

Electroretinogram evaluation of equine eyes with extensive ‘bullet-hole’ fundic lesions

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Abstract

Objective To evaluate the impact of extensive bullet-hole nontapetal fundic lesions in horses on retinal function as measured by full-field electroretinography (ERG).

Materials and Methods Full-field ERG was performed on two horses with numerous bullet-hole lesions in the nontapetal fundus of both eyes. The ERG was first recorded from the eye with the more extensive lesions in response to a low-intensity light stimulus (0.03 cd s/m^2) that was given at times (T) $T = 5, 10, 15, 20$ min of dark adaptation. Consecutively, combined rod–cone response was evaluated bilaterally in response to high-intensity light stimulus (3 cd s/m^2), followed by cone function evaluation by flicker stimulus (3 cd s/m^2 at 30 Hz). Off-line analysis of the ERG recordings was then performed.

Results Despite extensive bullet-hole lesions in the nontapetal fundus bilaterally in both horses, retinal function as measured by ERG did not show any observable deficits. The b-wave amplitude of the full-field ERG increased continuously from 5 to 20 min of dark adaptation peaking at $446 \mu\text{v}$ and $377 \mu\text{v}$ for horse number 1 and 2, respectively. The b-wave amplitudes of the combined rod–cone response were OS- $459 \mu\text{v}$ and OD- $392 \mu\text{v}$ for horse number 1 and OS- $491 \mu\text{v}$ and OD- $608 \mu\text{v}$ for horse number 2. The amplitude of the flicker ERG for horse number 1 was OS- $86 \mu\text{v}$ and OD- $110 \mu\text{v}$ and for horse number 2, OS- $80 \mu\text{v}$ and OD- $74 \mu\text{v}$.

Conclusions Extensive bullet-hole chorioretinal lesions do not appear to compromise outer retinal function in these horses.

Key Words: bullet-hole, electroretinogram, focal chorioretinopathy, horse, nontapetal fundus, retina

INTRODUCTION

Bullet-hole chorioretinal lesions, also termed focal chorioretinopathy,¹ are occasionally observed in equine eyes in the nontapetal fundus horizontally adjacent to or below the optic nerve head.^{2–6} One report suggested that bullet-hole scars may be observed in 10 to 20% of horses in the northeastern United States.⁴ The classic appearance is pinpoint focal nontapetal depigmentation with possible central hyperpigmentation and may be described as a bird-shot pattern.⁷ Lesions may be few in number, extensive with a ventral linear distribution, or more diffusely affect the nontapetal fundus causing a dramatic change in appearance. It has been noted that they rarely may extend into the tapetal fundus.¹

The exact cause or possible causes of bullet-hole lesions are not known although choroidal vasculitis, infarction,

and ischemia are the proposed pathogenesis.¹ An association with respiratory disease and viral chorioretinitis has previously been suggested.^{4,8} Studies in foals and ponies experimentally infected with EHV-1 demonstrated development of similar-appearing lesions, which supports viral infection as an etiology.^{9,10} An association with equine leptospirosis or a different causative agent of equine recurrent uveitis has also been discussed, and bullet-hole chorioretinal lesions may occur in association with peripapillary chorioretinitis or ‘butterfly’ lesions.^{11,12}

These lesions show histologic loss of normal retinal architecture with retinal pigment epithelium (RPE) hyperplasia and RPE cell migration into the degenerate neurosensory retina, but have an uncertain effect on retinal function or vision.^{1,13} Authors of articles detailing bullet-hole lesions in clinical surveys speculate varying impact on vision, but no objective assessment of retinal

function has been performed. The purpose of this report is to document electroretinogram (ERG) study of two horses affected with numerous bullet-hole lesions in the nontapetal fundus of both eyes.

MATERIALS AND METHODS

Two horses with similar bilateral extensive bullet-hole chorioretinal lesions (Fig. 1) were evaluated at the Iowa State University Lloyd Veterinary Medical Center (ISU LVMC). Both horses were intact female Arabians of similar age, 11 and 12 years old, weighing 430 and 446 kg, respectively. Complete ophthalmic examinations were performed including fluorescein staining, tonometry with a rebound tonometer (TonoVet[®], Tiolat Ltd, Helsinki, Finland), slit-lamp biomicroscopy (SL-14 Biomicroscope, Kowa Company, Ltd, Tokyo, Japan), and both direct (Welch Allyn, Inc., Skaneateles Falls, NY, USA) and indirect ophthalmoscopy (HEINE Omega 180[®] Ophthalmoscope, HEINE Optotechnik, Herrsching, Germany) following pupil dilation with tropicamide (1% tropicamide ophthalmic solution, Bausch and Lomb Inc., Tampa, FL, USA). Both horses had undergone complete examinations by the same ophthalmologist (RAA) between 18 and 24 months previously at the times of first fundus pathology recognition with no change in the clinical findings over time.

For ERG evaluation, horses were initially sedated with 5 mg of detomidine hydrochloride (Dormosedan[®], Pfizer Animal Health, New York, NY, USA) intravenously and additional 3 mg of detomidine was given IV to maintain adequate sedation for the duration of the ERG protocol. Auriculopalpebral nerve blocks were performed bilaterally with 1–2 ml of 2% lidocaine (Xylocaine[®], APP Pharma-

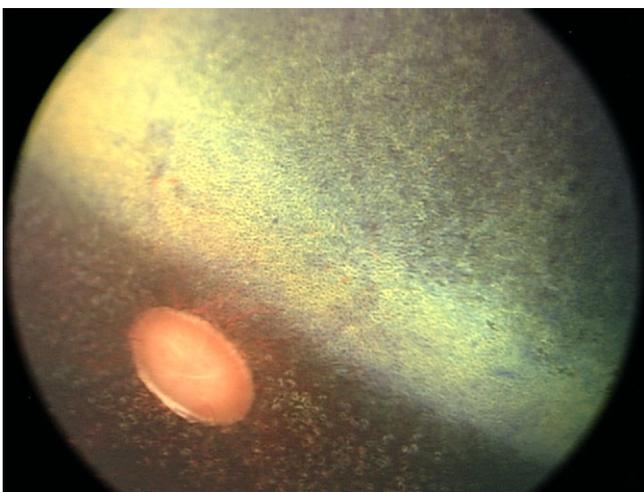


Figure 1. Fundic image of the right eye in a 12-year-old female Arabian (Horse 2) showing normal tapetal fundus, healthy optic disk, and retinal vasculature yet numerous bullet-hole lesions in the nontapetal fundus.

ceuticals, LLC, Schaumburg, IL, USA). To prevent drying of the cornea, manual blinking was performed during the recording period. To allow for optimal ERG results, no examination light illumination or photography was performed within 1 h of testing and horses were kept in ambient barn lighting.

A mini-Ganzfeld electroretinographic unit (Handheld Multispecies ERG [HMSeRG] Model 1000, Xenotec, Inc., Rolla, MO, USA) and gold foil contact lens electrode (ERG-jet[™], Fabrial, La Chaux-de-Fonds, Switzerland) were used to perform testing on both eyes of each horse as has been previously reported.^{14,15} Topical anesthesia (0.5% Tetracaine hydrochloride ophthalmic solution, Bausch and Lomb Inc., Tampa, FL, USA) was applied to each eye prior to corneal electrode placement. The contact lens recording electrode was placed on the cornea with 2.5% hypromellose (Goniovise[™], Sigma Pharmaceuticals, LLC, Monticello, IA, USA), while stainless steel reference and ground electrodes (GVM geliMED, Bad Segeberg, Germany) were placed subcutaneously 3 cm posterior to the lateral canthus and midway down the neck, respectively. All electrodes and the first-stage amplifier were secured to the halter with tape to facilitate maintaining electrode positioning, as previously described.¹⁴ The examination room was darkened so that testing of the dark adaptation curve could commence, and illumination was confirmed to be 0 Lux (LX1330B Digital Photometer, Dongguan Huayi Mastech Co., Ltd. Guangdong, China). The ERG was first recorded from the eye with the more extensive lesions in response to four low-intensity light stimuli (0.03 cd s/m²) given at a frequency of 0.1 Hz at each time (*T*) point: *T* = 5, 10, 15, 20 min of dark adaptation. Consecutively, the combined rod-cone response was evaluated bilaterally in response to four high-intensity light stimuli (3 cd s/m² at 0.1 Hz) followed by cone function evaluation by flicker stimulus (3 cd s/m² at 30 Hz). The four light stimuli were averaged for each time point. The low band-pass limit was 0.3 Hz, and the upper was 300 Hz.

Following data acquisition, off-line analysis of the ERGs was performed using the HMSeRG software. The a- and b-wave amplitudes and implicit times were measured for each horse.

RESULTS

Clinical evaluation of both horses revealed hundreds of bullet-hole lesions in the nontapetal fundus medial, lateral, and ventral to the optic nerve head in OU with OS lesions subjectively more numerous in both horses (Fig. 2). The tapetal fundus, retinal blood vessels, and optic nerve heads appeared normal bilaterally in both horses with no evidence of retinal vascular attenuation over affected nontapetal regions. Incidental findings in Horse 1 (11-year-old Arabian mare) included very mild cystic corpora nigra and very mild vitreal degeneration in OU. Although no

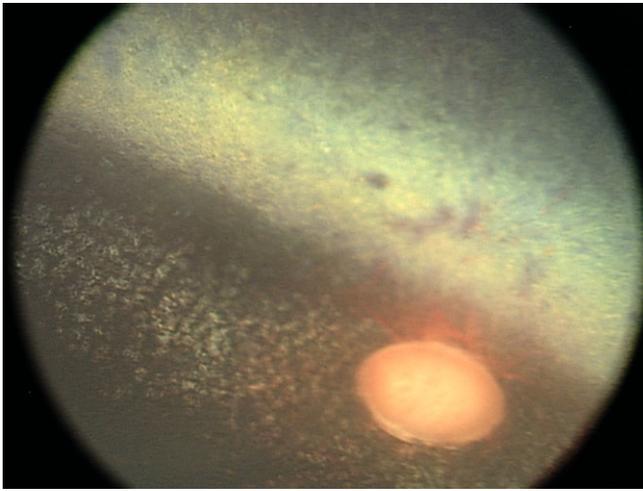


Figure 2. Appearance of the left fundus in the same patient showing subjectively denser bullet-hole lesions.

vision deficits were observed based on cranial nerve examination and navigation in ambient and dim light, moderate mydriasis was present in OU during clinical examination with positive, but incomplete pupil light reflexes. The intraocular pressures were normal (OS- 26 mm Hg and OD- 28 mm Hg). Repeat evaluation of the pupils outside the clinical setting in sunlight revealed normal complete pupil constriction OU. Horse 2 (12-year-old Arabian mare) also had mild vitreal degeneration (OD < OS), present and complete PLRs, and no detectable vision deficits based on cranial nerve examination and navigation in ambient and dim light. Intraocular pressures were OS- 17 mm Hg and OD- 16 mm Hg. Both horses initially exhibited occasional nervous excitement in the hospital setting, similar to other equine outpatients, but settled in quickly with no continued or consistent behavior issues.

The scotopic b-wave amplitude increased continuously from 5 to 20 min of dark adaptation peaking at 446 μV and 377 μV for Horses 1 and 2, respectively. The b-wave amplitudes of the combined rod-cone response were OS- 459 μV and OD- 392 μV for Horse 1 and OS- 491 μV and OD- 608 μV for Horse 2. The full data of the a- and b-wave amplitudes and implicit times are presented in Tables 1 and 2. The amplitude of the flicker ERG for Horse 1 was OS- 86 μV and OD- 110 μV and for Horse 2

Table 1. Rod response of the left eye: b-wave amplitude and implicit time during dark adaptation

Dark adaption (Min)	Horse 1 – b-wave		Horse 2 – b-wave	
	Amplitude (μV)	Implicit time (msec)	Amplitude (μV)	Implicit time (msec)
5	269	78	91	59
10	354	79	221	66
15	432	90	368	78
20	446	85	377	79

Table 2. Combined rod-cone response: amplitude and implicit time

	Horse 1		Horse 2	
	Amplitude (μV)	Implicit time (msec)	Amplitude (μV)	Implicit time (msec)
a-wave				
Left eye	160	13	140	14
Right eye	159	13	93	14
b-wave				
Left eye	459	77	491	62
Right eye	392	69	608	61

Table 3. Amplitudes of the cone flicker responses

	Horse 1 Amplitude (μV)	Horse 2 Amplitude (μV)
Left eye	86	80
Right eye	110	74

OS- 80 μV and OD- 74 μV (Table 3). Representative traces of the ERG recordings are shown in Figure 3.

DISCUSSION

Extensive bullet-hole, or focal, chorioretinal lesions were found in both of the horses in this report as an incidental finding during ocular examinations for other reasons. Horse 1 was noted to have numerous chorioretinal scars during prepurchase examination and was referred for evaluation. Horse 2 was noted to have bullet-hole lesions during a general physical, including a complete ocular examination. No evidence of lesion progression was noted in either horse up to 2 years following initial examination; however, the lesions were too numerous to accurately count during either examination. Visual deficits were not noted at any time by the current or previous owners and attempted maze testing performed in the ISU LVMC did not reveal any subjective visual impediments. Furthermore, both horses are used for trail riding, and no vision deficits have been observed when riding at any time of day, including night time.

Determining the effect of fundic or other ocular lesions on vision is extremely challenging due to lack of studies evaluating this correlation and the inability to use verbal communication with the veterinary patient, unlike with human patients. Subjective tests such as maze testing and observation of the horse in unfamiliar environments can provide a crude estimate of visual function. Retinal function tests such as the full-field ERG can help provide objective information to complete the assessment. As the full-field ERG evaluates cumulative retinal function, results within normal values do not guarantee normal function of all photoreceptors. Topographic evaluation of retinal function can be performed utilizing the multifocal ERG and may add to our understanding of the effect of

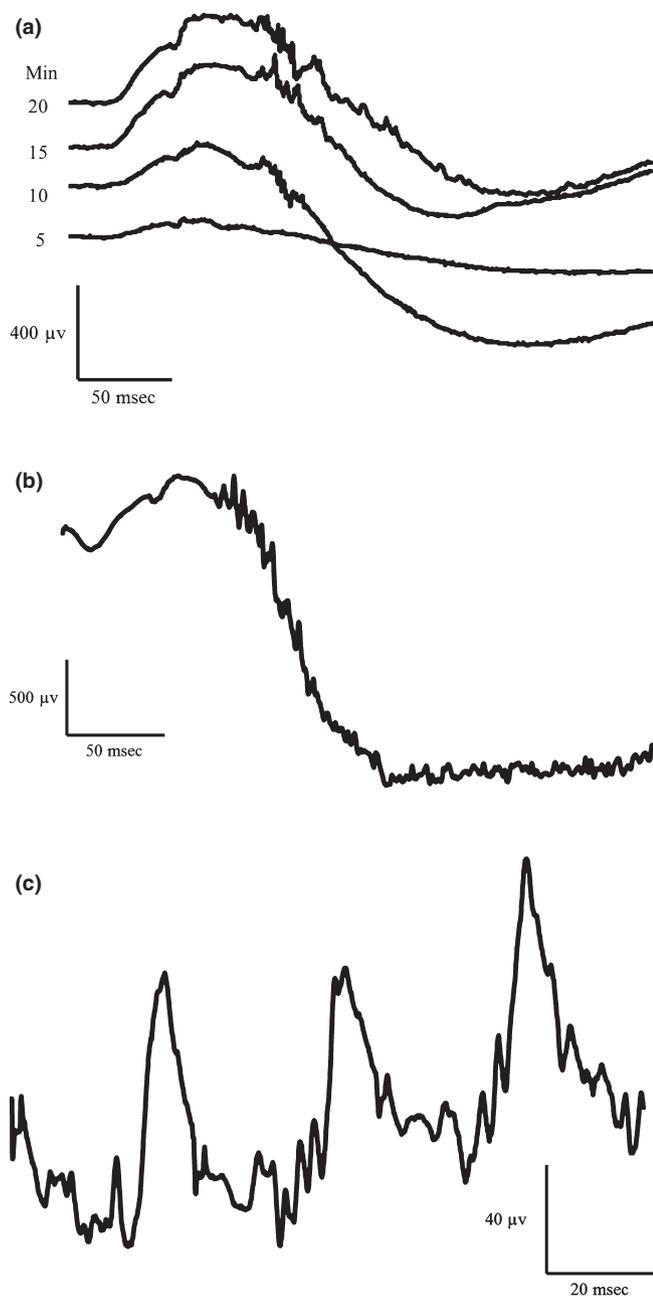


Figure 3. Representative traces of the different responses, recorded from the left eye of Horse 2. (a) Individual traces demonstrating the increased b-wave amplitude of the rod response during dark adaptation. (b) Combined rod-cone response. (c) Flicker cone response.

bullet-hole lesions on retinal function. Moreover, postretinal lesions may affect vision, but not the full-field ERG. Nonetheless, when ERG deficits are present, it is likely that visual deficits are also present.

For both horses, ERG recordings were consistent with retinal function measured in horses free of ocular disease as recorded in our laboratory (data not published) and as previously reported.¹⁴ The horses in this study are older than the horses in our previous report for which the

average age was 6.2 years.¹⁴ Comparison of ERG values should be ideally performed between breed- and age-matched groups. To date, there are no studies evaluating the effect of age on equine ERG. Nevertheless, the amplitudes in these two studies seem comparable. Ben-Shlomo *et al.*¹⁶ have demonstrated that multifocal outer retinal lesions spread throughout half of the retina lead to significant reduction of b-wave amplitude in the rat. While direct comparison between the equine and rat retina is suboptimal, we hypothesized that extensive bullet-hole lesions, as seen in these two horses, would affect the full-field ERG amplitude if these lesions involved the outer retina. Such an effect was not documented in this study; however, further anatomic study would help determine the effect of bullet-hole lesions on these horses' outer retinas.

Optical coherence tomography (OCT) could be performed to assess retinal structural changes in the region of these lesions as has been recently described.^{17,18} A single horse with bullet holes had spectral domain (SD)-OCT performed and images showed hyperechoic lesions, suggesting cellular proliferation or migration within the outer retina.¹⁸ It is unknown whether the changes represent primary retinal cells, migrating pigment cells, or other changes. As previously mentioned, histologically studied lesions show loss of normal retinal architecture with pigment cell alterations, but effect on retinal function or vision is still uncertain.¹ Fluorescein angiography could also be performed to further characterize the lesions in these two horses and compared with normal horse findings.¹⁹ Slater *et al.* noted hyperfluorescence to focal depigmented lesions in the nontapetal fundus which occurred in three ponies 6 to 8 weeks following experimental intranasal EHV-1 infection and speculated choroidal infarction as a cause, but did not note retinal vascular phase deficits or leakage to suggest peripapillary retinal compromise.¹⁰ A more recent publication points out that infarction of the choroidal vasculature would be expected to appear as nonfluorescing, dark areas on fluorescein angiography which is inconsistent with the previous description.¹¹

Critical review of the two cases in our study does reveal some indicators of possible retinal compromise. The first is the relative mydriasis and incomplete PLRs noted for Horse 1 at the time of both clinical examinations 2 years apart; however, when pupil size was later evaluated outside on a sunny day, complete pupil constriction was present OU. This finding suggests sympathetic stimulation affecting pupil dilation due to anxiety at the time of in-hospital examinations.²⁰ The second was initial nervous behaviors to unfamiliar objects and circumstances in the hospital as noted during the ophthalmic examinations and intermittently observed by owners of both horses. Behaviors like this are not uncommon in horses and are especially notable in Arabians with an apparent higher grade of reactivity than horses of some other breeds; hence, we did not attribute it to visual deficits.

As is consistent with a claim in the literature⁶ and personal experience, no evidence of active chorioretinal disease or bullet-hole lesion progression was noted in either of these patients. Nell and Walde¹¹ do state that widespread occurrence of bullet-hole lesions may lead to progressive fundus degeneration accompanied by subtle to obvious visual impairment, but that did not occur in these two horses with extensive lesions. Both horses were reexamined 16 months following ERG assessment for a total of 34–40 months follow-up with no changes noted. It is possible that respiratory disease or viral infection earlier in these horses' lives could have caused the chorioretinal scars. The lesion extent in both horses is more severe than those pictured in other reports, yet still did not affect ERG results or cause any observable visual deficits.

In one study of 204 racing Thoroughbreds, 50% of horses had peripapillary focal inactive bullet-hole lesions that numbered less than 20 and were presumed to have little impact on equine vision. Five horses in the study had greater than 20 lesions with one of the horses noted to have greater than 50 appearing in a linear band.³ The horses with more than 20 lesions were categorized with potential vision-threatening eye disease in that report. In these two horses with extensive bullet-hole chorioretinal lesions, no outer retinal function deficits were observed on electroretinographic evaluation. Further studies could be performed to evaluate *in vivo* structural changes to the retina and inner retinal function. Histologic examination could also be performed to look for microscopic structural changes if ocular tissues become available in these horses for other reasons.

In conclusion, even extensive bullet-hole chorioretinal lesions may not cause observable visual or ERG deficits in horses. This is consistent with the previous claim that equine bullet-holes may be considered nonprogressive incidental findings.⁶ Horses with lesions may still be good companion horses, and this should be considered when performing equine prepurchase examinations.

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