The effects of cataract stage, lens-induced uveitis and cataract removal on ERG in dogs with cataract

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Abstract

Objective The purpose of this study was to determine the effects of cataract stage, lens-induced uveitis and cataract removal on the electroretinogram (ERG) of dogs with cataract.

Animals studied Fifty-seven dogs diagnosed with unilateral or bilateral cataract whose ERG was recorded at Rakuno Gakuen University Teaching Animal Hospital from 2001 to 2004.

Procedures Four responses were recorded during the ERG: rod ERG, standard combined ERG, single-flash cone ERG and 30-Hz flicker ERG. Cataracts were divided into four stages: incipient, immature, mature and hypermature, and with or without lens induced uveitis (LIU). Noncataractous eyes of dogs with unilateral cataract were used as the control. We compared ERG amplitude, implicit time, and the b- to a-wave amplitude ratio of cataractous vs. noncataractous eyes, preoperative vs. postoperative cataractous eyes, and cataractous eyes with and without LIU.

Results No significant difference was found in ERG amplitude between incipient, immature and hypermature cataractous eyes, while in mature cataractous eyes decreased amplitude was confirmed in all responses compared with control eyes. However, no significant difference in b/a ratio was found at any stage of cataract. In postoperative eyes, increased amplitude was recorded in all responses compared to preoperative values. In eyes with LIU a decreased amplitude in the rod ERG and b-wave of standard combined ERG was recorded and, furthermore, a significant decline was confirmed in b/a ratio.

Conclusion ERG values were influenced by cataract stage and LIU. LIU was associated with a reduction in the b/a ratio.

Key Words: cataract, dog, electroretinogram, lens-induced uveitis

INTRODUCTION

Electroretinographic (ERG) recording is a valuable non-invasive tool in the evaluation of retinal function. Evaluation of retinal function by ERG in the presence of an opaque medium when the fundus is not visible is valuable in clinical practice. ERG recording is an essential examination prior to cataract extraction. However, the effects of cataract stage, lens-induced uveitis and cataract removal on ERG in dogs have not been reported.

The ERG is influenced by dark adaptation time, pupil size, stimulus intensity and other factors. The ERG measures an electrical potential which arises in the retina after light stimulation from the front of the eye. Light passes through the optic media (cornea, anterior chamber, lens and vitreous) and reaches the retina. Opacity of the media acts as a filter that reduces stimulus strength. It was reported that the ERG was slightly reduced in amplitude in a dog with cataract with a normal retina, but concrete differences in ERG amplitude, implicit time and b/a ratio, and the ratio of b- to a-wave amplitude in standard combined ERG according to the stage of cataract have not been reported. The present study examined the differences in ERG at various cataract stages, and compared the ERG before and after cataract surgery.

The development of juvenile cataract in dogs is rapid, and resorption of cataract and leakage of lens protein from the lens capsule frequently occur. As a result, lens protein enters the aqueous and is exposed to the immune system of the uvea. This causes lens-induced uveitis (LIU). LIU is a major cause of complications in cataract surgery. The influence of LIU on retinal electrophysiological function has...
not been previously reported. Therefore, we herein discuss the effects of cataract and LIU on ERG.

**MATERIALS AND METHODS**

**Animals**

Fifty-seven dogs diagnosed with unilateral or bilateral cataract, whose ERG was recorded at Rakuno Gakuen University Teaching Animal Hospital from 2001 to 2004, were used. Eighteen dogs had unilateral cataract, and 39 had bilateral cataract. Eighteen dogs (18 eyes) had noncataractous eyes, and their median age was 3.1 years old. Eleven dogs (12 eyes) had incipient cataract, and their median age was 3.4 years old. Eight dogs (nine eyes) had immature cataract, and their median age was 3.4 years old. Thirty-one dogs (39 eyes) had mature cataract, and their median age was 4.2 years old. Nineteen dogs (22 eyes) had hypermature cataract, and their median age was 3.3 years old. Thirty-one dogs (seven mature cataracts and seven hypermature cataracts) developed LIU, and their median age was 3.6 years old. In this study, the eyes that developed mature or hypermature cataract, conjunctival hyperemia, aqueous flare, or iris thickening, and did not have other causes of inflammation, were diagnosed as having LIU. Seven dogs (eight eyes) underwent ERG recording again 4–18 months after cataract surgery (median 10.9 months). Five dogs (five eyes) diagnosed with LIU underwent ERG recording again after treatment of LIU and before cataract surgery.

**Electroretinography**

The method of ERG recording was according to a previous study using a contact lens electrode with a built-in light source.15 The ERG instrument used was a portable ERG LE-3000 (TOMEY Corporation, Nagoya, Japan), which incorporates a stimulator, amplifier and recorder. The frequency band was 0.3–300 kHz. We used an ERG contact lens electrode with a built-in light source (LED electrode H2000, Kyoto Contact Lens, Kyoto, Japan). Before ERG recording, the pupils were dilated with 0.5% tropicamide and 0.5% phenylephrine hydrochloride (Mydrin-P, Santen, Osaka, Japan). ERG was recorded under sedation with a combination of 0.01 mg/kg medetomidine (Domitor, Meiji, Tokyo, Japan), 0.15 mg/kg midazolam (Dormicum, Yamanouchi, Tokyo, Japan), and 0.025 mg/kg butorphanol (Stadol, Bristol-Meyers, Tokyo, Japan). Four responses were recorded during the ERG: rod ERG, standard combined ERG, single-flash cone ERG, and 30-Hz flicker ERG. The light intensity of rod ERG was 0.0096 cd/m²/s, and that of the other responses was 3.0 cd/m²/s. Rod ERG and combined ERG were recorded after 30 min of dark adaptation, and cone ERG and flicker ERG were performed after 10 min of light adaptation.

**Statistical analysis**

ERGs of 18 noncataractous eyes were used as the control. Age and ERGs of incipient, immature, mature and hypermature cataractous eyes were compared to controls using the Student’s t-test. ERGs of postoperative eyes were compared to preoperative eyes and controls using the paired t-test or Student’s t-test, respectively. ERGs of LIU eyes were compared to ERGs of mature and hypermature cataractous eyes that were not inflamed using the Student’s t-test. ERGs of LIU eyes were compared to ERGs of eyes that were treated for LIU using a paired t-test. Differences of $P < 0.05$ were considered to be statistically significant.

**RESULTS**

There was no significant difference in age between cataractous dogs of each stage compared to controls. ERG amplitude, b/a ratio and implicit time at each cataract stage are shown in Tables 1 and 2. In incipient and immature cataractous eyes no significant differences were observed in ERG amplitude, b/a ratio and implicit time compared to controls. In mature cataractous eyes a significant decrease in ERG amplitude was observed in all responses ($P < 0.05$), but no significant difference was observed in b/a ratio compared to controls. In mature cataractous eyes there was significant prolongation of the a-wave implicit time in the standard combined ERG ($P < 0.05$). In hypermature cataractous eyes no significant differences were observed in ERG amplitude and b/a ratio compared to controls. In hypermature cataractous eyes there was significant prolongation of the a-wave implicit time in the standard combined ERG ($P < 0.05$).

ERG amplitude, b/a ratio and implicit time before and after cataract surgery for all cataract groups were combined and averaged and are shown in Tables 3 and 4. After cataract surgery, a significant increase in ERG amplitude was

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**Table 1.** ERG amplitude and b/a ratio in each stage of cataract

<table>
<thead>
<tr>
<th>Stage of cataract</th>
<th>Rod</th>
<th>Standard combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>a-wave</td>
<td>b-wave</td>
</tr>
<tr>
<td>Control (n = 18)</td>
<td>135.4 ± 45.6</td>
<td>138.1 ± 27.1</td>
</tr>
<tr>
<td>Incipient (n = 12)</td>
<td>131.5 ± 40.1</td>
<td>141.0 ± 42.1</td>
</tr>
<tr>
<td>Immature (n = 9)</td>
<td>126.4 ± 30.3</td>
<td>154.3 ± 32.6</td>
</tr>
<tr>
<td>Mature (n = 39)</td>
<td>63.5 ± 34.1*</td>
<td>116.6 ± 38.3*</td>
</tr>
<tr>
<td>Hypermature (n = 22)</td>
<td>121.0 ± 44.7</td>
<td>131.8 ± 48.8</td>
</tr>
</tbody>
</table>

Data are presented as mean value (in microvolts) ± standard deviation. The ERG amplitude and b/a ratio of cataracts at each stage were compared to those of control eyes. *Denotes a significant difference ($P < 0.05$), as evaluated by Student’s t-test, compared to control eyes.
observed \((P < 0.05)\), but no significant change was observed in b/a ratio compared to before surgery. Significant shortening was observed in the a-wave implicit time compared to before surgery \((P < 0.05)\). There was no significant difference in amplitude, b/a ratio and implicit time between postoperative and control eyes.

ERG amplitude, b/a ratio and implicit time in eyes with LIU are shown in Tables 5 and 6. Significant decreases were observed in the amplitude of rod ERG and b-wave of the standard combined ERG in LIU eyes compared to noninflamed mature and hypermature cataractous eyes \((P < 0.05)\).

The b/a ratio in LIU eyes was \(1.31 \pm 0.28\) (median \(\pm\) SD), which was significantly smaller than that in noninflamed mature and hypermature cataractous eyes \((P < 0.05)\). There was significant prolongation of the a-wave implicit time of the standard combined ERG in LIU eyes compared to mature and hypermature cataractous eyes \((P < 0.05)\).

ERG amplitude, b/a ratio and implicit time in eyes after treatment of LIU are shown in Tables 7 and 8. After treatment of LIU but before cataract surgery a significant increase in b-wave amplitude was observed compared to before treatment \((P < 0.05)\), and a significant increase in b/a ratio was
also observed ($P < 0.05$). There was no significant difference in implicit time between eyes after treatment of LIU and eyes before treatment.

**DISCUSSION**

In this study, the results showed that ERG a- and b-wave amplitudes decreased a similar amount, so that b/a ratio in the combined ERG was unaffected in canine eyes with cataract. In postoperative ERG recordings, increased amplitude was recorded in all responses compared to preoperative recordings. However, in cataractous eyes with LIU, b/a ratio decreased as well as ERG amplitude. Therefore, when evaluating the preoperative ERG, reduction of amplitude caused by lens opacity in the mature cataractous eye and reduction of b/a ratio in LIU eyes should be taken into consideration.

The ERG is influenced by stimulus intensity: ERG amplitude increases and implicit time decreases as light stimulation increases up to a certain intensity.6,7,9 The presumed reason for decreased ERG amplitude and prolonged implicit time in eyes with mature cataract is that cataract acts as a filter that reduces stimulus strength. However, greater ERG amplitude has been recorded in human eyes with cataract than in eyes without a cataract.16 The reason was considered to be that the cataract scattered stimulus light and a larger retinal area was illuminated. In the latter study an external light source that did not stimulate the full field was used. In our study, full-field stimulation was used, and the ERG amplitude was decreased in cataractous eyes.

After cataract extraction a significant increase in ERG amplitude was observed in all responses compared to before surgery. We considered that the stimulus intensity reaching the retina was increased after cataract extraction, resulting in a corresponding increase in ERG amplitude after surgery. In humans, it is reported that ERG amplitude was decreased 2–3 weeks after cataract surgery.16 This was explained by impairment of retinochoroidal circulation. In this study, the ERG was recorded 4–18 months after cataract surgery, and no intraocular inflammation was detected at the times the ERG was recorded. It appears that the reduction of amplitude in mature cataractous eyes was caused by lens opacity, because ERG amplitude of postoperative eyes with improved lens clarity increased compared to preoperative values.

A decreased b/a ratio resulting from decreased b-wave amplitude was detected in LIU eyes. ERG mainly evaluates the function of photoreceptor cells.1–3 The photoreceptor cell layer of the retina is nourished by diffusion from the uveal vessels in the choroid in dogs.17 It was considered that the reduction in ERG amplitude in LIU eyes was based on the reduction in photoreceptor function. We thought that

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**Table 6.** ERG implicit time in LIU eyes

<table>
<thead>
<tr>
<th>Eyes</th>
<th>Rod</th>
<th>a-wave</th>
<th>b-wave</th>
<th>Cone</th>
<th>Flicker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noninflamed ($n = 47$)</td>
<td>72.7 ± 12.6</td>
<td>14.8 ± 2.0</td>
<td>29.4 ± 3.9</td>
<td>25.1 ± 1.7</td>
<td>23.0 ± 2.3</td>
</tr>
<tr>
<td>LIU ($n = 14$)</td>
<td>70.7 ± 7.3</td>
<td>16.2 ± 2.6*</td>
<td>30.4 ± 3.5</td>
<td>26.3 ± 2.4</td>
<td>25.0 ± 2.7</td>
</tr>
</tbody>
</table>

Data are presented as mean value (in milliseconds) ± standard deviation. The ERG implicit time of LIU eyes was compared to that of noninflamed eyes. *Denotes a significant difference ($P < 0.05$), as evaluated by Student’s t-test, compared to noninflamed eyes.

**Table 7.** ERG amplitude and b/a ratio of eyes after treatment of LIU

<table>
<thead>
<tr>
<th>Standard combined</th>
<th>Rod</th>
<th>a-wave ± 31.9</th>
<th>b-wave ± 40.9</th>
<th>b/a ratio ± 0.21</th>
<th>Cone ± 8.83</th>
<th>Flicker ± 16.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before treatment</td>
<td>57.1 ± 28.8</td>
<td>104.35 ± 31.9</td>
<td>139.8 ± 40.9</td>
<td>1.36 ± 0.21</td>
<td>37.6 ± 8.53</td>
<td>48.2 ± 16.5</td>
</tr>
<tr>
<td>After treatment</td>
<td>72.9 ± 38.1</td>
<td>115.0 ± 30.9</td>
<td>219.7 ± 68.9*</td>
<td>1.92 ± 0.33*</td>
<td>43.2 ± 12.4</td>
<td>53.5 ± 13.0</td>
</tr>
</tbody>
</table>

Data are presented as mean value (in microvolts) ± standard deviation. The ERG amplitude and b/a ratio of eyes after treatment of LIU were compared to those of eyes before treatment. *Denotes a significant difference ($P < 0.05$), as evaluated by paired t-test, compared to eyes before treatment of LIU.

**Table 8.** ERG implicit time of eyes after treatment of LIU

<table>
<thead>
<tr>
<th>Standard combined</th>
<th>Rod</th>
<th>a-wave ± 6.5</th>
<th>b-wave ± 4.8</th>
<th>Cone ± 5.5</th>
<th>Flicker ± 3.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before treatment</td>
<td>72.4 ± 6.5</td>
<td>15.1 ± 3.0</td>
<td>29.4 ± 4.8</td>
<td>27.2 ± 3.5</td>
<td>25.5 ± 3.3</td>
</tr>
<tr>
<td>After treatment</td>
<td>72.8 ± 8.0</td>
<td>14.0 ± 1.3</td>
<td>30.1 ± 4.8</td>
<td>25.8 ± 1.7</td>
<td>25.4 ± 3.1</td>
</tr>
</tbody>
</table>

Data are presented as mean value (in milliseconds) ± standard deviation. The ERG implicit time of eyes after treatment of LIU was compared to that of eyes before treatment. There was no significant difference in implicit time between eyes after treatment of LIU and eyes before treatment.
the reduction in photoreceptor function was due to impairment of outer retinal perfusion by the choroid, caused by LIU. The ERG b-wave originates from bipolar and Müller cells present in the inner part of the retina.\(^3,^9\) The inner part of the retina is supplied by retinal vessels.\(^17\) In humans, a decreased ERG b-wave amplitude is caused by impairment of retinal circulation, such as central retinal vein occlusion.\(^9\) With LIU lymphocytic-plasmacytic perivascular cuffing of retinal vessels is reported.\(^18\) We propose that LIU may also affect choroidal and retinal circulation, resulting in a decrease in the ERG b-wave.

In this study the following two conclusions were determined. The effect of lens opacity on ERG was a decrease in all ERG parameters, while the effect of LIU on ERG was only decreased b-wave amplitude with a subsequent reduction of the b/a ratio. We therefore consider that the b/a ratio may be an indicator of LIU, in combination with other findings such as conjunctival hyperemia, episcleral injection, aqueous flare, and iris hyperpigmentation. Therefore, a b-wave reduction detected at the time of the preoperative ERG examination may indicate the need for more aggressive perioperative anti-inflammatory therapy and raise concern for a greater risk of postoperative inflammation and secondary glaucoma.

As a final conclusion, when the ERG amplitude is decreased, it is important to take into consideration not only the possibility of retinal diseases, but also the condition of the anterior segment, including the degree of lens opacity or the presence of anterior uveitis.

**REFERENCES**