discharge and conditions that gave no possibility to test the visual acuity postoperatively, such as early retinal redetachment, severe secondary glaucoma, and persistent vitreous hemorrhage.

In all, 141 patients (proliferative diabetic retinopathy, 108 eyes; proliferative vitreoretinopathy, 19 eyes; perforating injuries, 14 eyes) were included in the ERG group and 245 patients (proliferative diabetic retinopathy, 165 eyes; proliferative vitreoretinopathy, 46 eyes; perforating injuries, 34 eyes), in the VECP group. ERGs were recorded during the first 3 years of the study; they were later discontinued because they appeared to be of minimal value for surgical decisions. For the evaluation of functional recovery, the best postoperative visual acuity was compared with the immediate preoperative visual acuity. The χ^2 test was used for statistical evaluation. Because most patients suffered from proliferative diabetic retinopathy, the groups were too small for a comparison of the measured parameters between different diseases.

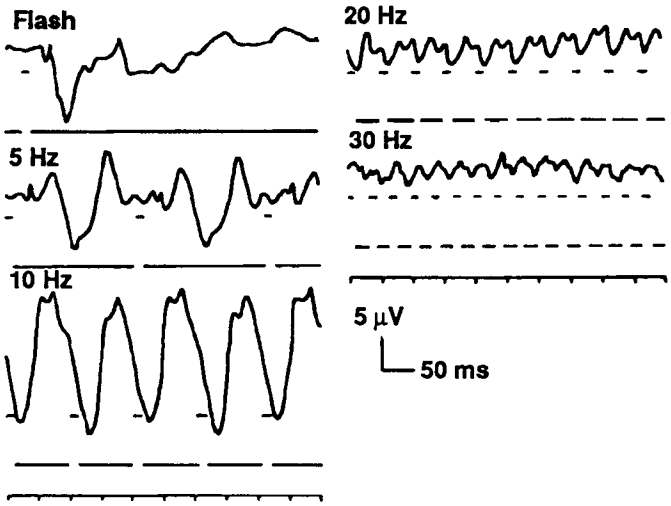

Fig. 1. Normal VECP responses to flash and flicker stimuli of up to 30 Hz

Table 1. ERG amplitudes in normals and patients

Response	Normals [$\bar{x} \pm s$ (μV)]	Patient [$\bar{x} \pm s$ (μV)]
Dark-adapted:		
A-wave	320±48	125± 90
B-wave	408±52	149±106
Light-adapted:		
A-wave	113±24	60±40
B-wave	106±26	54±35
30-Hz flicker	136±26	24±30

Table 2. VECP amplitudes in normals and patients

Stimulus frequency (Hz)	Normals [$\bar{x} \pm s$ (μV)]	Patients [$\bar{x} \pm s$ (μV)]
Single flash	22 ±8	7.7±4.5
5	17 ±4	6.1±3.9
10	17 ±5	6.1±4.1
20	8 ±2.5	2.8±2.7
30	6 ±3	1.3±2.1
40	3.2±1.5	
50	1.5±1	

Results

Visual acuity

Visual acuity as tested preoperatively had no predictive value for the functional outcome except in eyes with a very good preoperative visual acuity. In eyes with a preoperative visual acuity of ≤ 0.05, there was no correlation between pre- and postoperative visual function.

Electroretinography

In 141 eyes ERGs were recorded preoperatively. The mean visual acuity in those eyes was 0.01, and it im-

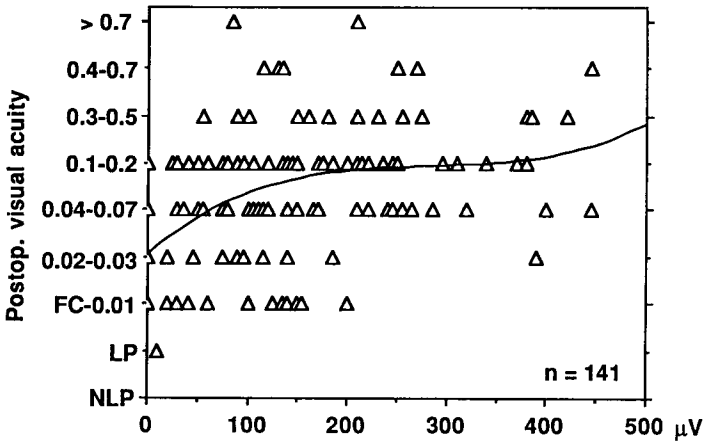

Fig. 2. B-wave amplitude at dark adaptation as correlated with the best postoperative (*Postop.*) visual acuity in 8 groups. The mean visual acuity increases with higher b-wave amplitudes, but the range is very broad. *FC*, Finger counting; *LP*, light perception or projection; *NLP*, no light perception

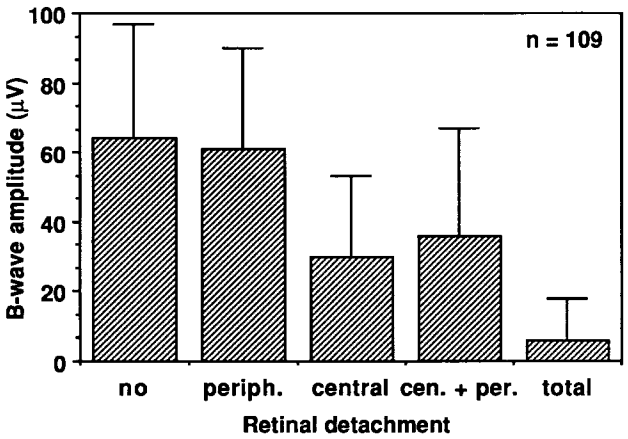

Fig. 3. B-wave amplitude at light adaptation and central retinal morphology. The normal value is 106 ± 26 μV. The b-wave amplitude is significantly more reduced when the central retina is detached and is nearly unrecordable in total retinal detachment. *periph.*, Peripheral; *cen.*, central

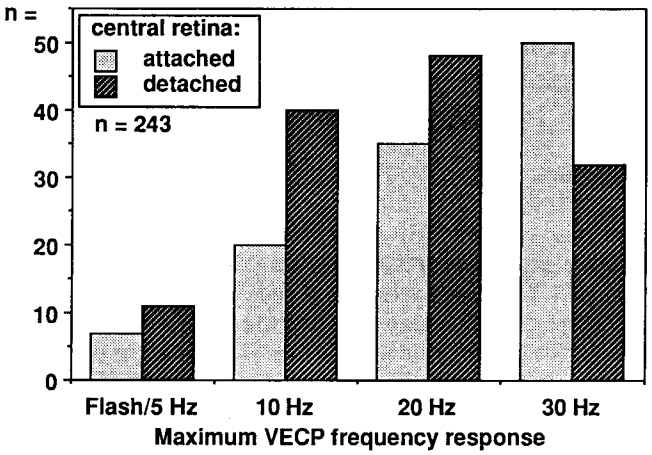

Fig. 4. Maximal flicker VECP frequency response and central retinal morphology. Patients with an attached central retina showed significantly more often a recordable 30-Hz flicker response

Table 3. VECP groups and postoperative mean visual acuity

Maximal frequency	*n*	Mean visual acuity
Single flash/5 Hz	18	0.03
10 Hz	61	0.08
20 Hz	84	0.1
30 Hz	82	0.16

proved to a mean postoperative visual acuity of 0.07 at the best. The amplitude values are given in Table 1. The dark-adapted responses were reduced to one-third of the normal values and the light-adapted responses, to one-half of normal. The largest amplitude reduction was found in the 30-Hz flicker response. The correlation between amplitude and postoperative visual acuity is given for the b-wave at dark adaptation in Fig. 2. Apparently there is a correlation between ERG amplitude and postoperative visual function in this as well as all other tested parameters. However, the range is extremely large. Therefore, the amplitudes of all tested ERG parameters have no predictive value in a single case.

We found significant differences in ERG amplitudes between eyes with an attached versus a detached central retina (Fig. 3). The b-wave amplitude at light adaptation was reduced to about 60% in eyes with attached central retina and was severely reduced in central retinal detachment to about 30 μV. In total retinal detachment a reduction to about 10 μV was seen. These differences are not useful for clinical application because of the variability. Combining all of the five measured parameters gave no additional information.

Visual evoked cortical potentials

The mean visual acuity in the 245 eyes with VECP recording was 0.02 preoperatively and 0.11 postoperatively. The amplitude values are given in Table 2. The amplitudes were reduced to about one-third under all recording conditions. Table 3 shows the mean visual acuity for the different groups of maximal recordable VECP frequencies. Patients who showed a response only to a flash stimulus or a 5-Hz flicker stimulus had a mean visual acuity of 0.03. With increasing maximal VECP frequency response, the mean visual acuity increased up to 0.16 for eyes showing a 30-Hz flicker response. Preoperatively, no difference in visual acuity was noted between these groups. The mean visual acuity was significantly better in eyes showing a response to a flicker stimulus of 10 Hz or higher frequencies as compared with eyes with a missing 10-Hz response ($P < 0.02$).

Fundus visibility was good in 83 patients and was missing in 75 patients. Although patients with a good fundus visibility had a better preoperative visual acuity, there was no difference between the two groups in either preoperative VECP findings or postoperative visual function. The VECP is independent of media opacities. In all, 131 patients had a central retinal detachment and 112 patients had an attached central retina. The 30-Hz flicker

response was more frequently recordable in the group with an attached central retina (45%) than in the other group (24%, $P<0.01$; Fig. 4).

Discussion

The usual preoperative functional evaluation gives no reliable data for predicting the possible postoperative function. Electrophysiological methods allow the physician to test the function of the retina and the transmission properties of the optic nerve objectively, even in opacified media. Several investigators tried to correlate preoperative electrophysiological findings with the postoperative functional development [1, 3, 4, 8–10, 16–21]. The methods used and the patients examined were very variable and the conclusions drawn were therefore controversial.

Our ERG findings showed a correlation with the functional properties of the retina. They depended on retinal morphology. The amplitudes were larger when the central retina was attached. The variability, however, was too large to allow the use of any tested ERG parameter or combination as a predictor of postoperative function in a single case. In conformity with our results, Algvere et al. [1] described a high variability of the ERG.

The overall small contribution of the macular retina to the ERG explains the minor value of the preoperative ERG. The morphology and function of the macular area will determine the visual acuity. After excessive pretreatment with laser and cryocoagulation, the ERG may be severely reduced, but the macular area can be well preserved. A long-term reduction in the 30-Hz flicker amplitude of up to 67% following moderate laser treatment has been described [14]. On the other hand, a normal peripheral retina with a central scar or macular edema limits the recovery of visual acuity. A detached retina with a missing ERG has the potential for functional recovery after reattachment. Focal ERGs would test the macular function more appropriately, but their use is impossible in media opacities.

Many investigators use flash evoked visual cortical potentials for the examination of the optic nerve. A missing flash VECP is a contraindication for surgical treatment [9]. Borda [2] and Halliday et al. [7] rated the flash VECP as not very useful because of its large interindividual variability and because of the occurrence of normal flash VECP responses despite severe optic nerve dysfunction. Scherfig et al. [19–21] found a lower postoperative visual acuity in patients showing delayed latencies in the flash VECP. However, an analysis of their data [19] shows that one-third of their patients with "delayed latency" had no measurable VECP at all. The majority of their successfully operated eyes with measurable VECP amplitude and delayed latency improved in visual acuity. On the other hand, Algvere et al. [1] found no prognostic value for amplitudes or latencies of the flash VECP.

Weinstein [23] noted the value of the different temporal stimulus properties and consequently introduced the flicker stimuli to the VECP. In small groups of patients, flicker VECPs were judged to be useful by Weinstein [23] and Huber and Knus [8]. Vadrevu et al. [22] found a good predictive value for the 10-Hz flicker response in diabetic eyes with vitreous hemorrhage. This result must be expected in eyes with less severe diabetic retinopathy. In that series of 44 eyes, only half of the eyes needed a vitrectomy and only 3 eyes had a retinal detachment [22]. In our series of more severe cases, the visual acuity was significantly better in the presence of a measurable VECP response to a 10-Hz flicker stimulus as compared with a missing 10-Hz flicker response. The difference between the higher frequencies was not convincing due to the variability of the results. However, a 30-Hz flicker response was more frequently recordable in eyes with an attached central retina.

The origin of the flicker evoked cortical potentials is not very well understood. The interpretation of clinical data therefore has to be done very cautiously. Higher flicker frequencies may be perceived in the peripheral retina than in the central retinal area. Therefore, frequencies higher than 30 Hz may be useless. In addition, the amplitudes at higher frequencies are very small (Table 2). The correlation between the 30-Hz flicker response and the attached central retina shows that the 30-Hz response is an indicator of macular function and of the transmission properties of the optic nerve. This observation is in contrast to the view of Fuller and Hutton [4]. They found the 10-Hz flicker response to correspond with the macular function and the 30-Hz flicker response to correspond with optic nerve function. No data were presented to support their opinion.

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