CLINICAL INVESTIGATIONS

Effect of Intraocular Irrigating Solution on Flicker Electroretinogram During Cataract Surgery in Human Eye

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Abstract: The effects of two commercially available intraocular irrigating solutions, Opeguard MA and BSS Plus, were studied during extracapsular cataract surgery in 45 eyes of 35 patients. After irrigation and aspiration of the residual cortex with Opeguard MA or BSS-Plus, the ERG amplitude increased, respectively, to 111.2 ± 5.8% and 109.5 ± 5.3% of the preirrigation amplitudes. The increases reached significance (116.9 ± 7.0% and 115.7 ± 6.5%; both $P < .05$) at the end of surgery compared with pre-irrigation ERG amplitudes. After irrigation with Opeguard MA or BSS-Plus, the ERG peak times were significantly prolonged to 103.9 ± 0.8% and 104.2 ± 1.2%, respectively, of the preirrigation peak times (both $P < .01$). The ERG peak times significantly shortened to 101.5 ± 0.9% and 101.3 ± 1.22%, respectively, at the end of surgery ($P < .001$ and $P < .05$) compared with just after irrigation. Although we have previously shown that Opeguard MA maintained amplitude and implicit time of 30 Hz flicker ERG during vitrectomy better than BSS-Plus, there were no statistically significant differences between the changes in amplitude and peak time with Opeguard MA and BSS-Plus during cataract surgery. We speculate that a drop in the retinal temperature during irrigation and aspiration in the anterior chamber and an increase in the photopic ERG amplitude during light adaptation with the operating microscope caused these ERG changes. **Jpn J Ophthalmol 1998;42:275–280** © 1998 Japanese Ophthalmological Society

Key Words: Cataract surgery, electroretinography, intraocular irrigating solution, retina.

Introduction

Improvements in intraocular irrigating solutions have been made since the 1960s, and several irrigating solutions have been developed on the basis of in vitro animal experiments.[1] The improvement of irrigating solutions has great significance because surgical procedures that employ the prolonged use of large volumes of intraocular irrigating solutions, such as phacoemulsification and pars plana vitrectomy, are being performed more frequently. In cataract surgery, the intraocular irrigating solution has the role of protecting the intraocular tissue, especially the cornea.[2]

Opeguard MA (Senju Pharmaceutical, Osaka) and BSS-Plus (Alcon Laboratories, Fort Worth, TX, USA) are representative of improved intraocular irrigating solutions that are used frequently in Japan. Horiguchi and Miyake[3] and Nao-i et al[4] recently recorded intraoperative electroretinograms (ERGs) during vitreous surgery and reported the effects of irrigating solutions on the human retina. Many reports also have been published about the effect of intraocular irrigating solutions on the corneal endothelium.[2,5–9] However, to the best of our knowledge, no reports have been published about the effects of irrigating solutions on retinal function during cataract surgery. In this report, we studied the effect of two

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intraocular irrigating solutions on the human retina during cataract surgery.

Subjects and Methods

The study population consisted of 19 women and 16 men (41 eyes; mean patient age, 70.9 years) who underwent planned extracapsular cataract surgery at the Department of Ophthalmology, Miyazaki Medical College Hospital, between 1992 and 1993. Patients who had ophthalmologic abnormalities other than cataract were excluded from the study. Informed consent was obtained from each patient after the nature and possible consequences of the study were explained.

Surgical Procedure

The pupils were dilated with a combination of 0.5% tropicamide and 0.5% phenylephrine hydrochloride. Eyes were not dark-adapted before surgery. Immediately before surgery, retrobulbar anesthesia was introduced with a mixture of equal parts of 2% lidocaine and 0.5% bupivacaine. Then, the Honan balloon (Lebanon Corporation, Lebanon, IN, USA) was placed over the closed eyelids and held in place with an adjustable headband for 15 minutes at 30 mm Hg. The surgery started 20.0 minutes (range, 17–25 minutes) after the retrobulbar anesthesia. The surgical limbus was exposed after an incision was created in the superior conjunctiva and Tenon's capsule, and a four-plane incision was made over 120° of the limbus. After a third-plane incision, sodium hyaluronate was injected into the anterior chamber. Following anterior capsulotomy using the can-opener method, the four-plane incision was completed and the nucleus was extracted using gentle compression. The cortex was removed with an irrigation-aspiration instrument. Then the anterior chamber was filled with sodium hyaluronate and a posterior chamber intraocular lens (IOL) was implanted. The scleral wound was closed with 8-0 silk or 10-0 nylon sutures. The sodium hyaluronate was aspirated from the anterior chamber and miosis was induced with acetylcholine to complete the operation.

The two kinds of perfusates were kept at room temperature (22–24°C), with 0.3 mL of 0.1% adrenaline (Bosmin) mixed with 500 mL of the perfusate. The temperatures of the irrigating solutions were between 21–22°C. All patients except one received a posterior chamber IOL. None of the patients had a ruptured posterior capsule intraoperatively.

ERG Recording

The method of recording the ERG during cataract surgery was similar to that described by Miyake et al.[10] We used a portable ERG recording system PE-300 (Tomey, Nagoya). A contact lens with a built-in red light-emitting diode (LED)[11] was sterilized with ethylene oxide gas and used as both the stimulus source and the recording electrode for 30-Hz flicker ERGs. This LED had a peak frequency of 660 nm with a 30-Hz flicker stimulus intensity of 3300 μW/cm^2. The duration of light stimulus was 16.7 milliseconds as shown in Figure 1. The reference electrode was attached to the center of the patient's forehead and the ground was placed on the earlobe. At designated times during surgery, the operating microscope was turned off and a 30-Hz flicker ERG was immediately recorded. Each recording took 7 seconds. To attain a relatively constant adaptational level during each recording, the responses during the initial 4 seconds were excluded from the averaged results, and only 30 responses from the next 3 seconds were averaged.

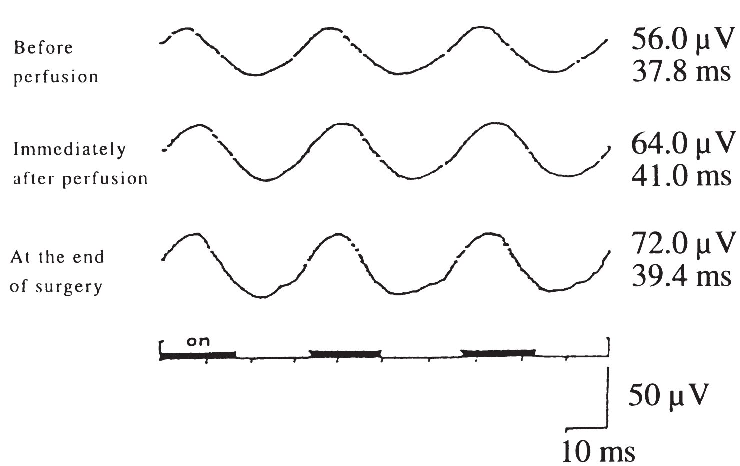

Figure 1. Actual electroretinogram (ERG) waveforms when BSS-Plus was used as perfusate. (**a**) Before perfusion. (**b**) Immediately after perfusion. (**c**) At end of surgery. Amplitude of ERG tended to increase both immediately after perfusion and at end of surgery. Peak time tended to be prolonged immediately after perfusion and recovered pre-perfusion level at end of surgery.

Every effort was made to maintain the intraocular pressure around 20 mm Hg during ERG measurement.

Three ERGs were recorded for each patient: before perfusion when the third-plane incision was completed, immediately after perfusion when the cortex was aspirated using either BSS-Plus or Opeguard MA, and at the end of surgery just before inducing miosis with acetylcholine. The first, second and last ERG recordings were obtained 15.8 ± 5.9 (range, 5–22) minutes, 39 ± 11 (range, 15–59) minutes, and 54 ± 13 (range, 28–82) minutes after the start of surgery, respectively.

The ERG recordings were anayzed by a technician who did not know which solution had been used.

Results

An example of a typical 30-Hz flicker ERG during cataract surgery is shown in Figure 1. The case is that of a 71-year-old man. The aspiration of the lens cortex required a perfusion of 200 mL of BSS-Plus for 6 minutes. The amplitude of the ERG increased from 56.0 μV before perfusion to 64.0 μV immediately after perfusion, and then increased further to 72.0 μV at the end of surgery. The peak time of the ERG was prolonged from 37.8 milliseconds before perfusion to 41.0 milliseconds immediately after perfusion, and it shortened to 39.4 milliseconds at the end of surgery.

Changes in the mean ERG amplitude with each perfusate are shown in Figure 2. The amplitudes immediately after perfusion (ERG2) and at the end of surgery (ERG3) increased compared with those before perfusion (ERG1) regardless of which perfusate was used. When Opeguard MA was used (mean volume, 145 ± 31 mL (range, 100–180 mL) and mean perfusion time, 7.5 ± 2.4 minutes (range, 3–10 minutes)), the amplitude immediately after perfusion increased to 111.2 ± 5.8% (mean ± standard error) (n = 11) compared with that before perfusion. At the end of surgery, it further increased significantly to 116.9 ± 7.0% compared with that before perfusion (P<.05). When BSS-Plus was used (mean volume, 149 ± 61 mL (range, 60–225 mL) and mean perfusion time, 7.6 ± 2.4 minutes (range, 4.5–10 minutes)), the amplitude likewise increased to 109.5 ± 5.3% (n = 10) immediately after perfusion compared with before perfusion. At the end of surgery, the amplitude increased significantly to 115.7 ± 6.5% compared with that before perfusion (P < .05). The difference between the two perfusates was not statistically significant.

Figure 3 shows the change in the ERG peak time with each perfusate. The peak time immediately after perfusion (ERG 2) was prolonged compared with that before perfusion (ERG 1), but at the end of sur-

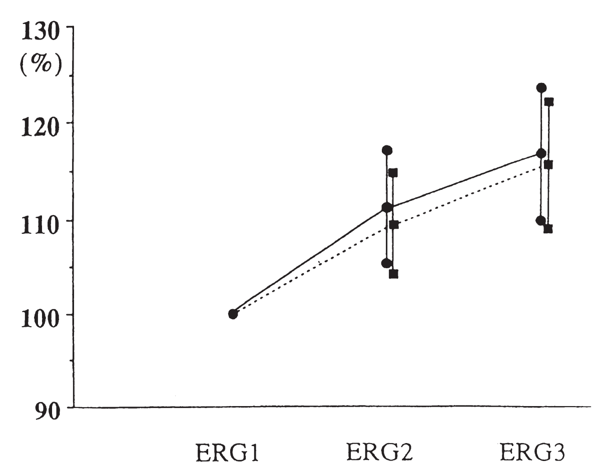

Figure 2. Changes in electroretinogram (ERG) amplitude. Amplitude increased immediately after perfusion (ERG 2) and at end of surgery (ERG 3) regardless of which perfusate was used. In either case, significant increase was seen at end of surgery compared with values before perfusion (P < .05). However, difference between two perfusates was not significant. ●: when Opeguard MA was used. ■: when BSS-Plus was used.

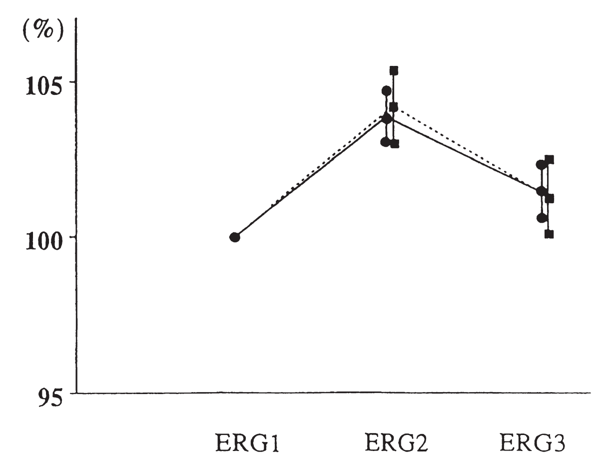

Figure 3. Changes in electroretinogram (ERG) peak time. Peak time immediately after perfusion (ERG 2) was prolonged significantly compared with values before perfusion (ERG 1) regardless of which perfusate was used (P < .01 for both). Peak time shortened to almost preperfusion value at end of surgery (ERG 3). Difference between ERG 2 and ERG 3 was statistically significant (P < .001 when Opeguard MA was used; P < .05 when BSS-Plus was used). Difference between two perfusates was not significant. ●: when Opeguard MA was used. ■: when BSS-Plus was used.

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gery (ERG 3) it almost reached the preperfusion level. When Opeguard MA was used, the peak time was prolonged to 103.9 ± 0.8% (n = 11) after perfusion compared with that before perfusion. A statistically significant difference was found with this prolongation ($P < .01$). This prolongation tended to recover, and the peak time shortened to 101.5 ± 0.9% at the end of surgery compared with before perfusion. A statistically significant difference was found between the value at the end of surgery and the value immediately after perfusion ($P < .001$). With BSS-Plus, the peak time was prolonged to 104.2 ± 1.2% (n = 10) after perfusion compared with before perfusion ($P < .01$) and shortened to 101.3 ± 1.22% at the end of surgery compared with that before perfusion. A statistically significant difference was found between the value at the end of surgery and the value immediately after perfusion ($P < .05$). The difference between the two perfusates was not significant.

Discussion

Intraoperative ERG monitoring was reported by Miyake et al[10] as a method for estimating the retinal function qualitatively and quantitatively under certain surgical conditions. In the present experiment, we monitored the ERG to observe the retinal function during perfusion of the anterior chamber during cataract surgery. The two perfusates used in this experiment are used frequently in Japan.

Glutathione bicarbonate ringer (GBR) irrigating solution was developed as the irrigating solution that caused the least corneal damage in the study of Edelhauser et al.[12] However, because GBR is not chemically stable, a more stable solution, BSS-Plus, containing oxidized glutathione (oxyglutathion) and disodium phosphate for stabilization, has been developed. Opeguard MA is the first intraocular perfusate developed in Japan by Otori et al.[8] Compared with Opeguard MA, BSS-Plus causes less corneal edema after cataract surgery. Because a decreased number of endothelial cells and fewer irregular cells also were observed with BSS-Plus,[6,7] it is receiving recognition as an intraocular perfusate that has less effect on the corneal tissue. We, therefore, measured the ERG intraoperatively to study the effect of intraocular perfusates on the retina during cataract surgery.

In a previously published study about the effect of various perfusates on the intraoperative ERG, Nao-i et al[4] reported that the peak time is prolonged significantly and the amplitude decreases, during perfusion with BSS-Plus compared with perfusion with Opeguard MA. It was expected that similar changes in the ERG could be observed even at the time of cataract surgery if the retina was sufficiently perfused. However, no significant difference was seen between the two solutions. This is probably because perfusion is performed directly in the anterior chamber only and the vitreous serves as a barrier to protect the retina from sudden environmental changes. This is unlike vitrectomy, during which the vitreous is removed and the retina is washed directly with a perfusate.

The reason for observed ERG changes during cataract surgery is speculative. There was a tendency for the peak time of the flicker ERG recorded during cataract surgery to be prolonged and for the amplitude to increase immediately after perfusion of the anterior chamber compared to the peak time and amplitude before perfusion. Moreover, the peak time returned to the original state with time after perfusion ended, but the amplitude increased further.

We theorize that the mechanism of the ERG changes is as follows. First, preoperative retrobulbar anesthesia may affect the ERG. However, Okada and Honda[13] reported that a mild attenuation of the a and b waves was observed when 1 mL of 2% xylocaine was injected into the retrobulbar region in rabbits, which contradicts the idea that the intraoperative ERG changes in the present study resulted from the effect of retrobulbar anesthesia.

Decreases in intraocular pressure (IOP) when the anterior chamber is opened during cataract surgery may be a factor in the ERG changes. However, Miyake et al[10] reported that decreases in the amplitude and prolongation of the peak time were seen when the IOP decreased upon draining of the subretinal fluid when recording the 30-Hz flicker ERG during retinal detachment surgery and that the ERG recovery was seen when the IOP was restored by buckling. If the results observed in the present study were only the result of hypotony, the ERG changes cannot be explained. It is likely that the influence of ocular hypotony, if any, is negligible.

The amount of light reaching the retina increases as the irrigation and aspiration of the cortex proceeds and causes the ERG amplitude to increase in cases in which lens opacity is severe.[14] When there is an increase in ERG amplitude with an increased amount of light, the amplitude increases but the peak time shortens, which is different from our observations during the present study. Therefore, it appears that the effect of removing a lens opacity is not the primary cause of the ERG changes. We paid particular attention to the adaptation of the retina and the cooling effect of the perfusate on the retina as the factors exerting the strongest influence on the intraoperative ERG. Miyake et al,[15] Iijima and Yamaguchi,[16] and Ota et al[17] reported independently that the photopic ERG amplitude after sufficient dark adaptation increased with the progression of light adaptation compared with the amplitude immediately after light adaptation, even though the peak time remained almost constant during the course of light adaptation.

The retina is in a state of mild dark adaptation for 15 minutes, during preparation, and light adaptation will continue to progress because of illumination from the surgical microscope during the subsequent operation. Therefore, it is possible that an ERG recorded during progressing light adaptation has an increased amplitude although the peak time remains unchanged. It takes approximately 15–20 minutes from the start of surgery or the beginning of light adaptation to the time of the ERG recording immediately after perfusion. This may raise the doubt that the phenomenon of the cone ERG increasing under light adaptation might end in the meantime. According to Miyake et al,[15] the ERG amplitude does not reach a plateau and tends to increase further for another 20 minutes in most cases, even at the end of measurement. In the report of Iijima and Yamaguchi,[16] the photopic ERG amplitude also did not reach a plateau at 10 minutes after the inception of light adaptation. Therefore, we believe that the phenomenon of the cone ERG increasing under light adaptation is likely to continue beyond 20 minutes. However, further experiments are needed to answer the question of how the ERG amplitude changes during light adaptation under a powerful light such as that from a surgical microscope.

May et al[18] reported that irrigation of the anterior chamber lowered the temperature of the eye on the whole. When a fall in ocular temperature has occurred, according to Horiguchi and Miyake,[3] the peak time of the flicker ERG is prolonged and the amplitude decreases. In the present experiment, the amplitude increased but the peak time was prolonged, possibly because the temperature of the eyeball falls with the progression of light adaptation immediately after perfusion. In ERGs recorded later, the peak time may have shortened again because the ocular temperature was restored to its former level, and the amplitude continued to increase because of the further progression of light adaptation.

When the anterior chamber was irrigated and aspirated with two kinds of perfusates, each affecting the ERG differently during vitreous surgery, no evident difference in the intraoperative ERG was seen. The retina is protected by barriers such as the posterior capsule and vitreous during cataract surgery; therefore, some differences in the ion composition and other components will not give rise to electrophysiologic differences, and the physical properties of the perfusate, such as the temperature, will exert a greater influence on the intraoperative ERG. According to our previous observations on the intraoperative ERG, the ERG amplitude decreased sharply and the peak time was prolonged markedly when the anterior chamber was perfused with a low-temperature perfusate of approximately 2°C, but this change was reversible. Horiguchi and Miyake[3] reported that heating the perfusate to close to body temperature is sufficient to minimize the changes in the intraoperative ERG. However, another study[19] reported that cooling the intraocular perfusate at the time of cataract surgery relieves postoperative inflammation and also prevent burns of the scleral wound. Concerning the physical properties of the perfusates, much still is unknown as to what constitutes the optimal condition for the ocular tissues. Future studies are needed to answer these questions.

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