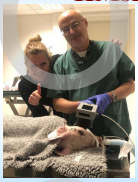
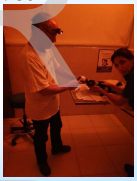
# EVERYTHING YOU WANTED TO KNOW ABOUT ERG BUT WERE AFRAID TO ASK

Ron Ofri, DVM, PhD, DECVO
Hebrew University of Jerusalem, ISRAEL

# DISCLOSURE

I HAVE TAUGHT ERG COURSES AND CONSULTED FOR HMsERG, AnVision & RETevet



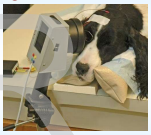


THANK YOU!

SPONSORED BY:

# LECTURE OUTLINE

- The origin of the ERG and its waveform
- Separating rod & cone responses
- How to record an ERG
  - Patient, equipment and protocols
- Factors affecting your recording
- Troubleshooting, limitations and alternatives
- Clinical cases – interpreting your recording



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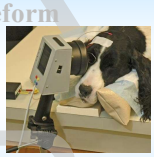

## LECTURE OUTLINE. HOW TO RECORD AN ERG?

- Your patient
- Your equipment
- Your protocols


## LECTURE OUTLINE. HOW TO RECORD AN ERG?

- Your patient
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## PREPARING THE PATIENT

1. **Prepare in ambient light**
   - **Avoid fundus photography/ophthalmoscopy**


## PREPARING THE PATIENT

**2. Anesthesia/sedation is mandatory (???)**

*Documenta Ophthalmologica* 105: 83–92, 2002.
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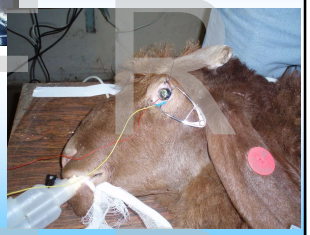
**Guidelines for clinical electroretinography in the dog**

KRISTINA NARFSTRÖM[1], BJÖRN EKESTEN[2], SERGE G. ROSOLEN[3], BERNHARD M. SPIESS[4], CHRISTINE L. PERCICOT[5] and RON OFRI[6]

ISCEV STANDARDS

**Guidelines for clinical electroretinography in the dog: 2012 update**

Sedation is insufficient for diagnostic ERG recordings (using the longer type of protocol). The dog must be fully anaesthetized in order to prevent artifacts through involuntary muscle movement. As the recording may be

Ezra-Elia…& Ofri R 2014

## Effects of chemical restraint on electroretinograms recorded sequentially in awake, sedated, and anesthetized dogs

Kate S. Freeman, MEM, DVM; Kathryn L. Good, DVM; Philip H. Kass, DVM, PhD; Shin Ae Park, DVM, PhD; Natalia Nestorowicz, DVM; Ron Ofri, DVM, PhD

**Objective**—To quantitatively and qualitatively compare electroretinography (ERG) recordings in awake, sedated, and anesthetized dogs.

**Animals**—Six 6-month-old Beagles.

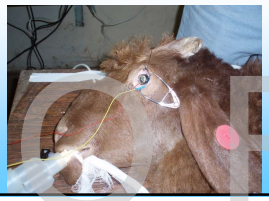
**Procedures**—A brief ERG protocol for dogs was used. Following 1-minute and subsequent 5-minute dark adaptation, mixed rod-cone responses were recorded bilaterally with a hand-held multispecies ERG device with dogs in each of 3 states of consciousness: awake, sedated (dexmedetomidine and butorphanol), and anesthetized (atropine and hydromorphone, followed by propofol and midazolam and anesthetic maintenance with isoflurane). Low- and high-frequency noise levels were quantified via Fourier analysis, and the effect of consciousness state on signal amplitude, implicit time, and noise was analyzed via repeated-measures ANOVA. In addition, 13 veterinary ophthalmologists who were unaware of the dogs' consciousness states subjectively graded the ERG recording quality, and scores for each tracing were compared.

**Results**—ERG amplitudes were highest in awake dogs and lowest in anesthetized dogs. Implicit times were shortest in awake dogs and longest in anesthetized dogs. Differences in b-wave amplitudes and a-wave implicit times were significant. Neither low- nor high-frequency noise levels differed significantly among consciousness states. Furthermore, no significant differences were identified among observers' scores assigned to ERG tracings.

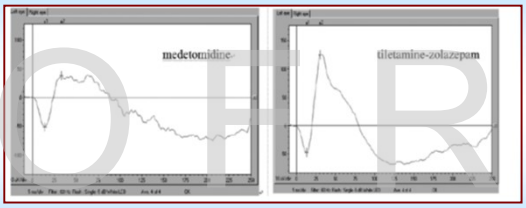
**Conclusions and Clinical Relevance**—Anesthesia and sedation resulted in significant attenuation and delay of ERG responses in dogs. Chemical restraint of dogs had no consistently significant effect on low- or high-frequency noise levels or on observer perception of signal quality. (*Am J Vet Res* 2013;74:1036–1042)

## BOTTOM LINE

- Not needed for brief recordings in animals that can be restrained safely
- Required for long protocols, animals that can't be safely restrained manually
  - Be consistent!




## ANESTHESIA & ERG. Be consistent!!!!

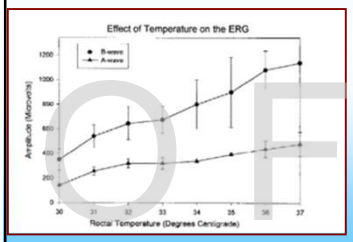



Lin SL et al. 2009

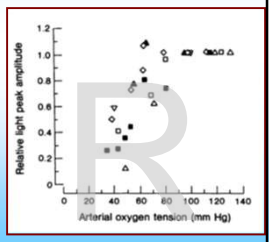
- Anesthesia may also affect dark adaptation, visual thresholds…

## OTHER ANESTHETIC FACTORS

- ERG affected by temperature, $pO_2$, $pCO_2$, pH, glucose…
  - Maintain oxygenation, ventilation & body temp.

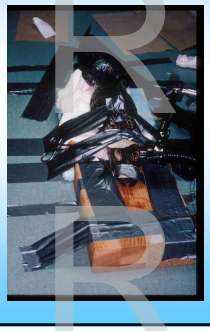



Kong & Gouras, 2003



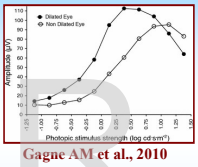

Linsenmeier et al, 1983

## SOMETIMES CHEMICAL RESTRAINT IS NOT ENOUGH…



## PREPARING THE EYE

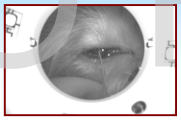
1. Pupil must be dilated
2. Position eye
   - Sub-conjunctival suture
3. Retract eyelids
   - Not with fingers

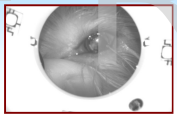


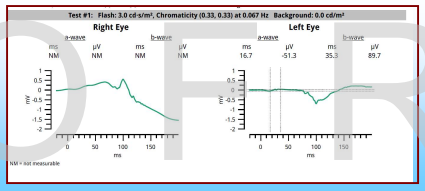

Gagne AM et al., 2010

Ezra-Elia…& Ofri R 2014

## LID RETRACTION







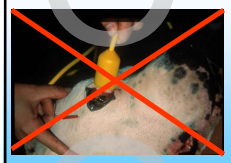

## LECTURE OUTLINE. HOW TO RECORD AN ERG?

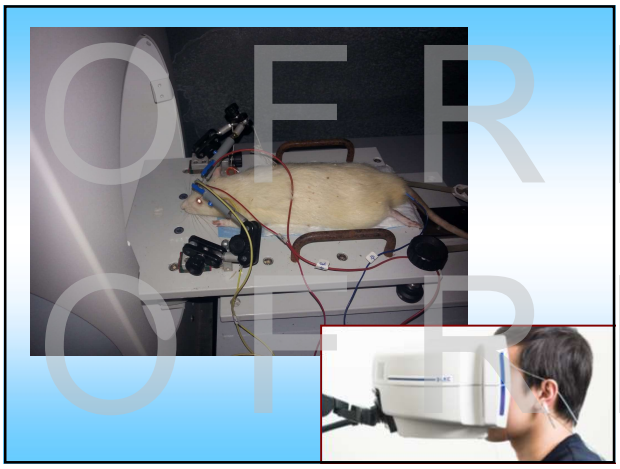
- Your patient
- **Your equipment**
- Your protocols


## EQUIPMENT. I. STIMULATOR.

**FULL FIELD CONDITIONS**

- **Ganzfeld sphere/ mini-GF**
- **Optical diffuser**





## EQUIPMENT. I. STIMULATOR.

**Stimulator output (flash intensity) should be periodically rechecked**

| Date | Unit |
|---|---|
| 26MAR15 | 908127 |

Flash Intensity

| Test | Reading 1 | Reading 2 | Reading 3 | divisor | Tgt val | Deviation | |
|---|---|---|---|---|---|---|---|
| VER-FLASH-30000 | 24000 | 23900 | 24200 | 1 | 30000 | -19.89% | ERROR |
| VER-FLASH-10000 | 8850 | 8840 | 8840 | 1 | 10000 | -11.57% | ERROR |
| VER-FLASH-1000 | 4450 | 4440 | 4440 | 5 | 1000 | -11.13% | ERROR |
| VER-FLASH-100 | 895 | 886 | 895 | 10 | 100 | -10.80% | ERROR |
| VER-FLASH-10 | 447 | 432 | 436 | 50 | 10 | -12.33% | ERROR |
| VER-FLASH-1 | 82.5 | 71.0 | 82.5 | 100 | 1 | -21.33% | ERROR |

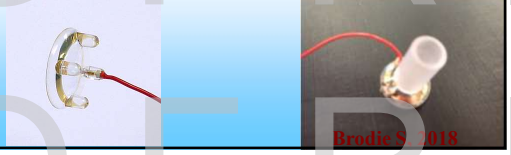
Background Intensity

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| VER-BKG-30000 | 23400 | 23400 | 23400 | 1 | 30000 | -22.00% | ERROR |
| VER-BKG-20000 | 14890 | 14980 | 14990 | 1 | 20000 | -25.27% | ERROR |

## III. ACTIVE ELECTRODES

**Contact lens**

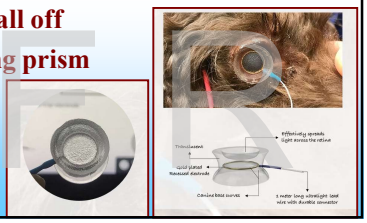
- **Jet**
  - **Check gold foil integrity with slit lamp**



## III. ACTIVE ELECTRODES

**CONTACT LENS – THE RM ELECTRODE**

- Recessed electrode more durable than the Jet gold foil (longer lasting)
- Less likely to fall off
- Light-scattering prism





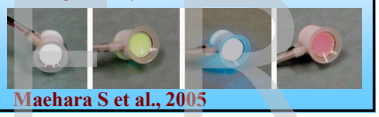
## III. ACTIVE ELECTRODES

**Contact lens**

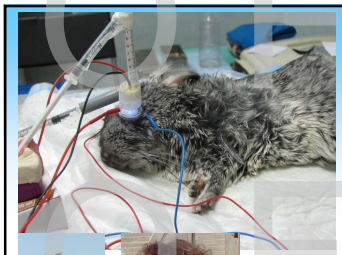
- With "extras":

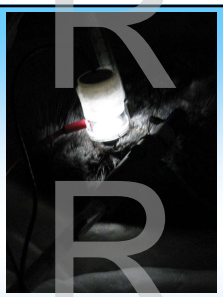
➢Burian-Allen: built-in reference electrode

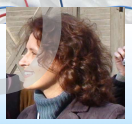
➢Built-in LED (Kooijman)



Machara S et al., 2005





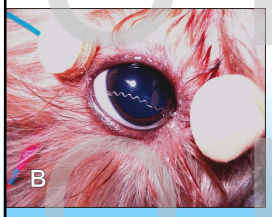


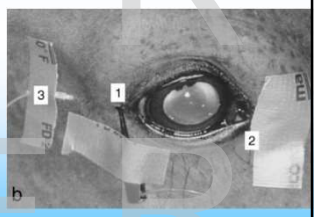
Contrary to popular belief, chinchillas do not have a pure rod retina

Shai Sandalon[1] | Anna Boykova[2] | Maya Ross[1] | Alexey Obolensky[3] | Eyal Banin[3] | Ron Ofri[1]

Vet Ophthalmol , 2018

## DTL ELECTRODES

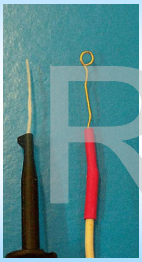



Pereira et al., 2013

Komaromy et al., 2003

## FOR SMALLER EYES



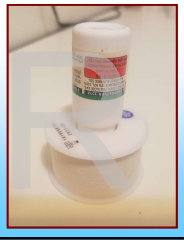
Rodent contact lens

Cotton tip, gold loop

## III. ACTIVE ELECTRODES

**"RULES" FOR ACTIVE ELECTRODE**

- Use methylcellulose for conduction
  - ➢No air bubbles
- Don't use topical anesthesia
- Make sure electrode did not "slip" while dark adapting



Doc Ophthalmol (2009) 118:101–108
DOI 10.1007/s10633-008-9141-x

ORIGINAL RESEARCH ARTICLE

**The effect of topical anesthesia on the rat electroretinogram**

Shai Sandalon · Ron Ofri

## III. ACTIVE ELECTRODES

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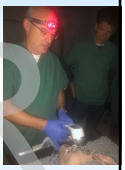


## INACTIVE ELECTRODES

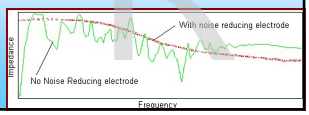
- Commercial needle electrode
- Silver wire (0.3mm) inserted in 18g needle

**REFERENCE/INDIFFERENT ELECTRODE:**

- Temporal canthus

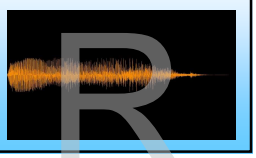
**GROUND ELECTRODE:**

- Ear pinna, base of tail…
- NOT on forehead, back of skull




## ELECTRODE IMPEDANCE

- IMPEDANCE = RESISTANCE IN AC
  - ➢HMsERG, An-Vision, RETevet & BPM300 have built-in meters
- Maintain < 5k Ω



## CLEANING YOUR ELECTRODES

**NEEDLE ELECTRODES – Alcohol pads**

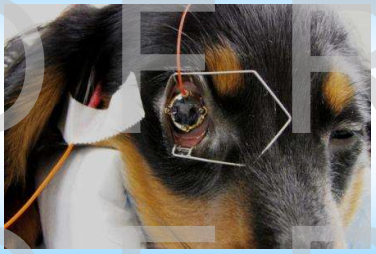
**CONTACT LENS ELECTRODES**

1. Rinse gently under tap water
2. Soak 5 min in mild detergent
3. Rinse 5 min under running tap water
   - Place in beaker under gently running tap
4. Rinse with DW to avoid spots/deposits
5. Air dry & inspect

## LECTURE OUTLINE. HOW TO RECORD AN ERG?

- Your patient
- Your equipment
- **Your protocols**


## SAMPLE PROTOCOLS



**What are you asking?**

Documenta Ophthalmologica 105: 83–92, 2002.
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Guidelines for clinical electroretinography in the dog

KRISTINA NARFSTRÖM[1], BJÖRN EKESTEN[2], SERGE G. ROSOLEN[3], BERNHARD M. SPIESS[4], CHRISTINE L. PERCICOT[5] and RON OFRI[6]
[1]College of Veterinary Medicine, University of Missouri-Columbia, USA; [2]Faculty of Veterinary Medicine, University of Agricultural Sciences, Uppsala, Sweden; [3]Clinique Vétérinaire Voltaire, Asnières, France; [4]Veterinär-Chirurgische Klinik, University of Zürich, Zürich, Switzerland; [5]Ophthalmic Research Unit, CIBA Vision, Basel, Switzerland; [6]Koret School of Veterinary Medicine, Hebrew University of Jerusalem, Israel

These procedures described for the dog ERG were approved at the 1st European Conference on Veterinary Visual Electrophysiology in Vienna, Austria, May 30, 2000. Dr. Narfström was Chair of the Committee for a Harmonized ERG Protocol, appointed by the European College of Veterinary Ophthalmology (ECVO), and Dr. Ofri was secretary. The other countries committee members. Guidelines for ERG procedures in other animal species for clinical and

Doc Ophthalmol (2013) 127:79–87
DOI 10.1007/s10633-013-9388-8

ISCEV STANDARDS

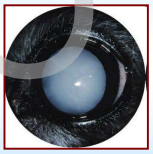
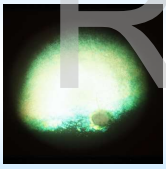
Guidelines for clinical electroretinography in the dog: 2012 update

Björn Ekesten · András M. Komáromy · Ron Ofri · Simon M. Petersen-Jones · Kristina Narfström

## DUAL PROTOCOLS. I. "Short"

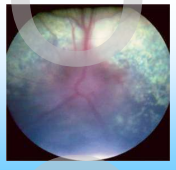
**Rapid yes/no determination of retinal function**

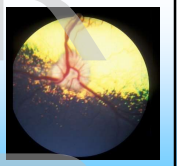

## PRE-OPERATIVE EVALUATION OF CATARACT PATIENTS

IS  HIDING  ?

## WORKUP OF AMAUROSIS

- Cortical vs retinal blindness
- SARDS vs distal optic neuritis
  - Both patients present with acute blindness, dilated and non-responsive pupils, and a normal-looking fundus





## "I don't need an ERG for this. I use chromatic PLR"

Optic neuritis in dogs: 96 cases (1983-2016)

Sara M. Smith, Hans D. Westermeyer, Christopher L. Mariani, Brian C. Gilger and Michael G. Davidson

Department of Clinical Sciences, North Carolina State University College of Veterinary Medicine, Raleigh, NC 27607, USA

Presumed optic neuritis of non-infectious origin in dogs treated with immunosuppressive medication: 28 dogs (2000-2015)

J Sm Anim Pract 2020

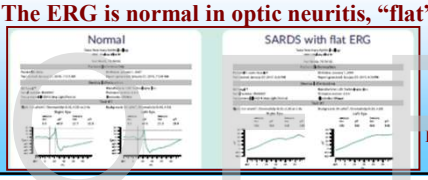
- Workup included bloodwork, CSF, MRI, ERG…
- 0/124 cases worked up with chromatic PLR!

## DIAGNOSING SARDS/OPTIC NEURITIS

Acute blindness in dogs: Sudden acquired retinal degeneration syndrome versus neurological disease (140 cases, 2000–2006)

Keith W. Montgomery,* Alexandra van der Woerdt* and Nancy B. Cottrill*†

- 120 dogs with SARDS, 20 with neurological disease
  - "An ERG to rule out ND is indicated in amaurosis"
- The ERG is normal in optic neuritis, "flat" in SARDS




Kraszewska O et al. ARVO 2017

## DUAL PROTOCOLS. II. "Long"

### Early diagnosis of hereditary retinal diseases

Table 15-6 Onset of Ophthalmoscopic, Behavioral, and Electroretinogram Signs of Inherited Retinal Dystrophies and Degenerations

| BREED | DISEASE | OPHTHALMOSCOPIC SIGNS | BEHAVIORAL SIGNS | ERG ABNORMALITIES |
|---|---|---|---|---|
| Akita | *PRA* | 1.5-2 yrs | 1-3 yrs | 1.5-2 yrs |
| Alaskan malamute | *cd* | Normal looking fundus | 8-10 wks | 6 wks |
| American cocker spaniel | *prcd* | 3-5 yrs | 3-5 yrs | 9 mos |
| Bull Mastiff | *PRA* | 6 mos | 6 mos | 12 mos |
| Cardigan Welsh corgi | *rcd3* | 6-16 wks | 6-8 wks | 3-6 wks |
| Collie | *rcd2* | 6 wks | 6 wks | 2 wks |
| Dachshund (miniature longhaired) | *crd1* | 6-12 mos | 6 mos | 4-9 mos |
| Dachshund (shorthaired) | *crd* | 3 yrs | 3 yrs | 5 wks |
| English cocker spaniel | *prcd* | 4-8 yrs | 3-5 yrs | 12 mos |
| German shorthaired pointer | *cd* | Normal looking fundus | 8-10 wks | 6 wks |
| Irish setter | *rcd1* | 12-16 wks | 6-8 wks | 3-6 wks |
| Labrador retriever | *prcd* | 4-6 yrs | 3-5 yrs | 1.5 yrs |
| Mastiff (Old English) | *PRA* | 6 mos | 6 mos | 12 mos |
| Miniature schnauzer | *PRA-A* | 1-2 yrs | 6-12 mos | 6-8 wks |
| Norwegian elkhound | *erd* | 6-12 mos | 6 wks | 5-6 wks |
| | *rd* | 6-18 mos | 6 mos | 6 wks |
| Papillon | *PRA* | 1.2-5 yrs | 7 yrs | 9 mos-1.5 yrs |
| Pit bull terrier | *crd2* | 3-6 mos | 8 wks | 7 wks |
| Poodle (toy and miniature) | *prcd* | 3-5 yrs | 3-5 yrs | 6-9 mos |
| Portuguese water dog | *prcd* | 3-6 yrs | 3-5 yrs | 1.5 yrs |
| Samoyed | *XLPRA1* | 1.5-2 yrs | 2-4 yrs | 6 mos |
| Siberian husky | *XLPRA1* | 1.5-2 yrs | 2-4 yrs | 6 mos |
| Tibetan terrier | *PRA* | 10-18 mos | 6-12 mos | 10 mos |

Ofri R. Diseases of the Retina. In Maggs, Miller and Ofri. Slatter's Fundamentals of Veterinary Ophthalmology, 6th ed, 2018.

## "Quick Ret Check"

- Dark adapt for 20 min
- Three flashes (0.01, 3 and 10 cd*sec/m²) to test rod and mixed rod-cone response
- Recommended for quick evaluation of retinal function in wildlife (Labelle et al., 2010)

ORIGINAL ARTICLE WILEY

Treatment with chloroquine is retinotoxic in captive African penguins (*Spheniscus demersus*). Attenuation and recovery of electroretinographic responses

Maya Ross | Nili Avni-Magen | Oren Pe'er | Asaf Berkowitz | Ron Ofri



## CONE FUNCTION. GENE THERAPHY IN DAYBLIND SHEEP

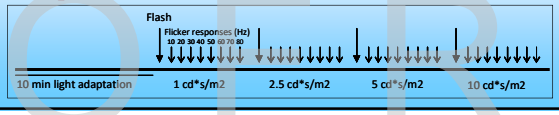
Doc Ophthalmol (2014) 129:141–150
DOI 10.1007/s10633-014-9458-6

ORIGINAL RESEARCH ARTICLE

Flicker cone function in normal and day blind sheep: a large animal model for human achromatopsia caused by CNGA3 mutation

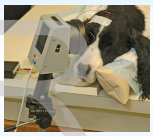
Raaya Ezra-Elia · Eyal Banin · Hen Honig · Alexander Rosov · Alexey Obolensky · Edward Averbukh · William W. Hauswirth · Elisha Gootwine · Ron Ofri

- ➢Light adaptation (10 min, 30 cd/m²)
- ➢Photopic response & Flicker Fusion Test
  - ➢10-80 Hz, in 10 Hz increments – 8 CFF tests
- ➢Repeated at 1, 2.5, 5 & 10 cd*sec/m²



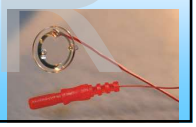

## LECTURE OUTLINE

- How to record an ERG
  - ➢Patient, equipment and protocols
- Factors affecting your recording
- Troubleshooting,



## FACTORS AFFECTING RECORDING

- Stimulating & acquisition protocol
- Stimulating & acquisition equipment
- Anesthesia & pupil size
- Patient oxygenation, temperature, glucose…
- Environment – noise, surrounding light
- Age, Gender & Breed (coming up!!!)
- Retinal pathology…

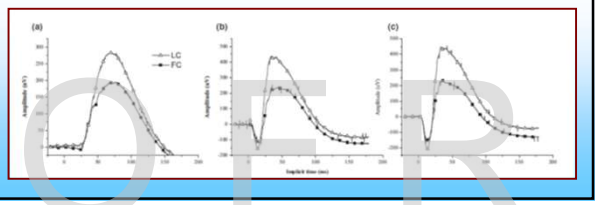


## SPECIES DIFFERENCES

*Veterinary Ophthalmology* (2017) 20, 3, 266–270 DOI:10.1111/vop.12414

Scotopic electroretinography in fishing cat (*Prionailurus viverrinus*) and leopard cat (*Prionailurus bengalensis*)

Metita Sussadee,*,† Narathip Vorawattanatham,‡ Anuchai Pinyopummin,§ Janjira Phavaphutanon¶ and Aree Thayananuphat¶




FREE

ARVO Annual Meeting Abstract | May 2007

Dark-Adaptation ERG Recovery in Different Mice Strains

R. T. Tzekov; N. Matson; D. McGee; R. Kubota

+ Author Affiliations & Notes

Investigative Ophthalmology & Visual Science May 2007, Vol.48, 1520. doi:

Original Article

J Vet Sci 2015, 16(1), 67-74 · http://dx.doi.org/10.4142/jvs.2015.16.1.67

JVS

Normal clinical electroretinography parameters for poodle, Labrador retriever, Thai ridgeback, and Thai Bangkaew

Metita Sussadee[1,2], Janjira Phavaphutanon[3], Kornchai Kornkaewrat[1], Aree Thayananuphat[1,4]

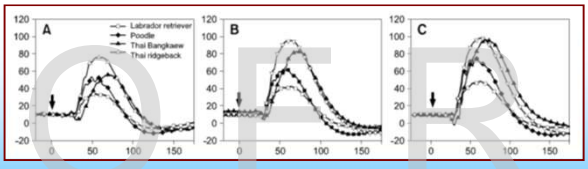
Original Article

JVS

Normal clinical electroretinography parameters for poodle, Labrador retriever, Thai ridgeback, and Thai Bangkaew

Metita Sussadee[1,2], Janjira Phavaphutanon[3], Kornchai Kornkaewrat[3], Aree Thayanauphat[3,*]

4 MIN 8 MIN 12 MIN



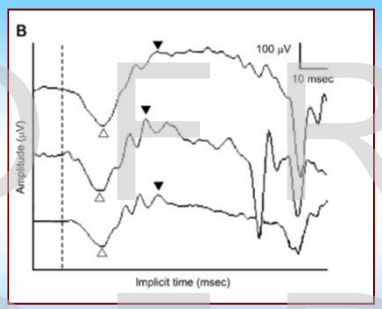

- Responses of Labradors retrievers were consistently lowest
- Ridgeback had highest scotopic responses, Poodles had highest mixed and cone responses

## EFFECT OF AGE

Young

Adult

Senile



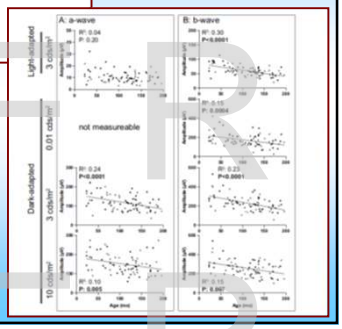

Veterinary Science

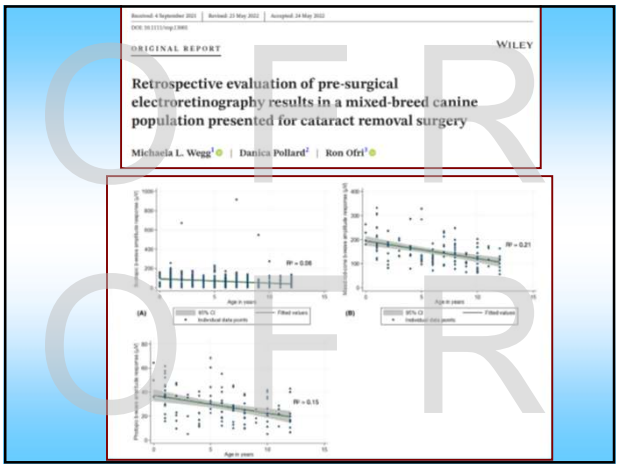
Electroretinography recordings using a light emitting diode active corneal electrode in healthy beagle dogs

ORIGINAL RESEARCH ARTICLE

Age-associated changes in electroretinography measures in companion dogs

Michele M. Salzman · Natascha Merten · Wojciech K. Panek · Gilad Fefer · Alejandra Mondino · Hans D. Westermeyer · Margaret E. Gruen · Natasha J. Olby · Freya M. Mowat





ORIGINAL REPORT

WILEY

Retrospective evaluation of pre-surgical electroretinography results in a mixed-breed canine population presented for cataract removal surgery

Michaela L. Wegg[1] | Danica Pollard[2] | Ron Ofri[1]

## FACTORS AFFECTING RECORDING

- Stimulating & acquisition protocol
- Stimulating & acquisition equipment
- Anesthesia & pupil size
- Patient oxygenation, temperature, glucose…
- Age, Gender & Breed
- Environment – noise, surrounding light
- **Retinal pathology…**

*Documenta Ophthalmologica* **106**: 229–230, 2003.
© 2003 *Kluwer Academic Publishers. Printed in the Netherlands.*

The lens-coating agent and the electroretinogram

Alexandra Serrato, Radouil Tzekov & Michael F. Marmor
*Department of Ophthalmology, Stanford University Medical Center, Stanford, CA, USA*

ORIGINAL REPORT

WILEY

Retrospective evaluation of pre-surgical electroretinography results in a mixed-breed canine population presented for cataract removal surgery

Michaela L. Wegg[1] | Danica Pollard[2] | Ron Ofri[1]

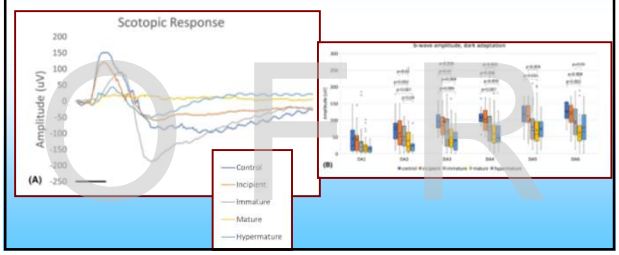
*Veterinary Ophthalmology* (2007) **10**, 5, 308–312

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

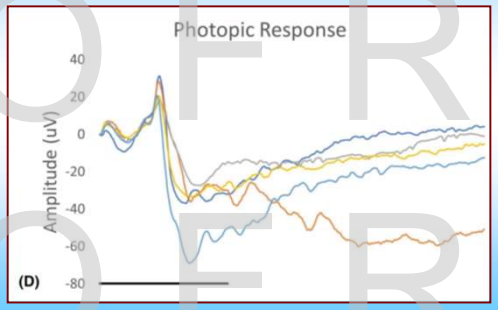
Seiya Machara, Norihiko Itoh, Shinsuke Wakaiki, Ayako Yamasaki, Keiko Tsuzuki and Yasuharu Izumisawa
*Department of Small Animal Clinical Sciences, School of Veterinary Medicine, Rakuno Gakuen University, Ebetsu, Hokkaido Japan*

## DARK ADAPTED ROD RESPONSES

- Amplitudes, but not implicit times, decreased in mature and hypermature cataracts

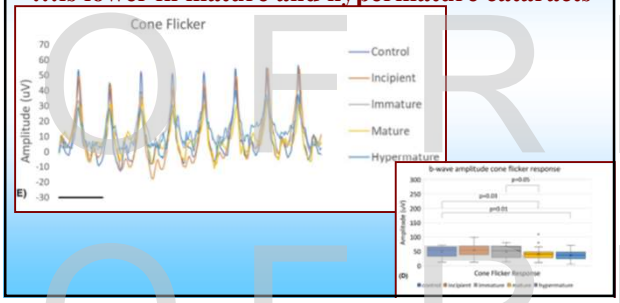



## SINGLE-FLASH PHOTOPIC (CONE) RESPONSE NOT AFFECTED

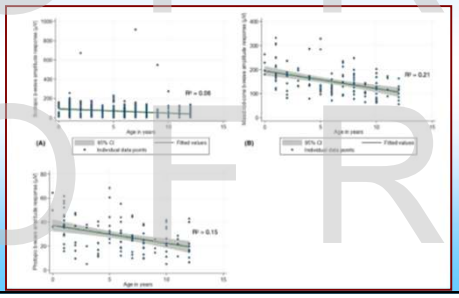



## BUT CONE FLICKER AMPLITUDE…

…is lower in mature and hypermature cataracts

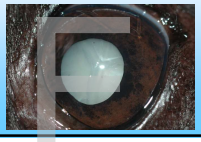


## And once again, age matters!



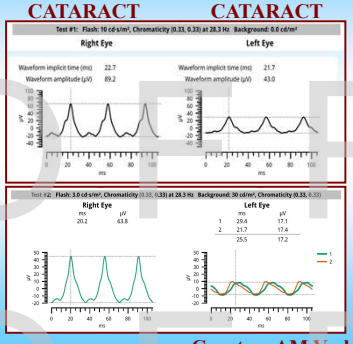
## TAKE-HOME LESSONS

- Post-operatively, all dogs were visual, with normal fundus exam, so decrease in advanced cataract likely due to stimulus diffusion by cataract
  - Maehara et al report increased amplitude post-operatively, and similar findings in humans
- Advanced age/cataract may affect your recordings!



## IMMATURE CATARACT

## MATURE CATARACT




Courtesy AM Verbruggen

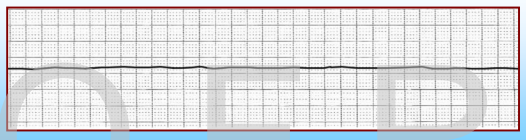
## LECTURE OUTLINE

- How to record an ERG
  - ➢Patient, equipment and protocols
- Factors affecting your recording
- **Troubleshooting**

## POSSIBLE PROBLEMS & SOLUTIONS. I

**FLAT LINE**

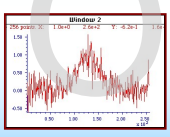
- **Is amplifier connected to power?**
- **Are electrodes connected to amplifier?**

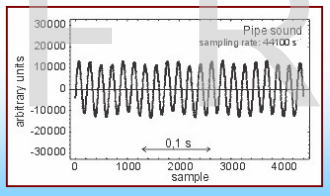


## POSSIBLE PROBLEMS & SOLUTIONS. II

**NO ERG SIGNAL, LARGE 50 Hz NOISE**

- **Are all electrodes connected to patient?**

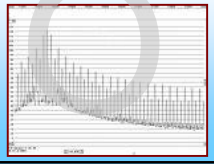


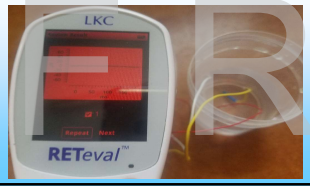


## POSSIBLE PROBLEMS & SOLUTIONS. III

**ERG SIGNAL & SIGNIFICANT 50Hz NOISE**

- Place 3 electrodes in saline cup.
- If noise is gone, your problem is the connection to the patient

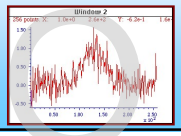


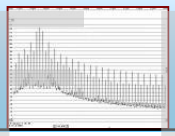



## POSSIBLE PROBLEMS & SOLUTIONS. III

**If there is no 50 Hz noise in the saline cup…**

- Check electrode impedance & reposition
  - Are needle electrodes inserted all the way?
  - Too much methylcellulose in active electrode?
- Check electrodes and cables for small breaks
  - Clean/replace all electrodes

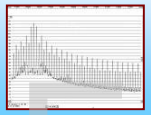




## POSSIBLE PROBLEMS & SOLUTIONS. III

**If the 50 Hz noise persists in the saline cup…**

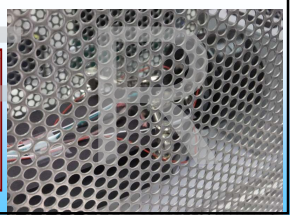
- Disconnect other electric equipment in room
- Uncoil all electric cables in room
- Disconnect electric equipment in nearby rooms



## POSSIBLE PROBLEMS & SOLUTIONS. III

**If the 50 Hz noise persists in the saline cup…**

- **Move to a different room**
- **Shield animal/equipment**
  - ➢**Faraday cage**

## THANK YOU!