Artifact Removal Procedure Distorts Multifocal Electroretinogram

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Purpose: To study whether the Artifact Removal procedure available for eliminating artifacts in multifocal electroretinograms (mERG) works correctly or not.

Methods: A test response was made using a photo-diode circuit. mERGs were recorded from 3 well-trained normal subjects using the Veris III system, and were then analyzed by the procedure that is included in the Veris Science (Artifact Removal) software program. The stimuli consisted of densely arranged arrays of 103 or 37 hexagonal elements. It took a total of 8 minutes to obtain one mERG record, and 16 sessions were required to complete this record. The first-order as well as the second-order kernel response components were extracted by Veris Science software, and the Artifact Removal procedure was used for both components.

Results: The Artifact Removal procedure influenced both the test response on the center element as well as the neighboring traces just around the test response. After the repetitions of the Artifact Removal procedure, the shape of the test response changed considerably. Some of the traces of the second-order kernel response components elicited from a normal subject changed irregularly when the Artifact Removal procedure was repeatedly used. The noise increased at the first iteration of the Artifact Removal procedure.

Conclusion: This procedure has been considered useful for eliminating artifact distortion in mERG, but should be carefully checked by well-established testing methods before clinical use. **Jpn J Ophthalmol 2000;44:419–423** © 2000 Japanese Ophthalmological Society

Key Words: Artifact Removal procedure, electrophysiology, multifocal electroretinogram.

Introduction

Four years have passed since the Veris III system, which was developed for simultaneous recording of multiple focal electroretinograms in the posterior polar region of the fundus, was created.[1] It has been reported that second-order kernel response components of multifocal electroretinogram (mERG) reflect the function of the inner retinal layers.[2] However the second-order kernel response component is in general much smaller than the first-order kernel response component.[3] There are two kinds of software programs related to eliminating artifacts: Eliminate Artifact procedure and Artifact Removal procedure. The former is built into the Veris Clinic software, whereas the latter is the version-up program that is built into the Veris Science software program. The artifact elimination routine is the same in Veris Science and Veris Clinic. The Artifact Removal procedure can be repeated maximally three times: first, second, and third iterations.

Some papers,[1–5] dealing with mERG data processed by these procedure have been published. Since we could not obtain a reliable second-order kernel response component of mERG using the Veris III system without the Artifact Removal procedure, we have studied the second-order kernel response component in terms of the stimulus and recording parameters,[3,6] and the influence of the spatial averaging procedures.[7] Because we could

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never evaluate whether the algorithm of the Artifact Removal procedure is correct, we have never intended to use this procedure of mERG analysis.

First, the Artifact Removal procedure was checked by a test response that was produced using a photo-diode circuit and the Veris III system. Second, the first-order and the second-order kernel response components of mERG elicited from a well-trained normal subject were analyzed using the Artifact Removal procedure.

Materials and Methods

Multifocal electroretinograms were recorded using the Veris III system (Mayo, Nagoya). The old version of the operating software is Veris Clinic, and the new one is Veris Science (version 3.0.1). The standard stimuli displayed on a CRT monitor (Sony, Tokyo) consist of densely arranged arrays of 103 or 37 hexagonal elements (in 103-hexagon or 37-hexagon patterns). The size of the CRT monitor was 42° in height by 45° in width. A well-trained normal emmetropic male subject (27 years old) participated in this study after his informed consent was obtained. Each hexagonal element was independently altered between brightness and darkness according to a pseudo-random sequence mode (binary m-sequence) at a frequency of 75 Hz. The mean luminance was 91 cd/m^2 (L_{max} = 178 cd/m^2, L_{min} = 4 cd/m^2). The contrast was 96%. The pupils were fully dilated by topical instillations of 0.5% tropicamide and 0.5% phenylephrine hydrochloride solution.

Multifocal electroretinograms were recorded using a bipolar contact lens electrode after corneal anesthesia was induced with two drops of oxybuprocaine hydrochloride solution. One or more drops of artificial tear solution (sodium hyaluronate) were added before installing the contact lens electrode. A ground electrode was placed on the right earlobe. The subject was seated comfortably with his chin and forehead tightly fixed, wearing the bipolar contact lens electrode. He was asked to look monocularly and intensely at the fixation point in the center of the CRT monitor. His eye movement was strictly monitored during the experiment. If any eye movement was observed, the experimental session was discontinued. The distance between the tested eye and the CRT monitor was 32 cm. Signals were amplified using the model 12-4 Neurodata Acquisition System (Astro-Med, Grass Instrument Division, West Warwick, NJ, USA) and bandpass-filtered from 10 to 300 Hz. It took 8 minutes to obtain one mERG record, and 16 sessions were required to complete this record (for example, 30 seconds per session).

The test response was produced using a photodiode circuit (Figure 1) made by Mayo Corporation. The photo-diode was placed just in front of the central element only during the routine mERG stimulation. The electronic current of the photodiode changes according to the luminescence property of the CRT monitor. This current change is amplified and transformed into voltage. The sharp spike response is dulled by a band-pass filter (since the data-sampling rate of Veris III system is 1200 Hz = 75 mHz × 16, the input signal must be restricted below 600 Hz). A low-pass filter was used to remove the signals above 10 Hz. A high-pass filter was used for the purpose of preventing the signals from being saturated, and the signals below 1 Hz including the direct current were removed. This blunt response was input to the Veris III system. After detecting a

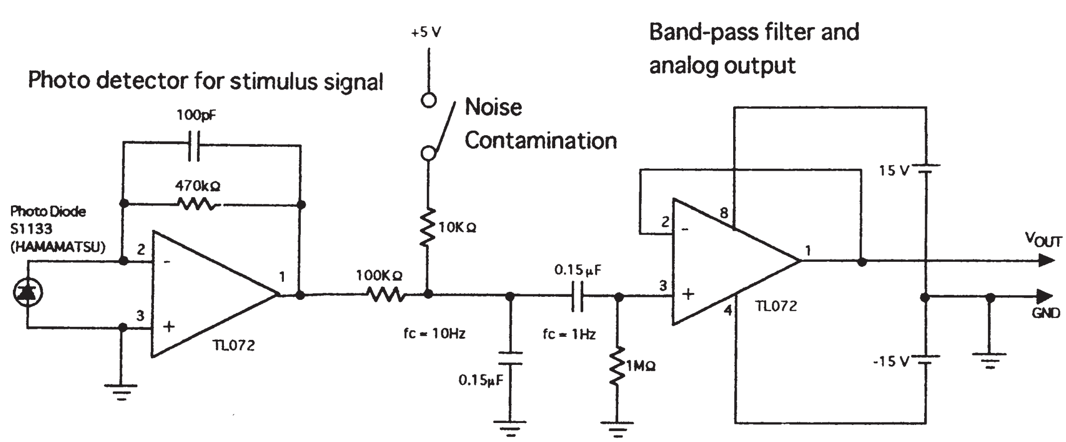

Figure 1. Photodiode circuit for producing a test response. GND: ground.

sharply rising positive response using the photodiode circuit, the Artifact Removal procedure was used. Mayo Corporation carried out the same experiment obtaining the same test response.

In order to study the effect of the Artifact Removal procedure on the human second-order kernel response component of mERG, the larger hexagonal pattern (37-hexagon) was selected to record larger second-order kernel response components.[6] The Artifact Removal procedure was repeated three times. The spatial averaging procedure was not used in this study.

Results

Using a photodiode circuit (Figure 1), large positive test responses were detected as shown in Figure 2. The test response, which was processed by the Artifact Removal procedure, was reduced and did not show a configuration similar to the original test response (Figure 4A). Small positive waves appeared on adjacent elements after the first Artifact Removal procedure. However, the adjacent small positive waves around the test response disappeared, and noisy components were recognized at the latter part of the test response at the second and third iterations of the Artifact Removal procedure. Our results and the data obtained in tests by the Mayo Corporation were carefully examined and found to be identical.

Multifocal electroretinograms elicited with 37-hexagon 37 patterns from a normal subject showed the noiseless first-order kernel response components (Figure 3A) and the smaller second-order kernel response components (Figure 3B). All traces were summed using the sum of area mode, which represents the total linear summation of 37 hexagon pattern in μ V (Table 1). As a whole, it seems that there is a tendency for the first-order kernel response components to be reduced at the second iterations of the Artifact Removal procedure, and in the case of the second-order kernel response components there may also be a reduction at the first iteration of the Artifact Removal procedure, as shown in Table 1. When we look minutely at the test responses and the trace array for each order kernel response component (Figure 4), as indicated by the arrowheads (Figure 3), these findings can be confirmed.

Discussion

Generally speaking, newly developed medical computer software-dependent equipment is not completely checked by clinical ophthalmologists before clinical application as to whether the software

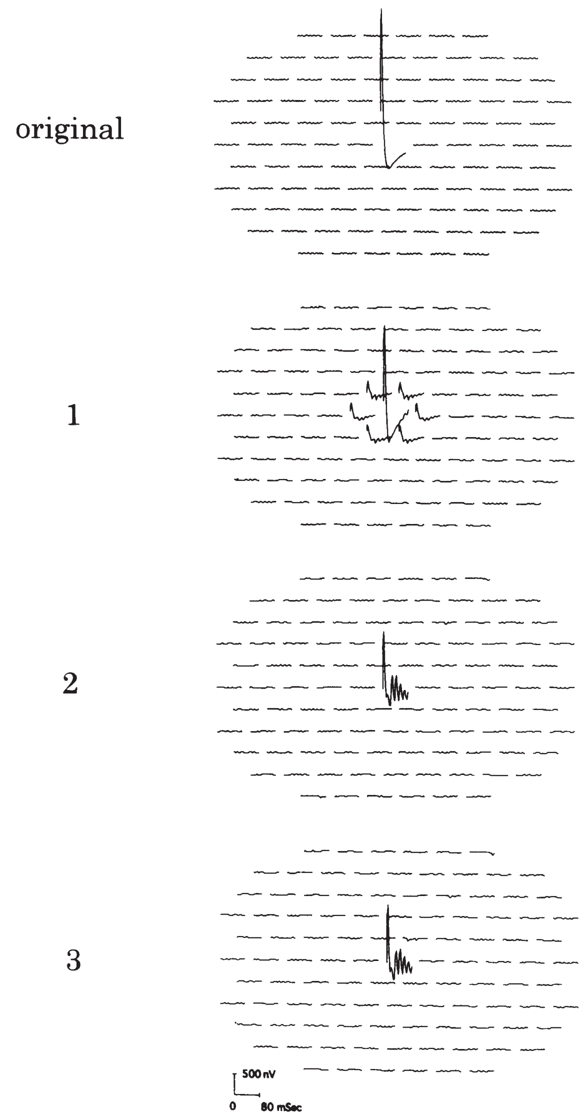

Figure 2. Effect of Artifact Removal procedure on original test response (top). Procedure was done once (1), twice (2), and three times (3) using 103 hexagon pattern.

and hardware components work correctly. Approximately 4 years have passed since the Veris III system was distributed throughout the world. Since we were never informed about the algorithm of both the Eliminate Artifact and the Artifact Removal procedures in detail, the present authors have never analyzed all the data that have been obtained using these procedures.[3,6–8] Recently, it has been recommended by the Mayo Corporation to use the Artifact Removal procedure for the analysis of mERG, as shown in Veris Quick Reference of the Veris instrument manual. This is why we have tried to check the Artifact Removal procedure now. We found that

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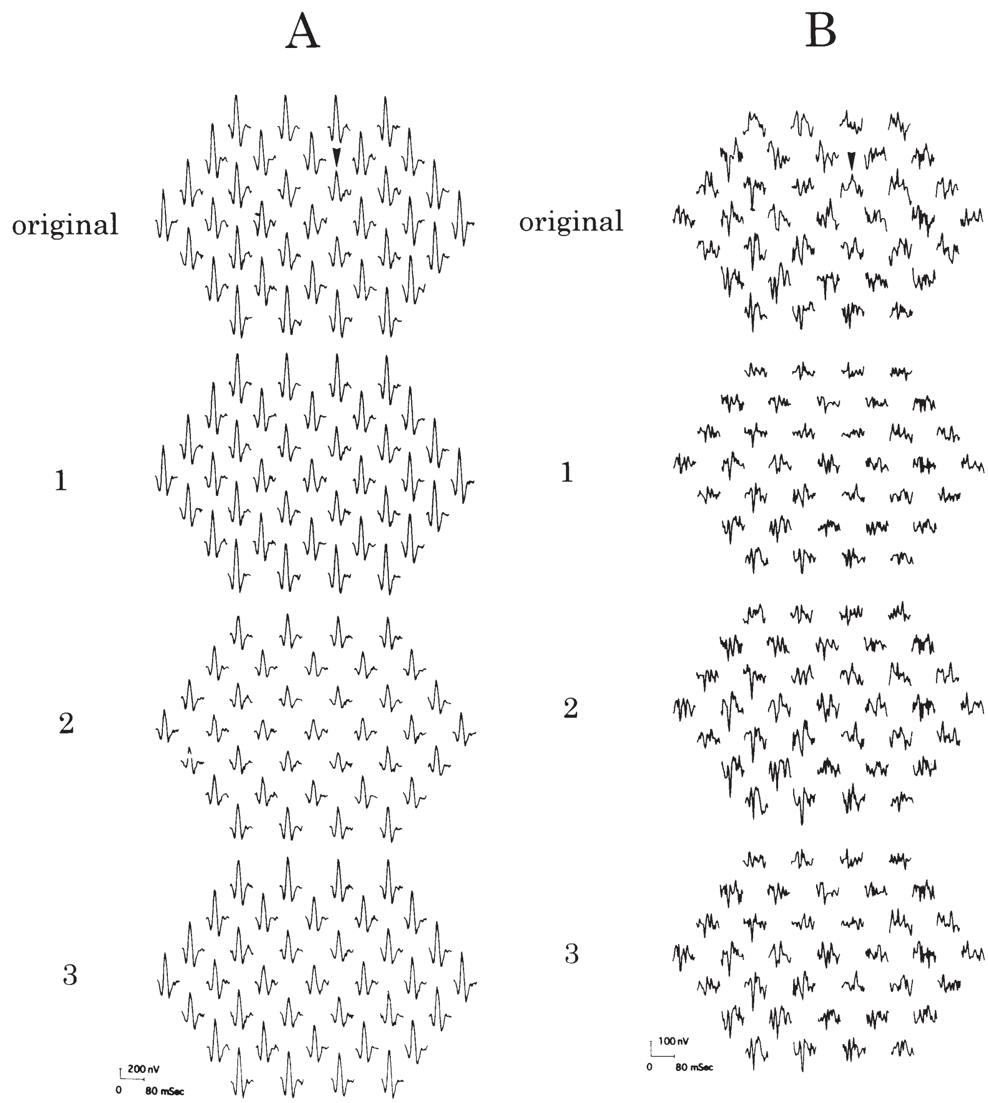

Figure 3. Multifocal electroretinogram elicited from normal subject using 37 hexagon pattern. Both first-order (**A**) and second-order kernel response components (**B**) were analyzed using the Veris Science software program. Artifact Removal procedure was done once (1), twice (2), and three times (3).

at the first iteration, the latter part of the test response is different from that of the original test response in terms of the waveform, and the test response becomes noisier in comparison with the original one (Figure 4A). The original information on the second-order kernel response component significantly decreases at the first iteration of the Artifact Removal procedure in terms of the summation of all traces (Table 1). These findings suggest that it may be misleading to use the Artifact Removal procedure even only once. The Artifact Removal procedure influences the test response itself and the

Table 1. Sum of Area of First-Order (FO) and Second-Order (SO) Kernel Response Component*

		Artifact Removal		
	Original	1	2	3
FO (μV)	34.4	34.1	21.6	34.4
SO (μV)	4.6	3.6	4.5	4.4

*These data are obtained from traces in Figure 3. Values are measured between initial positive and after-negative peaks in sum of area mode.

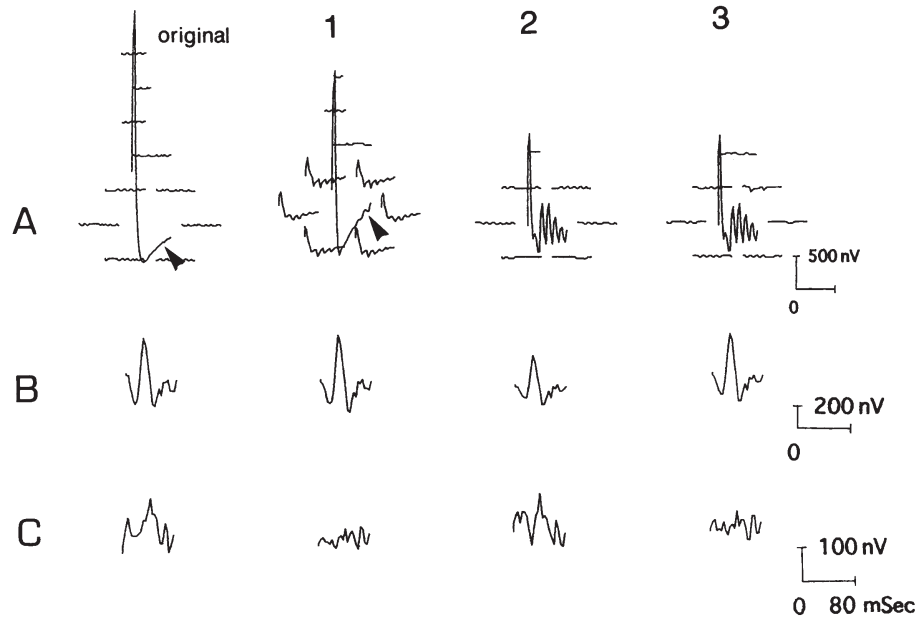

Figure 4. Traces of test response (**A**), first-order (**B**), and second-order kernel response components (**C**), as are indicated by arrowheads in Figure 3, are repeatedly processed by Artifact Removal procedure from left column (raw) to right column (after third application).

neighboring traces adjacent to the central test response. After repetitions of the Artifact Removal procedure, the shape of the test response drastically changes (Figures 2, 4).

In using the digital filter that is well-known to electrophysiologists, it is easy to understand the difference in the waveform between before and after the digital filtering procedure. This is because a wave changes in a regular way after each procedure. With the Artifact Removal procedure, since some traces of the second-order kernel response component elicited from the normal subject change irregularly whenever the Artifact Removal is repeatedly used, it is very difficult to know which type of procedure was used when we see the second-order kernel response components before and after the procedure simultaneously. Although the larger hexagonal stimulus patterns produce larger first-order and second-order kernel response components, the second-order kernel response components are in general much noisier. It is possible that the Artifact Removal procedure can be used mainly for the analysis of the second-order kernel response component.[5]

Based on the present results, we conclude that the Artifact Removal procedure considerably distorts waveform. We also emphasize that when any device with features that are not fully explained to the users is marketed, it should be carefully check by well-established testing methods before clinical use. It may be also necessary to check all other Veris Science software programs for generating and filtering the original waves of mERGs.

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