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Long-term ophthalmologic examinations of eyes with Equine Recurrent Uveitis after an intravitreal injection of gentamicin

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Summary: Equine Recurrent Uveitis (ERU) is an episodic inflammatory disease of the eye and the most common cause of blindness in horses. The objective of this study was to evaluate a long-term success rate after an injection of 4 mg gentamicin performed between 2016 and 2020 on 82 eyes with a history of ERU. Owners of the horses were contacted and follow-up information was obtained for 69 horses (82 treated eyes). An ophthalmological reexamination including tonometry, induction of mydriasis, slit lamp biomicroscopy and direct ophthalmology was performed in 54 horses (65 treated eyes). An examination of visual acuity was conducted by the dazzle reflex and the menace response. Further information such as gender, age and breed of the horses, as well as leptospiral status were included. Pre-existing damages and further development of these from injected eyes are described using a score. In this study, 75.6% of eyes showed no further recurrences of ERU after injection. Thirty-two eyes (39%) were blind at the time of reexamination which represents a deterioration of 12.2% compared status to before injection. The main reasons for blindness are mature or hypermature cataract formation and retinal detachment as a result of the previous damage. The breed and coat colour, the kind of anaesthesia (general anaesthesia or sedation) and the number of ERU episodes pre-injection showed no significant correlation with the prevalence of recurrences. The risk of suffering recurrences of ERU increased significantly with an increasing pre-injection score. Furthermore, there is a significant influence of increasing age on the chance of recurrences of ERU after injection, and five leptospiral negative eyes were shown significantly more recurrences than ten leptospiral positive eyes. The present study shows, even if a clearing of the optical axis is not to be expected, that the intravitreal injection of gentamicin against ERU seems to be a useful addition to the therapy methods existing already.

Keywords: equine recurrent uveitis, ERU, intravitreal injection, gentamicin, horse, eye, ophthalmology

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Introduction

Equine Recurrent Uveitis (ERU) is an inflammation of the inner structures of the eye and its vascular tissue (iris, ciliary body, choroidea) in horses (*Gilger* and *Michau* 2004). It can occur either as bouts of inflammation with an acute stage alternately with a quiescent stage, or as a persistent and mild inflammation of the eye (*Gilger* and *Deeg*, 2011, *Allbaugh* 2017). Due to the continuing destruction of the eye, ERU is the most common reason for blindness in horses (*Dwyer* et al. 1995, *Gilger* and *Deeg* 2011, *Gerding* and *Gilger* 2015) and results in not only economic loss for the owners (*Gerhards* and *Wollanke* 2001, *Gerding* and *Gilger* 2015) but also means a great deal of effort spent for the welfare management of the horses concerned (*de Boyer des Roches* et al. 2021). The prevalence of ERU in Europe is between 2.7 and 7.8% (*Alexander* and *Keller* 1990, *Szemes* and *Gerhards* 2000, *Henriksen* et al. 2022). Typical clinical symptoms of ERU are blepharospasm, epiphora, photophobia, miosis, aqueous flare, cataract formations of the lens, synechiae/residues of the iris and cloudiness of the vitreous due to products caused by inflammation up to fibrin deposits. The general condition could also be disordered because of the painful inflammation in the eye (*Gilger* and *Michau* 2004, *Pichon* 2015, *Allbaugh* 2017, *Kleinpeter* et al. 2019). Phthisis bulbi and retinal detachment could be seen in the "end-stage" of the condition (*Allbaugh* 2017). The exact aetiology of ERU is not yet fully understood. A combination of autoimmune disease, genetic predisposition, infection with leptospira and their building of biofilms, and different environmental factors could be responsible for ERU (*Dwyer* et al. 1995, *Gilger* 2010, *Pichon* 2015, *Baake* et al. 2016, *Bellone* 2020, *Degroote* and *Deeg* 2021, *Geißler* and *Wollanke* 2021, *Himebaugh* and *Gilger* 2021, *Geiger* et al. 2022, *Hack* et al. 2022). In addition to a detailed ophthalmologic examination of the horse affected, a conversation with the owner about its clinical history is very important to differentiate ERU from a traumatic uveitis which occurs mostly once (*Tömördy* et al., 2010, *Gilger* and *Deeg*, 2011). The treatment of ERU should be started as quickly as possible to reduce pain, prevent destruction of the inner structures of the eye and avoid

loss of sight (*Gilger* and *Michau*, 2004, *Baake* et al., 2016). After treating the acute inflammation with topical ophthalmic ointment and drops (*Gilger* and *Michau* 2004, *Gilger* 2010), the common surgical procedures in the quiescent stage are a pars plana vitrectomy (*Frühauf* et al. 1998, *Gerhards* and *Wollanke* 2001, *von Borstel* et al. 2005, *Tömördy* et al. 2010, *Baake* 2017, *Schinagl* 2017) and insertion of a cyclosporine implant (*Gilger* et al. 2000, *Keller* and *Hendrix* 2005, *Gilger* et al. 2006). A suprachoroidal injection of 5 mg triamcinolone has also been described to reduce inflammation, especially in horses which are not responsive to standard therapies (*Gagnon* et al. 2021). Oral doxycycline administration is also described in the literature anecdotally, but the concentrations achieved in the vitreous body do not seem to be sufficient against leptospiral ERU (*Gilger* and *Michau* 2004, *Gilmour* et al. 2005). By contrast, systemic administration of enrofloxacin achieved vitreous concentrations above the minimum bactericidal concentration of leptospires (*Giguère* and *Bélanger* 1997, *Gilger* and *Michau* 2004, *Divers* et al. 2008, *Popp* et al. 2013), but this did not result in complete leptospiral death and 30.1 % of samples continued to show positive culture results. Reliance on this treatment method alone is not recommended (*Popp* et al. 2013). An intravitreal injection of 4 mg gentamicin (0.14 mg/ml vitreous), a bactericidal aminoglycoside antibiotic, in equine eyes suffering from ERU was performed for the first time in 2005 (*Pinard* et al. 2005). Although knowledge about the effect of gentamicin against ERU is limited (*Launois* et al. 2019), more authors used this technique in the following years because of the absence of bouts of inflammation after injection (*Fischer* et al. 2019, *Kleinpeter* et al. 2019, *Launois* et al. 2019). An intravitreal injection of gentamicin is easy to perform, cost-efficient and could be executed in sedation at the home stable. Authors in four studies since 2005 have had good experiences with an intravitreal injection of a low dose of gentamicin to avoid recurrences of ERU (*Pinard* et al. 2005, *Fischer* et al. 2019, *Kleinpeter* et al. 2019, *Launois* et al. 2019). No recurrences of uveitic symptoms were observed in these studies in a range between 88.1 (*Fischer* et al. 2019) and 98.6 % (*Launois* et al. 2019) of the eyes included in the studies. These success rates are comparable to published studies about reexaminations after vitrectomy (73.6–97.7 %) (*Winterberg* and *Gerhards* 1997, *Frühauf* et al. 1998, *von Borstel* et al. 2005, *Tömördy* et al. 2010, *Keiter* et al. 2017, *Schinagl* 2017, *Baake* et al. 2019, *Voelter* et al. 2020), but the number of cases in studies regarding the intravitreal injection of gentamicin are much lower (eyes evaluated after vitrectomy: 1245; eyes evaluated after an intravitreal injection of gentamicin: 209). The aim of the current study was to establish a long-term prognosis for eyes affected by ERU after an intravitreal injection of gentamicin based mainly upon ophthalmologic reexaminations and depending on pre-existing alterations.

Materials and Methods

Patient population

A total of 82 eyes from 69 horses with ERU were treated with an intravitreal injection of gentamicin either at the equine clinic of the University of Veterinary Medicine of Hannover or at a home stable between 2016 and 2020 and fitted the study criteria. All data (individual descriptions, medical history, clinical records) were collected from medical records or imposed by the authors. Information on the further course after the injection could be determined by the authors.

Ophthalmologic examination and ERU Score

All horses were diagnosed with ERU by a German veterinarian specialist for ophthalmology at the home stable or the clinic for horses after referral. They were examined under mydriasis including slit lamp biomicroscopy, direct ophthalmoscopy, tonometry and, if necessary, with ultrasonography to evaluate the pre-existing damage of the eyes affected and the status of the disease. The eyes examined were evaluated according to an ERU Score established previously to determine a preinjection score (*von Borstel* et al. 2010). The iris, lens, vitreous, fundus oculi and other chronic changes were judged with values ranging from zero (no abnormality detected) to five (high-grade abnormalities) (Table 1). At the end, every eye was given a total score (*von Borstel* et al. 2010). The ERU Score was used for all 69 eyes (58 horses) where clinical data from ophthalmologic examinations before and after injection were available. The score post intravitreal injection of gentamicin was compared to the score pre-injection of gentamicin in the vitreous that was based on medical records.

Intravitreal injection

Recurrently inflamed eyes (n = 67) were injected in the quiescent phase of disease, while high-grade and persistently inflamed eyes which did not show any improvement on conservative therapy with topical ophthalmic ointment and drops were also injected in the acute phase (n = 15 eyes).

Until September 2018 a total of 34/69 horses (49.3 %) with 42/82 eyes (51.2 %) were treated under general anaesthesia in the clinic for horses. Accordingly, they were stabled at least one day prior to the intravitreal injection and received dexamethasone, neomycin and polymyxin B[1] as a topical ophthalmic ointment every three hours and atropine as topical ophthalmic drops[2] (0.5 %) twice a day for preinjection treatment. Horses were given flunixin-meglumin[3] through an intravenous catheter in a dosage of 1.1 mg per kg body weight one hour prior to the intravitreal injection.

A total of 35/69 horses (50.7 %) with 40/82 eyes (48.8 %) underwent an intravitreal injection of gentamicin under sedation. This was done either in the clinic for horses or the home stable by the same veterinarian. The preinjection treatment was the same as that under general anaesthesia, with dexamethasone, neomycin and polymyxin B[1] as a topical ophthalmic ointment, atropine as topical ophthalmic drops[2] (0.5 %) and flunixin-meglumin[3] intravenously in a dosage of 1.1 mg per kg body weight.

Thirty-four horses were put under general anaesthesia with triple drip (guaifenesin[4], xylazin[5], ketamin[6]) and placed in lateral recumbency with the affected eye above. The eye was flushed with a 1 % povidone-iodine solution and, subsequently, with saline solution[7]. After draping surgically, the eyelids were opened by using an eye speculum and the dorsal sclera was

presented by utilising a rotator in the ventral conjunctival sac. Thirty-five standing horses were sedated with detomidin[8] and butorphanol[9] after premedication for their procedure. After flushing the affected eye with 1% povidone-iodine solution and saline solution[7], a topical anaesthesia of conjunctiva and cornea was induced with Oxybuprocain[10] ophthalmic drops. A nerve block anaesthesia was performed subcutaneously with Mepivacain[11] at the nervus auriculopalpebralis caudal of the arcus zygomaticus and at the nervus frontalis located above the foramen supraorbital. The dorsal sclera was presented to the veterinarian by utilising a single eyelid lifter dorsal, a rotator in the conjunctival sac ventral and by rotation of the head of the horse in the longitudinal axis with the eye affected above.

The intravitreal injection in both anaesthesia techniques was performed approximately 10–12 mm above the dorsal limbus in the pars plana at nearly 12 o'clock by protection of the vessels. An amount of 4 mg gentamicin[12] in 0.1 ml mixed with 0.5 ml saline solution[7] was slowly and steadily injected into the vitreous with a 1 ml syringe and a 25 gauge needle. The needle was aimed at the papilla optics to prevent the lens and retina from damage. After the injection, the puncture was compressed by tweezers to avoid haemorrhage of the conjunctiva and leakage of vitreal material. All horses, except one which had an acute corneal ulceration, received 10 mg triamcinolone[13] in 1 ml subconjunctivally at 10 or 2 o'clock in the same eye after the intravitreal injection. Finally, the eyes treated were nursed with vitamin A[14] ophthalmic ointment.

An ophthalmologic examination with a slit lamp and direct ophthalmoscopy was performed every day after injection and treatment with dexamethasone, neomycin and polymyxin B[1] as a topical ophthalmic ointment every three hours was continued during hospitalization the following 24 hours and for another 14 days every 8 hours subsequently at the home stable. The oral flunixin-meglumin[15] therapy was sustained in the evening of the injection day, the morning after at the full dosage of 1.1 mg per kg body weight and in the evening one day after injection at the half-dosage of 0.55 mg per kg body weight.

Four eyes of four horses were treated with an intravitreal injection of gentamicin after vitrectomy. One of these eyes was injected in the same surgical intervention because of retinal detachment at the beginning of the vitrectomy. The remaining horses were treated 2, 6 and 11 months after vitrectomy because of recurrences.

Samples of aqueous humour were collected from the anterior ocular chamber in 15 eyes to measure the leptospiral concentration with a microscopic agglutination test (MAT) and polymerase chain reaction (PCR) in an external laboratory[16]. Four eyes were sampled during vitrectomy. The remaining eleven eyes were sampled during injection in general anaesthesia.

Table 1 Score for chronic uveitis findings of the ocular compartments most affected (*von Borstel* et al. 2010). | *Score für chronische Uveitis-Befunde der am meisten betroffenen Augenkompartimente (von Borstel et al. 2010).*

Score	Iris	Lense	Vitreous	Fundus oculi	Other chronic changes
0	no abnormality detected	no abnormality detected	no abnormality detected	no abnormality detected	no abnormality detected
1	low-grade depigmentation; focal small synechia	focal capsular cataract; focal iris residues	low-grade liquefication with several floating filamentous strands of cell debris and inflammatory products	single focal chorioretinopathies ("bullet-hole lesions")	low-grade reduction in the size of the bulb/reduction in size of the anterior chamber
2	low-grade depigmentation; focal large scale synechia	multifocal capsular/subcapsular cataract; local bullous subcapsular/cortical cataract; multifocal iris residues	low-grade liquefication; several curtain-like strands of cell debris and inflammatory products	a few focal chorioretinopathies ("bullet-hole lesions"); small-area peripapillary choriorentinopathy ("butterfly lesion")	moderate reduction in the size of the bulb/reduction in size of the anterior chamber; local corneal haze
3	moderate depigmentation; several focal synechia	local reticular capsular/subcapsular cataract; local immature corticale/nuclear cataract	moderate liquefication; moderate curtain-like strands of cell debris and inflammatory products; low-grade diffuse yellow haze	multiple focal chorioretinopathies; large-scale peripapillary choriorentinopathy	low-grade bulb enlargement/enlargement of the anterior chamber; laminar corneal haze; low-grade increase in intraocular pressure
4	moderate depigmentation; atrophy; circular synechia	diffuse immature capsular/subcapsular/cortical and/or nuclear cataract; lens subluxation	high-grade liquefication; moderate curtain-like strands of cell debris and inflammatory products; moderate diffuse yellow haze	laminar chorioretinopathies; laminar degeneration of the retina; partial retinal detachment	moderate bulb enlargement/enlarge-ment of the anterior chamber; laminar corneal haze/Haab's striae; moderate increase in intraocular pressure
5	high-grade depigmentation; seclusion pupillae	mature/hypermature cataract; lens luxation	high-grade liquefication; high-grade visible strands of cell debris and inflammatory products; high-grade diffuse yellow haze	complete retinal detachment	high-grade bulb enlargement/enlargement of the anterior chamber; laminar corneal haze/Haab's striae; high-grade increase in intraocular pressure; phthisis bulbi

Intra- and postinjection findings

Intra- and postinjection findings during hospitalization were documented and collected from conversations with the owners of the horses treated until reexamination.

Contacting for reexamination

Owners of all horses included in the study were contacted by phone. Data was collected about the development of the eye/eyes treated after hospitalization with the help of a standardised questionnaire (*https://www.hippiatrika.com/downloads/20230509.pdf*). The main question aimed at finding out whether recurrences occurred or were diagnosed by a veterinarian. Owners were asked about every change or any other signs of inflammation in the eye/eyes injected. All data were classified in three different outcomes: free of complaints (FOC), recurrences (REC) and non-specific ocular inflammatory symptoms (NOIS), such as conjunctivitis or corneal ulceration. The FOC and NOIS were summarised as an improvement (IMP) (*Baake* et al. 2019) (Table 2).

The ophthalmologic reexamination was performed in 65 eyes (79.3%) by the first author, a veterinarian trained by a German veterinarian specialist of ophthalmology. The ophthalmologic examination included tonometry, induction of mydriasis by tropicamide[17], slit lamp biomicroscopy and direct ophthalmoscopy. In 17 eyes (20.7%) only rechecks on the phone with owners or current treating veterinarians were done. The ERU score (Table 1) was reapplied to develop a postinjection score as a comparison to the preinjection score.

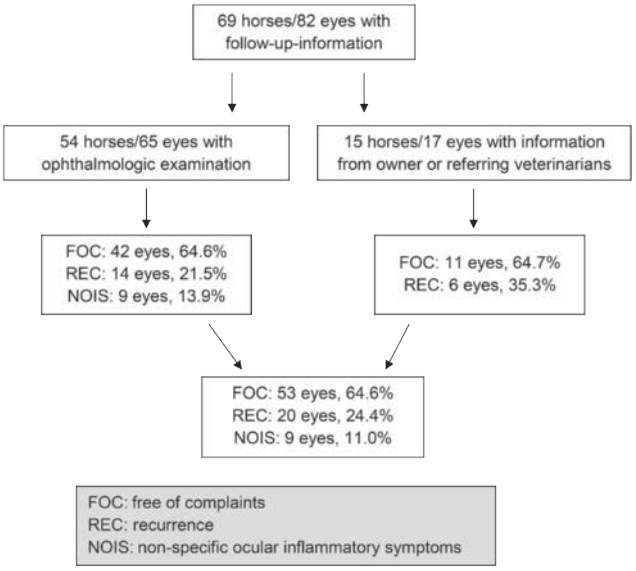

Fig. 1 Overview of the horses included in the study. | *Überblick über die in der Studie einbezogenen Pferde.*

Statistical evaluation

Data were collected from medical records, our own ophthalmologic examinations and owner conversations. The analysis of data was performed using SAS® Version 9.4[18]. The data were predominantly ordinally or categorically scaled, therefore, mainly non-parametric methods or contingency tables were used for the analyses. Fisher's exact test was used to compare the outcome of REC, FOC and NOIS after the intravitreal injection of gentamicin executed either under general anaesthesia or sedation. Furthermore, Fisher's exact test was used to evaluate correlations between the recurrence rate and breed, coat colour, number and course of bouts of inflammation before injection and leptospiral status of the eye. Whether general anaesthesia or sedation had any influence on the incidence of calcific band keratopathy after injection was also tested with Fisher's exact test. The latter was used to evaluate the influence of high or low pre-ERU score values on the recurrence rate. The Wilcoxon signed rank test was performed to evaluate the significance of differences between the height of the pre- and postinjection ERU scores. The symmetry McNemar's test and calculation of concordance index kappa (and the prevalence- and bias-adjusted kappa [PABAK]) was used to compare pre- and postinjection scores of single assessment values. The logistic regression model was used to impose the probability of suffering REC according to gender and/or age. Furthermore, the likelihood of suffering REC in accordance with the pre-ERU score was illustrated by a logistic regression model. The Kaplan-Meier estimator demonstrated the probability of the non-recurrence of intraocular inflammation after an intravitreal injection of gentamicin depending on time after injection.

Results

Patient population

Figure 1 gives a review of the patient population and follow-up information. Eighty-two eyes from sixty-nine horses were included in the follow-up study, with 36 (43.9%) right eyes and 46 (56.1%) left eyes treated. There were 36 (52.1%) mares with 45 eyes, 32 (46.4%) geldings with 36 eyes and one (1.5%) stallion with one eye treated in the study. The most frequent breed in this study was Warmblood (36 horses; 52.2%) with 43 treated eyes (52.4%) and the most frequent coat colour was "black and brown" (40 horses; 57.8%) with 48 eyes treated (58.5%). The remaining gender, breed and

Table 2 Possible postinjection outcomes after an intravitreal injection of low-dose gentamicin (classification by *Baake* et al. 2019). | *Mögliche Klassifizierung nach intravitrealer Injektion von niedrig dosiertem Gentamicin (Klassifizierung von Baake et al. 2019).*

Postinjection findings	Abbreviation for progression of ERU	
signs of ocular inflammation, similar to the episodes prior to the intravitreal injection of gentamicin	REC (recurrence of uveitis)	
no signs of ocular inflammation	FOC (free of complaints)	IMP (improvement)
mild signs of ocular inflammation, not comparable to the episodes prior to the intravitreal injection of gentamicin (e.g. epiphora, chemosis, due to conjunctivitis/keratitis)	NOIS (non-specific ocular inflammatory symptoms)	

coat colour distribution can be found in Table 3. The mean age was 10.9 ± 6.2 years (ranged from 2–26 years).

Follow-up

There was follow-up information about 82 eyes of 69 horses. Ophthalmologic examinations at the home stable were executed on 65 eyes (79.3%) of 54 horses. The owners or referring veterinarians for 15 horses (17 eyes, 20.7%) were contacted by telephone (Figure 1). The time period from the intravitreal injection of gentamicin to the ophthalmologic reexamination of the 82 eyes with follow-up information ranged from 1 to 55 months. The median time till reexamination was 18 ± 8.2 months (Figure 2). Figure 2 shows that in the reexamination period up to 24 months, a small proportion of eyes were included where contact with owners or the referring veterinarian was only by telephone (maximum 42.9%, 6 eyes, 7–12 months).

A total of 64.6% (53/82) of the eyes showed no signs of ERU or other problems with ocular inflammation or irritation (FOC) in this time period. Conjunctivitis with reddened conjunctiva and purulent epiphora, increased epiphora during wind, for example, cornea ulcer or other mild signs of ocular inflammation not comparable with the clinical diagnosis of ERU prior to the injection appeared in 11.0% (9/82) of horses involved (NOIS). In summary, 75.6% (62/82) of the eyes showed an improvement of the ERU status after a low-dose injection of gentamicin intravitreally (IMP). A REC was shown in 24.4% (20/82) of the eyes treated during the time period till reexamination. Active ERU was seen in 5 of 14 eyes examined classified as REC. The most common clinical symptoms were blepharospasm, epiphora, endothelial precipitates, aqueous flare, corneal opacity and miosis. The remaining nine eyes classified as REC in ophthalmologic examinations did not show any signs of active ERU and the division as REC was based upon the owner's information about the course of ERU. A total of 15/82 (18.3%) eyes were high-grade and persistently inflamed at the time of the injection of gentamicin and could not be controlled by conservative therapy with topical ophthalmic ointment and drops. Eight of these 15 eyes (53.3%) suffered from REC after injection.

Sight

Eyes with a negative menace response were classified as blind. At the time of reexamination, 35 eyes (42.7%) had unrestricted sight, and 15 eyes (18.3%) had limited vision because of mild cataract formations or retinal degeneration. Overall, both groups (50/82 eyes, 61.0%) were classified as sighted. The remaining 32 eyes (39.0%) were blind at the reexamination. A negative menace response and a negative dazzle reaction were observed in 62.5% (20/32). A negative menace response combined with a positive dazzle reaction was shown in 37.5% (12/32). Six eyes (18.8%) were blind because of a complete retinal detachment (fundus score 5). The other 13 blind eyes (40.6%) had a lens score of 5, which implied a mature or hypermature cataract of the lens. Both a lens score of 5 and a fundus score of 5 could be diagnosed in another 8 eyes treated (25.0%). Five eyes (15.6%) from 3 horses showed lasting blindness due to the intervention. A total of 22/32 eyes (68.8%) were already blind before the intravitreal injection of gentamicin. In addition to blindness due to the intervention, increased cataract formation to a mature cataract is the main reason for blindness after injection.

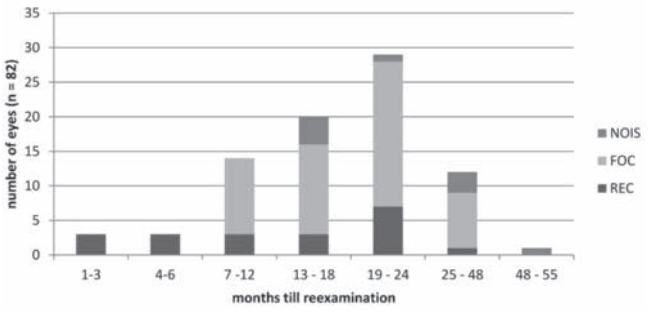

Fig. 2 Time between the intravitreal injection of gentamicin and reexamination in months (n = 82 eyes treated). | *Zeit zwischen intravitrealer Gentamicin-Injektion und Nachuntersuchung in Monaten (n = 82 behandelte Augen).*

ERU Score

The average total score from pre-injection was 1.6 ± 1.4. The Wilcoxon signed rank test showed a significant difference to the post-injection score of 2.1 ± 1.8 for re-examined eyes ($p < 0.001$). A deterioration was shown in 50/69 (72.5%) eyes, while 6 eyes (8.7%) had no alteration and 13 eyes (18.8%) showed an improvement. Eyes classified as IMP showed an almost identical rate of deterioration (72.2%) as those classified as REC (73.3%) on average, because of an increasing lens score due to the increase in cataract formation also without REC. The vitreous and lens score only showed a few similarities in the comparison of pre- to post-injection. The alteration for the vitreous score is not significant, while the mean lens score increased significantly from pre-injection (2.5 ± 1.7) to post-in-

Table 3 Gender, breed and coat colour distribution of horses with follow up information after intravitreal injection of gentamicin (n = 69) | *Geschlecht, Rasse und Fellfarbe von Pferden mit Follow-up-Informationen nach intravitrealer Injektion von Gentamicin (n = 69)*

Gender	mares	36	52.1%
	geldings	32	46.4%
	stallions	1	1.5%
Breed	Warmblood	36	52.2%
	Icelandic horse	6	8.7%
	Pony	9	13.0%
	Shetland pony	3	4.4%
	Irish Sport horse	2	2.9%
	Thoroughbred	2	2.9%
	Quarter horse	2	2.9%
	other	9	13.0%
Coat colour	black and brown	40	57.9%
	chestnut	16	23.2%
	grey	7	10.1%
	dun	3	4.4%
	other	3	4.4%

jection (3.9 ± 1.2) ($p < 0.05$) for all eyes. The score values of fundus show a perfect agreement from pre- to post-injection, the iris according to PABAK showed a good agreement of the different score values. The risk of suffering REC increased significantly with an increasing pre-injection score (Figure 3).

Intravitreal injection

The kind of anaesthesia (general anaesthesia or sedation) did not influence the outcome after intravitreal injection of gentamicin significantly ($p > 0.05$) (Table 4). Table 4 also differentiated the results for the respective anaesthesia method in ophthalmological reexamination and recheck by phone. The eye which was injected without triamcinolone subconjunctivally had a traumatic ERU postinjection, but no recurrences in the follow-up period.

Intra- and postinjection findings

The postinjection or follow-up period started immediately after injection and continues until ophthalmologic reexamination or phone call if no personal reexamination was possible. There were no complications or findings during injection of gentamicin. Postinjection findings were seen in 31 eyes during the follow-up period until the reexamination and can be divided into calcific band keratopathy, traumatic uveitis immediately after injection, blindness due to the intervention, glaucoma and lens dislocation to posterior. No eye was affected by multiple complications. The most frequent postinjection complication documented after an intravitreal injection of gentamicin was a calcific band keratopathy in 14 eyes (16.8%), which occurred in the first 3 months after injection (0.5–3 months, 1.6 ± 0.9 months). A calcific band keratopathy appeared significantly more often in horses, which were treated in sedation (12/14, 85.1%; $p < 0.05$). Six (42.9%) of these eyes needed a superficial keratectomy with the AlgerBrush II Corneal Burr[19] in a second sedation. Two eyes suffered a traumatic uveitis immediately after injection which was not counted as a recurrence of ERU. One of these eyes received no triamcinolone because of an existing cornea ulcer. The other eye showed partial retinal detachment during the intervention. Both eyes suffered no further recurrences and were evaluated as IMP. Blindness due to the intervention was found in seven eyes from five horses, all of which had unrestricted vision prior to the injection. These horses showed a negative menace response but a positive dazzle reflex on the eye affected one day after injection. Two eyes from two horses got back their complete vision after a few weeks in which they were only partially sighted. The remaining five eyes were still blind at the time of the follow-up examination. None of these eyes showed recurrences of ERU. Glaucoma was developed after injection in six eyes. In five of these seven eyes, glaucoma occurred in conjunction with recurrence of ERU. The remaining eye developed glaucoma without recurrences because of the chronic damage to the inner structures of the eye (complete posterior synechia, blockage of the chamber angle due to degradation products) as a result of the bouts of ERU before injection.

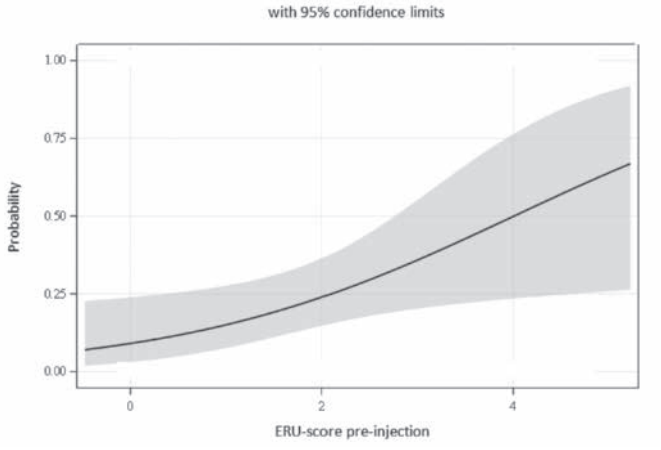

Fig. 3 Prognosis of the probability of recurrences (REC) with increasing equine recurrent uveitis (ERU) score value before injection (logistic regression model). | *Prognose der Wahrscheinlichkeit für REC mit zunehmendem ERU-Score vor der Injektion (logistisches Regressionsmodell).*

Table 4 Comparison of results after the intravitreal injection of gentamicin from eyes treated under general anaesthesia vs. treatment under sedation (no significant differences); differentiation between an ophthalmological reexamination and telephone contact | Vergleich der Ergebnisse nach intravitrealer Gentamicin-Injektion in Narkose vs. Sedierung (kein signifikanter Unterschied); Differenzierung zwischen eigener, ophthalmologischer Nachuntersuchung vs. Telefonbefragung

<table>
<tr><td colspan="4">Injection under general anaesthesia</td><td colspan="4">Injection under sedation</td></tr>
<tr><td colspan="2" rowspan="2">23.8% REC (10 eyes)</td><td colspan="2">80% (8 eyes) in person[1]</td><td colspan="2" rowspan="2">25.0% REC (10 eyes)</td><td colspan="2">60% (6 eyes) in person</td></tr>
<tr><td colspan="2">20% (2 eyes) by phone[2]</td><td colspan="2">40% (4 eyes) by phone</td></tr>
<tr><td rowspan="2">59.5% FOC (25 eyes)</td><td>84% (21 eyes) in person</td><td rowspan="3">76.2% IMP (32 eyes)</td><td rowspan="2">87.5% (28 eyes) in person</td><td rowspan="2">70.0% FOC (28 eyes)</td><td>75% (21 eyes) in person</td><td rowspan="3">75.0% IMP (30 eyes)</td><td rowspan="2">76.7% (23 eyes) in person</td></tr>
<tr><td>16% (4 eyes) by phone</td><td>25% (7 eyes) by phone</td></tr>
<tr><td rowspan="2">16.7% NOIS (7 eyes)</td><td>100% (7 eyes) in person</td><td rowspan="2">12.5% (4 eyes) by phone</td><td rowspan="2">5.0% NOIS (2 eyes)</td><td>100% (2 eyes) in person</td><td rowspan="2">23.3% (7 eyes) by phone</td></tr>
<tr><td>–</td><td>–</td></tr>
</table>

[1] in person = reexamination by an Ophthalmologist; [2] phone = only phone recheck

Two out of 82 eyes were shown with lens dislocation to the posterior. Only one of these eyes was affected by REC.

Number and course of uveitis episodes

The owners were asked about the number of bouts of inflammation before the intravitreal injection of gentamicin and about the course of inflammation in the eye. The number of ERU episodes pre-injection did not influence the occurrence of REC significantly. There were significantly more REC after the intravitreal injection of gentamicin in persistently inflamed eyes (8/15 eyes, 53.3%) compared to eyes which got well within the first week after the initial treatment with topical ointments and drops ($p < 0.05$). Persistently inflamed eyes before injection represented 40% (8/20) of all eyes with REC.

Correlation of gender, breed, coat colour and age

There was a significant increasing risk of developing REC with increasing age for geldings ($p < 0.05$). A REC was suffered in 33.3% (12/36) of the eyes of geldings (FOC: 20/36; NOIS: 4/36). By contrast, there were only 17.8% (8/45) of the eyes of mares classified as REC (FOC: 32/45; NOIS: 5/45). The eye treated of one stallion was free from any signs of inflammation during the reexamination period after the intravitreal injection of gentamicin (FOC).

The breed and coat colour of horses treated did not influence the occurrence of REC significantly.

The risk for REC generally increased with increasing age significantly ($p < 0.05$). Horses with an age from 20–25 years had a likelihood of nearly 50% of developing REC (Figure 4).

Time of recurrence

The time between the intravitreal injection of gentamicin and the first REC ranged from 1–22 months. Most eyes (11/20 eyes, 55.0%) showed the first REC after the injection within the first two months. Eight eyes showed REC of ERU only after 10–22 months. The remaining eye developed REC after 4 months.

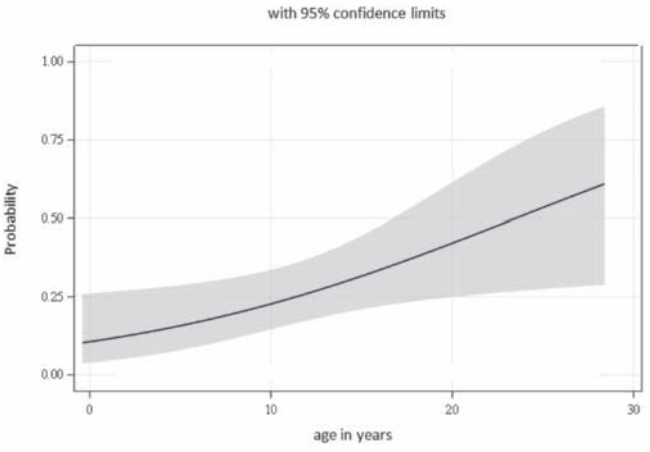

Fig. 4 Prognosis of the probability of REC with increasing age (logistic regression model). | *Prognose der Wahrscheinlichkeit für REC mit zunehmendem Alter (logistisches Regressionsmodell).*

Leptospiral status

Overall, 15 eyes were tested for their leptospiral status. The PCR and MAT showed a negative result in five samples. Four samples tested positive in MAT. Four samples tested positive in PCR. The remaining two samples showed a positive result in MAT and PCR. Grippotyphosa was the leptospiral serovar measured most. Three of five leptospiral negative eyes showed REC. Out of 10 leptospiral positive tested eyes 3 eyes (30%) showed recurrences of ERU.

Discussion

Intravitreal injection

For topical anaesthesia of conjunctiva and cornea Oxybuprocain ophthalmic drops were used because it is easy to apply and, in the authors' experience, has a good local anaesthetic effect. Alternatively, tetracaine eye drops could have been used. A supraorbital nerve block is sufficient for performing the gentamicin injection, as only the movement of the upper eyelid needs to be suppressed for using a single eyelid lifter dorsal. In the current study 0.1 ml gentamicin was applied in solution with 0.5 ml saline solution as it impoves the administerability. In one study they used saline solution as dilution to 0.8 ml injectable volume, too (*Kleinpeter* at al. 2019). In two other studies no dilution was used and small volumes from 0.04–0.3 ml of gentamicin applied (*Fischer* et al. 2019, *Launois* et al. 2019) (Table 5).

Follow up

Follow-up surveys are a useful method to check the success of a new treatment option. Four studies about the outcome after the intravitreal injection of gentamicin on eyes affected by ERU have been published since 2005 with rates of non-recurrence from 88.1 to 98.6% (Table 5) (*Pinard* et al. 2005, *Fischer* et al. 2019, *Kleinpeter* et al. 2019, *Launois* et al. 2019). The lack of information about some patients over time and the different approaches to handling data, which is responsible for the interval of results, are typical for follow-up surveys. Furthermore, the variations may be due to different methods, patient populations, study designs and possibilities of interpretations by the authors. Between 18 and 71 eyes were evaluated in the literature in a time period from 1 up to 96 months (*Pinard* et al. 2005, *Fischer* et al. 2019, *Kleinpeter* et al. 2019, *Launois* et al. 2019). Ophthalmological reexaminations were performed in the majority of the eyes included in two out of the four studies (*Fischer* et al. 2019, *Kleinpeter* et al. 2019). In the remaining two studies, information about the number of episodes of inflammation that occurred after intervention was collected by phone from owners and referring veterinarians (*Pinard* et al. 2005, *Launois* et al. 2019). According to the pre-existing damage, vision persisted in 33–78% of cases (*Pinard* et al. 2005, *Fischer* et al. 2019, *Kleinpeter* et al. 2019, *Launois* et al. 2019). The success rates of an intravitreal injection of gentamicin described in the literature and in the current study (Table 5) were, at first sight, comparable to the success rates after vitrectomy with non-recurrences from 73.6 to 97.7% (*Winterberg* and *Gerhards* 1997, *Frühauf*

et al. 1998, *von Borstel* et al. 2005, *Tömördy* et al. 2010, *Keiter* et al. 2017, *Schinagl* 2017, *Baake* et al. 2019, *Voelter* et al. 2020). However, in studies about the success rate of vitrectomy, more than four times as many eyes were examined than before and after the gentamicin injection in a longer re-examination interval. Furthermore, the preservation of vision or improvement of the optical axis is an important aim of vitrectomy, which is also shown by the results with a 67–87% conservation of visual acuity. The main aim of a gentamicin injection is to prevent recurrent inflammatory episodes and may not improve vision in, for example, already cataractous eyes that are no longer suitable for vitrectomy. Thus, remains somewhat behind vitrectomy in terms of success.

Conjunctivitis and corneal ulceration, diagnosed by referring veterinarians or the owner, or mild signs of inflammation not comparable with the clinical diagnosis ERU prior to the injection (epiphora, increased blink) were classified as NOIS, as in the study by *Baake* et al. (2019). Owners of a horse with ERU after treatment are sensitised to recognizing signs of ocular inflammation and should be able to differentiate between mild signs of inflammation and a bout of ERU over the years. Furthermore, eyes with ERU seem to be very sensitive to environmental stimuli from the authors' experience and, therefore, tend towards conjunctivitis, for example. On the other hand, it could be observed, that a corneal ulcer can occur, for example, because of pruritus in the case of ERU. Nevertheless, the author decided to classify NOIS together with FOC as improvement (IMP) and not as REC, because no significant difference could be found between the follow-up-group (information about the course only by telephone from the owners) and the reexamination-group in a study about the success rate after vitrectomy (*Baake* et al. 2019). The difference of the success rate compared to other studies published could arise in addition to the method of evaluation (ophthalmologic examination vs. contact only) from different time periods between injection and reexamination. *Fischer* et al. (2019) evaluated 59 of 86 eyes after a minimum follow-up period of 30 days and determined a success rate of 88.1%. After a minimum follow-up period of a year and 12 of 86 eyes examined, the success rate decreased to 75%, which is similar to this study. Two authors contacted the owner or referring veterinarian only via telephone for information whether a new episode of eye inflammation had occurred that necessitated ocular medication (*Pinard* et al. 2005, *Launois* et al. 2019). In both studies, only one eye developed REC and the success rates were high: 94% (1 REC out of 18 eyes) and 98.6% (1 REC out of 71 eyes), respectively. Differences in treatment after injection could also influence the outcome. In one study, they used anti-inflammatory drugs after therapy for a comparatively long time and administered 0.5 mg/kg flunixin-meglumine[20] twice daily for 1 month and dexamethason[21] 0.025 mg/kg once a day on alternate days for 15 days after injection (*Launois* et al. 2019). The different time periods from one month up to 96 months until reexamination in the literature could explain why the results differ from each other in this way. It could be expected that if the ophthalmological reexamination and owner interview in the current study had been performed only nine months after each intravitreal injection of gentamicin, the success rate (IMP) would have increased up to 83.8%. *Fischer* et al. (2019) evaluated 24/86 eyes injected (14%) after a minimum follow-up period of 7 months and

Table 5 Published studies regarding the long-term prognosis of horses with ERU after an intravitreal gentamicin injection. | *Veröffentlichte Studien über die Langzeitprognose von Pferden mit ERU nach einer intravitrealen Gentamicin-Injektion.*

	Number of eyes evaluated	Observation period after surgery (months)	Ophthalmological re-examinations[2]	No uveitic symptoms[3]	Conservation of visual acuity (not blind)	kind of drug (gentamicin)	dosage of gentamicin	amount of injected volume
Pinard et al., 2005	18	2–26	–[4]	94%	33% (6/18)	No information	4 mg	No information
Kleinpeter et al., 2019	61	2–96 (Ø 25,8)	93.4% (57/61)	91.8% (56/61)	70.5% (43/61)	Genta 100 mg/ml[5]	4 mg	0.8 ml (0.76 ml NaCl, 0.04 ml gentamicin)
Fischer et al., 2019	59 of 86[1] (68.6%)	1	100% (59/59)	88.1% (52/59)	78% (46/59)	Genta 100 mg/ml[5] or Gentamicin-ratiopharm[6] (80 mg/1 ml)	4 mg	0.04 ml Genta 100 mg/ml or 0.05 ml Gentamicin-ratiopharm
Launois et al., 2019	71	6	94.4% (67/71)	98.6% (70/71)	No information	gentamicin 2%: Gentalline[7] (40 mg/2 ml)	6 mg	0,3 ml gentamicin 2%
Neumann et al. (current study)	82	1–55 (Ø 18)	79.3% (65/82)	75.6% (62/82)	62.2% (51/82)	Gentamicin-ratiopharm (80 mg/2 ml)[6]	4 mg	0.6 ml (0.5 ml NaCl, 0.1 ml gentamicin)

[1] response to therapy was evaluated in 59 out of 86 eyes treated; [2] remaining horses were euthanized, the owner had changed or the home stable was too far away for an ophthalmological re-examination; [3] FOC and non-specific ocular inflammatory symptoms; [4] follow-up by examination by the referring veterinarian or owner information by telephone; [5] Genta® 100 mg/ml, CP-Pharma, Burgdorf, Germany; gentamicin solution containing preservatives; [6] Gentamicin-ratiopharm® 80 mg/2 ml SF, ratiopharm GmbH, Ulm, Germany; preservative-free gentamicin; [7] Gentalline, MSD Tiergesundheit, Germany

demonstrated a success rate in this area with 83.3%. The anaesthesia method seems to have had no influence on the success rates. Two studies in the literature use general anaesthesia for the intravitreal injection with gentamicin (*Pinard* et al. 2005, *Kleinpeter* et al. 2019). The other two studies treated horses under sedation with local nerve blocks (*Fischer* et al. 2019, *Launois* et al. 2019). The current study also reveals the lack of influence of the method of anaesthesia. There was no significant difference between the general anaesthesia group (76.2% IMP) and the sedation group (75% IMP). One might expect that general anaesthesia means more stress for the horses and, therefore, could induce another bout of ERU as a consequence of this, which is not the case.

Sight

The rate of blind horses at the time of reexamination seems to be high in the literature. The result of 67% of horses being blind after the intravitreal injection of gentamicin in a study from 2005 comes from the fact that 9 of 18 eyes (50%) were blind before treatment (*Pinard* et al. 2005). The same was reported in another study, in which 13 of 18 blind eyes at the time of reexamination had a high-grade loss of visual acuity or were blind preinjection. The remaining 5 blind eyes lose their vision because of progressive cataract formation (*Kleinpeter* et al. 2019). In this study, 32 eyes (39.0%) were blind at reexamination. The majority of these eyes (22/32, 68.8%) were already blind before the intravitreal injection of gentamicin because of retinal detachment and/or mature cataract. After the injection, an increased cataract formation to a mature cataract is the main reason for blindness because of pre-existing damage at the lens due to bouts of ERU in the past. *Gerding* and *Gilger* showed in a study about the prognosis and impact of ERU that about 50% of the eyes suffering from ERU already at the initial examination have a cataractous lens change even before the individual start of therapy (*Gerding* and *Gilger* 2015). Cataract formations in a recent study on Icelandic horses were also found to be significantly associated with ERU and could result in a loss of sight (*Henriksen* et al. 2022). The mean lens score in this study increased significantly from pre- to post-injection and also led to a worsening of the average score at reexamination in the majority of eyes classified as IMP without REC. The progression of cataract formations could not be stopped with an intravitreal injection of gentamicin if the lens is affected, and it is not aim of therapy. A mature cataract formation was observed in one study especially when gentamicin with preservatives[22] was used (preservatives: Sodium methyl 4-hydroxybenzoate, sodium propyl 4-hydroxybenzoate, sodium metabisulphite), but there was always a small amount of cataract formation in the eyes affected before injection (4/34 eyes, 11.8%). The remaining 52 eyes in the study were treated with a preservative-free, human gentamicin solution[12] and only a single cataract progressed from immature to mature (*Fischer* et al. 2019). A reallocation seems justified because no suitable solution is allowed for the horse (*Bienert-Zeit* et al. 2018). The rate of blindness at the time of injection is relatively high in this study because in the early time since 2016, the intravitreal injection of gentamicin was the last treatment option for eyes with ERU and high pre-existing damage, because of the retinotoxic effect (*Peyman* et al. 1974). The first choice, a vitrectomy, cannot be executed without a clear sight in the vitreous because of cataract formation or with retinal detachment. Therefore, initially, only high-grade aggrieved eyes were treated with an intravitreal injection of gentamicin in the present study. When the procedure was performed in sedation, more owners consciously chose the intravitreal injection of gentamicin first. It is an advantage that neither of the two treatment options in case of failure excluded the other generally. The retinal toxicity of gentamicin could be one reason for blindness due to the intervention in seven eyes from five horses in this study. An accumulation in the pigment epithelium of the retina leads to a dysfunction of the lysosomes with increased storage of lipids (*D'*Amico et al. 1984). The toxicity depends on the concentration directly in front of the retina and is also influenced by the injection technique (*Meyer* et al. 2008). During the injection the needle targets the papilla optica to prevent damage to the lens and retina. Furthermore, the solution with gentamicin was slowly and steadily injected into the vitreous to keep the concentration in front of the retina as low as possible. In this study, the exact cause of blindness after the intravitreal injection of gentamicin in some horses is questionable, but seems to be a degeneration or atrophy of the retina, which is partially reversible within 2–8 weeks, and should not be due to an increase in pressure in the eye caused by the injection (*Launois* et al. 2023).

ERU score

Comparable to increased blindness due to escalating cataract formations and growing lens score, the total ERU score from pre- to post-injection changed significantly because of the high pre-existing damage and, therefore, the inexorable chronic changes, also in eyes without REC. The risk of suffering REC increased significantly with an increasing pre-injection score, which could be one explanation for the comparatively high REC rate considering the high level of previous damage at the beginning of the treatment period. A total of 40% of all eyes with REC were persistently inflamed. In these eyes, intravitreal gentamicin injection was the last option. The risk of suffering REC is significantly higher in these eyes.

The eyes were evaluated pre- and post-injection with a Hyalitis score in one study about the intravitreal injection of gentamicin (*Launois* et al. 2019). The vitreous opacity was assessed from 0, which stands for no opacity, to 4, which means high-grade turbidity of the vitreous due to the release of proteins and cells. The authors could determine an improvement of the vitreous opacity but no disappearance in the examination of 46/71 eyes over three months (*Launois* et al. 2019). A significant decrease of the vitreous score after an intravitreal injection of gentamicin, similar to that in a study about long-term results after vitrectomy (*Baake* et al. 2019), cannot be proved in this study.

Correlation of gender, breed, coat colour and age

This research showed a significantly increasing risk of developing REC for geldings with increasing age. A third (33.3%) of eyes from geldings developed REC. Regarding mares, only 17.8% of the eyes treated suffered REC. The meaning of this

outcome is questionable and certainly caused by the relatively small number of patients. However, the number of mares and geldings was comparatively well-balanced (36 mares with 45 eyes vs. 32 geldings with 36 eyes). Nevertheless, an increasing risk of developing REC after an intravitreal injection of gentamicin with increasing age could generally be found. Horses with a black or brown coat colour were summarised in the group "black and brown" because of same genetic patterns (*Castle* 1954). Although a significant accumulation of horses affected with ERU with the coat colour "black and brown" could be observed in the literature (*Kulbrock* et al. 2013b), in this study, no significant influence between the coat colour and REC rate could be found.

Leptospiral status

No influence on the REC rate after injection could be found in a study in which the leptospiral status of the eye and the c-value were determined (*Fischer* et al. 2019). This study also showed that the likelihood of suffering REC did not correlate significantly with the leptospiral status of the injected eye. However, in another study, two leptospiral-negative eyes showed recurrences of ERU, while all leptospiral-positive eyes were free from any inflammation (*Kleinpeter* et al. 2019).

Impact of gentamicin

In the literature, it was under discussion whether intravitreally injected gentamicin showed an antibiotic effect against gram-negative leptospires (*Gilger* 2010). There was a high and long-lasting concentration of gentamicin in the vitreous due to special characteristics of binding of gentamicin to proteins, free amino acids and melanin (*Kleinpeter* et al. 2019). From this point of view, an antibiotic effect against leptospires in the eye is conceivable. An additional immunosuppressive effect of gentamicin (*Rahman* and *Mazumder* 2001, *Fischer* et al. 2019) is controversially discussed in the literature (*Kleinpeter* et al. 2019). On the one hand, suppression of specific T-cells would be possible (*Fischer* et al. 2019). On the other hand, an inhibition of the protein synthesis in the vitreous could prevent further bouts of inflammation (*Launois* et al. 2019). To make matters worse, biofilm bacteria are protected from the effects of the immune system and are very difficult to eliminate with antibiotics (*Nickel* et al. 1985, *Costerton* et al. 1999, *Lewis* 2001, *Geißler* and *Wollanke* 2021). Against this background, one explanation for the absence of REC of ERU after an intravitreal gentamicin injection might be a treatment of the leptospires in the planktonic stage, which could already lead to an improvement of the clinical picture. There is currently no clear explanation about the impact of gentamicin in the vitreous of a horse in the treatment of ERU (*Fischer* et al. 2019).

Intra- and postinjection findings

The findings described in the literature during or immediately after the procedure are minor (reflux of vitreous material, subconjunctival and intravitreal hemorrhage, and low grade expression of pain with blepharospasm, photophobia and epiphora) (*Fischer* et al. 2019, *Kleinpeter* et al. 2019). In this study, there were no complications observed during or immediately after the injection. There was a noticeable cumulative occurrence in calcific band keratopathy in the first three months after the injection (14 eyes), especially in the horses treated under sedation (12 of 14 eyes). However, this complication would be caused more by topical treatment with corticosteroids, subconjunctival triamcinolone or the disease ERU itself than with the intravitreal gentamicin injection. A study from 2017 showed that 84.4% (38/45 eyes) of the eyes presented with calcific band keratopathy at the University of California-Davis Veterinary Medical Teaching Hospital were affected by ERU. A total of 36 of 45 eyes (80%) diagnosed with calcific band keratopathy were topically treated with a corticosteroid prior to diagnosis (*Berryhill* et al. 2017). According to the literature, there seems to be an association between the topical administration of corticosteroids, ERU and calcific band keratopathy (*Rebhun* et al. 1993). The results of this study could be coincidental.

Subkonjunctival triamcinolone

The subconjunctival application of triamcinolone[13] in the context of a gentamicin injection remains to be discussed, since triamcinolone itself also has an anti-inflammatory and immunosuppressive effect which could mask the effect of gentamicin against ERU. It is used to reduce the irritating effect of gentamicin in the eye. The use of triamcinolone in the course of the intravitreal gentamicin injection is not reported in the literature. A subconjunctival injection with dexamethasone disodium phosphate in humans described in the literature not only results in a high drug concentration in the anterior chamber, but is also the most effective method of delivering dexamethasone into the posterior segment of the eye, compared with a peribulbar injection or oral administration (*Weijtens* et al. 1999). The duration of action of subconjunctivally injected triamcinolone is described in the literature as 2–3 weeks (*Allbaugh* 2017) up to 3–6 weeks (*Gaudio* 2004, *Athanasiadis* et al. 2013). By contrast, a suprachoroidal injection of triamcinolone, which will be safe and effective at controlling intraocular inflammation, especially in horses with chronic, poorly responsive ERU, showed a statistically significant decrease in inflammation for at least three months after injection (*Gagnon* et al. 2021). Further research is necessary to evaluate the role of subconjunctival injected triamcinolone in an intravitreal injection of gentamicin against ERU. Nevertheless, only three eyes were re-examined within the first three months in this study. All of these eyes suffered REC within 2–8 weeks after injection, which argues against an immunosuppressive involvement of triamcinolone and a gentamicin-masking effect during this period. However, due to a corneal defect, a subconjunctival triamcinolone injection could not be performed in one horse in this study. This horse suffered traumatic ERU in the corresponding eye after injection, which may have been promoted by the lack of triamcinolone and could confirm the anti-inflammatory effect.

Limitations

Limitations of this study were, on the one hand, the low number of eyes treated compared to vitrectomy studies and, on the other hand, the fact that not all eyes had the findings that

made scoring possible. Another limitation is that the observation period was limited. The number and variety of horses considered in the different studies and the various research criteria make it generally difficult to compare the studies directly.

Conclusion

The intravitreal injection of gentamicin against ERU seems to be a useful addition to the already existing therapy methods based on the study results to date. It has some advantages, especially compared to vitrectomy, that might seem attractive to some owners: no transport to clinic and no anaesthesia are necessary, a gentamicin injection is significantly more favourable and can also be performed on the already severely damaged eyes. However, a clearing of the optical axis through the change of vitreal material, as in vitrectomy, is not to be expected. Even though the number of the patient population so far is significantly lower than in studies regarding vitrectomy, the results are promising. However, the main advantage is that neither of the two treatment methods excludes the other if treatment is not successful, therefore a suitable treatment can be found for each horse.

Manufacturer's addresses

[1] IsoptoMax®, Novartis Pharma GmbH, Nürnberg, Germany
[2] Atropin POS® 0,5 %, Ursapharm Arzneimittel GmbH, Saarbrücken, Germany
[3] Flunidol® RPS 50 mg/ml, CP-Pharma, Burgdorf, Germany
[4] Myorelax® 100 mg/ml, Dechra, Aulendorf, Germany
[5] Xylavet®, 20 mg/ml, CP-Pharma, Burgdorf, Germany
[6] Narketan® 100 mg/ml, vetoquinol, Ismaning, Germany
[7] Natriumchlorid-Lösung 0,9 % ad us. vet. WDT, Wirtschaftsgenossenschaft deutscher Tierärzte eG, Garbsen, Germany
[8] Cepesedan® 10 mg/ml, CP-Pharma, Burgdorf, Germany
[9] Butorgesic® 10 mg/ml, CP-Pharma, Burgdorf, Germany
[10] Novesine® 0,4 % Augentropfen, OmniVision GmbH, Puchheim, Germany
[11] Mepidor® 20 mg/ml, Richter-Pharma AG, Wels, Austria
[12] Gentamicin-ratiopharm® 80 mg/2 ml SF, ratiopharm GmbH, Ulm, Germany
[13] Triam 10 mg Lichtenstein, Zentiva Pharma GmbH, Frankfurt am Main, Germany
[14] Vitamycin® Augensalbe, CP-Pharma, Burgdorf, Germany
[15] Flunidol® 5 % Gel, CP-Pharma, Burgdorf, Germany
[16] IVD GmbH Hannover, Seelze-Letter, Germany
[17] Mydriatikum Stulln UD®, Pharma Stulln GmbH, Stulln Germany
[18] SAS Institute Inc., Cary, NC, USA
[19] AlgerBrush II Corneal Burr, Eickemeyer, Tuttlingen, Germany
[20] Finadyne® Paste 50 mg/g, MSD Tiergesundheit, Germany
[21] Azium, TVM

Abbreviations

ERU: Equine Recurrent Uveitis
n: number
MAT: microscopic agglutination test
PCR: polymerase chain reaction
FOC: free of complaints
REC: recurrences
NOIS: non-specific ocular inflammatory symptoms
IMP: improvement
PABAK: prevalence-adjusted and bias-adjusted kappa
c-value: Goldmann-Witmer coefficient

Statement of informed consent

All owners provided informed consent that information can be included in the study.

Conflict of interest statement

The authors declare that they have no competing interests.

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