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Corneal oedema of suspected endothelial origin in five horses: diagnostics, superficial keratectomy and Gunderson inlay flap and preliminary outcome

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Summary: Corneal oedema in the adult horse can be caused by multiple problems such as glaucoma, uveitis, iridocyclitis and keratitis, endothelial disease or trauma. This retrospective clinical case study describes five horses with severe local band shaped or diffuse corneal oedema of suspected primary endothelial origin treated with a superficial keratectomy and Gunderson inlay flap. The value of ultrasound as an advanced imaging modality in order to ensure correct diagnosis and therefore proper case selection is also described. Case records of horses admitted for diagnosis and treatment of unilateral band shaped or diffuse corneal oedema between May and October 2020 were reviewed and five horses were included. Patient details, clinical history, ophthalmic and ultrasonographic examination results, treatment and clinical outcome and follow-up after surgery were recorded. Ophthalmic and ultrasonographic examination showed corneal oedema of endothelial origin. By performing ultrasound other possible causes for severe corneal oedema could be considered less likely. However, in 1 horse signs of previous uveitis were seen. Previous medical treatment generally consisted of topical corticosteroids but was unsuccessful in all cases. Surgical treatment in all 5 horses consisted of superficial keratectomy and a Gunderson inlay flap. Mild ocular discomfort was seen in 2 out of 5 horses (Case 2 and 5) the first week after surgery. One horse (Case 3) showed severe ocular discomfort the first 2 weeks after surgery which was suspected to be due to anterior uveitis. One horse (Case 4) suffering from chronic uveitis prior to surgery resulting in increased intra-ocular pressure is still dependent on topical medication. Two horses had a methicillin resistant *Staphylococcus aureus* (MRSA) on bacterial culture and sensitivity testing, one horse postoperatively and one pre-operatively. The follow-up period varied between 2 to 7 months. At time of follow-up, all horses showed a reduction in corneal oedema, had no signs of ocular discomfort and had retained vision. In conclusion, horses with corneal oedema of endothelial origin may benefit from a superficial keratectomy and Gunderson inlay flap. If medical treatment fails to reduce the corneal oedema, this surgical treatment shows promising preliminary results. Culture and sensitivity testing prior to performing corneal surgery might be useful. Ultrasonographic examination could aid in differential diagnoses prior to surgery and prognosis. Further research is warranted.

Keywords: bullous keratopathy, conjunctival graft, endotheliitis, ultrasound, histopathology

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Introduction

The cornea consists of three important anatomical layers: the superficial epithelium, central stroma and deep endothelium (*Gilger* et al. 2017). Corneal transparency relies on the normal physiology of these anatomical structures, since the cornea needs to maintain a state of relative dehydration to remain clear (*Scherrer* et al. 2017). The specialised basement membrane of the endothelium is called the Descemet's membrane (DM) and is localised between the stroma and the endothelial layer (*Gilger* et al. 2017). The average thickness of the DM in the adult horse is 30–38μm and it increases in thickness with age as it is formed throughout life (*Gilger* et al. 2017, *Slenter* et al. 2020). The endothelium is a monolayer of hexagonal shaped cells with endothelial cell density ranging from 2473–3581 cells/mm^2. Endothelial cell density has been shown to decrease with increasing age and since endothelial cells have a limited capacity to divide, cell loss is primarily compensated by migration and spread of existing cells (*Gilger* et al. 2017). Cell density would have to decrease to 400–700 cells/mm^2 before stromal hydration ensues and corneal oedema is clinically present (*Klyce* et al. 2020). The response of the human endothelium to gradual cell loss or endothelial damage involves spreading and migration of existing cells rather than a regenerative response (*Joyce* et al. 2012). Therefore, the endothelium in considered to be a fragile structure with a lack of regenerative response in many species (*Scherrer* et al. 2017). Healing of the human endothelium consists of an increase in overall cell size and alteration of the hexagonal shape to a pleiomorphic shape (*Joyce* et al. 2012). Knowledge about endothelial disease and regeneration in horses is currently limited (*Scherrer* et al. 2017). The endothelial layer has an important function to transport water from the stroma to the aqueous against osmotic and hydrostatic gradients. It does so by leaky junctional complexes and Na^+/K^+ ATPase-dependant

transmembrane pumps (*Gilger* et al. 2017, *Klyce* et al. 2020). This states the importance of the normal anatomy and function of the endothelial cell layer and it's DM and when corneal oedema is present a disorder in these layers could be suspected (*Gilger* et al. 2017). Corneal oedema occurs when the epithelial barrier is interrupted or the endothelial pumps are not functioning well (*Gilger* et al. 2017).

Diffuse or local band shaped corneal oedema in the adult horse can have multiple causes such as glaucoma, uveitis, heterochromic iridocyclitis and keratitis (HIK), endothelial disease and trauma (*Scherrer* et al. 2017, *Linde Henriksen* et al. 2017). It is important to discriminate between these possible causes of corneal oedema since there are several treatment options with different prognostic outcomes. Therefore, complete ophthalmic examination and advanced imaging modalities are essential in order to properly diagnose the origin of the corneal oedema, to select possible treatment options and determine prognosis.

Ultrasonography has been shown to be an adequate, non-invasive tool to diagnose disorders in the anterior and posterior segment of the eye (*Gilger* et al. 2017, *Slenter* et al. 2020, *Herbig* et al. 2015). This diagnostic modality is especially of value when corneal oedema is severe and complete ophthalmic evaluation is impossible due to decreased visibility of ocular structures posterior to the cornea.

Medical treatment of corneal oedema is based on osmotic principles. By applying hyperosmotic agents fluid could be drawn from the cornea. However, hyperosmotic agents have not shown to be reliable when it comes to reducing corneal oedema (*Scherrer* et al. 2017). Surgical options for severe corneal oedema due to a primary endothelial disorder have been previously reported. These include penetrating keratoplasty, thermokeratoplasty and conjunctival grafts (*Scherrer* et al. 2017). Recently four horses with corneal oedema were treated with a superficial keratectomy and Gunderson inlay flap with promising results (*Scherrer* et al. 2017). The superficial keratectomy and Gunderson inlay flaps were previously intended in human cases with local corneal oedema. *Scherrer* et al. described that this method could also be used in horses with diffuse corneal oedema. It offered ocular comfort, decreased corneal oedema and improved vision in horses with diffuse and severe corneal oedema.

This case series describes five horses with severe local band shaped or diffuse corneal oedema of suspected primary endothelial origin treated with a superficial keratectomy and Gunderson inlay flap. We aim to contribute to the results previously recorded by *Scherrer* and colleagues. Additionally, we describe the value of ultrasound as an advanced imaging modality in order to ensure correct diagnosis and therefore proper case selection.

Methods

Case selection

Five horses were presented to the Equine Clinic of the Faculty of Veterinary Medicine, Utrecht University, The Netherlands, between May and October 2020 with band shaped or diffuse corneal oedema. Patient details, clinical history, ophthalmic and ultrasonographic examination results, treatment and clinical outcome after surgery were recorded.

Ophthalmic examination

Complete ophthalmic examination was performed of both eyes in all horses. Examinations were performed by a board-certified veterinary surgeon (ECVS diplomate) and/or board eligible veterinary ophthalmologist (ECVO diplomate) and included neuro-ophthalmic testing, hand-held slit lamp biomicroscopy (SL-15)[a] and direct ophthalmoscopy (Pneumatic Otoscope)[b], tonometry (Tonovet®)[c] and fluorescein staining.

Ultrasonographic examinations

Ultrasonographic examinations of both eyes were performed in all horses by a board-certified veterinary radiologist (ECVDI diplomate). Horses were sedated with detomidine hydrochloride (Domosedan)[d] 0.01 mg/kg bwt IV if necessary and a standard transpalpebral method was performed using a high frequency linear 5–18 MHz transducer (L18–5) in combination with an Epic 5 ultrasound machine[e]. Care was taken to maintain mechanical and thermal index below 1, to minimise risk of retinal detachment. Measurements of the globe and specific findings in the anterior or posterior segment or retrobulbar area were also recorded. Corneal thickness was measured and close examination for detachment of the DM was performed. The contralateral eye was used as a reference, especially in cases where corneal oedema was diffuse.

Surgical procedure

All horses were treated with a superficial keratectomy and Gunderson inlay flap under general anaesthesia in lateral recumbency with the affected side facing upwards. Eye lashes were clipped and the conjunctival sac and lacrimal duct were flushed with a 1% diluted povidone iodine solution. Bulbar conjunctiva was separated from the Tenon's capsule using a Stevens tenotomy scissor in order to prepare the conjunctival graft. A superficial keratectomy was performed using a beaver corneal blade 64 to make the initial incision and a Martinez corneal dissector was used to perform the lamellar dissection. To complete the procedure the undermined anterior corneal stroma and epithelium were removed by cutting the remaining attached edges with corneal section scissors. In three horses the location of the keratectomy was the local band of affected cornea and the Gunderson conjunctival inlay graft was placed in the same location. In the horse with diffuse oedema the location of the keratectomy and graft was on the dorsal 1/3 of the cornea. One horse had a severe broad band of oedema from the dorsal limbus to the ventral limbus. Therefore, it was decided to perform the keratectomy and placement of the inlay flap on two separate locations, one on the dorsal 1/3 and one on the ventral 1/3 of the cornea, leaving the central part free. The Gunderson conjunctival inlay flaps were sutured to the cornea using a 8–0 polyglactin 910[f] in an

interrupted pattern. All horses received a subpalpebral lavage system[g] (SPL) in the lower eyelid and a temporary tarsorrhaphy using a nylon non-absorbable suture material[h]. The tarsorrhaphy was removed directly after recovery.

Results

Patient details

The five horses in this study included a Quarter horse, Irish Cob, Hanoverian, Appaloosa and a Dutch Warmblood (Table 1). Two horses were considered young, 1 and 2 years of age (Case 1, 2). Two horses were considered middle aged, 11 and 13 years old (Case 3, 5) and the age of one horse (Case 4) is unknown. This study included one mare (Case 4), three geldings (Case 2,3,5) and one stallion (Case 1). One horse (Case 4) only had one eye, as the other eye had been removed one year previously due to equine recurrent uveitis.

History and ophthalmic examination

All cases presented with unilateral corneal oedema and no clinical signs of ocular discomfort. Complaints were present for 2 weeks in Case 1–3, 5 and for 2 days in Case 4. All horses had been treated by the referring veterinarian with topical corticosteroids prior to presentation at the clinic, without improvement. One horse (Case 4) was also treated with dorzolamide and timolol[i] to lower intra-ocular pressure and ketorolac[j] since uveitis and secondary glaucoma was suspected. In four cases the corneal oedema was focal and band shaped, either running from the dorsal to ventral limbus or parallel to the dorsal limbus (Figure 1, 2, 4, 5). In one case (Figure 3) severe diffuse corneal oedema was seen. In 2 horses, intra-ocular pressure (IOP) was measured but not recorded. Horse 3 had an IOP of 31 mmHg in the affected eye versus 22 mmHg in the non-effected eye. Horse 4 had an IOP of 17 mmHg and horse 5 an IOP of 8 mmHg on the affected side and 15 mmHg on the non-affected side. All horses had fluorescein negative corneal staining and no other clinically relevant abnormalities were found on ophthalmic examination. However, in Case 3 the corneal oedema was severe and diffuse which limited the examination.

Ultrasonographic examinations

In all five cases the corneal thickness was increased and had a hyperechoic appearance with some loss of definition towards the epithelial and endothelial layering. Thickness was compared to the healthy cornea in the same eye if oedema was focal or in the healthy eye if cornea oedema was diffuse (Table 2). In one horse (Case 4) a premature detachment of the Descemet's membrane was suspected due to focal hyperechoic irregular endothelial lining. In this horse a significant amount of hyperechoic material was seen attached to the posterior lens capsule and therefore uveitis was suspected. A second ultrasound of this horse was made 13 days after surgery due to a sudden increase in corneal oedema. No signs of Descemet's membrane detachment were seen, however an increase in corneal thickness was seen ventral to the conjunctival graft and persistent presence of vitreal debris noted.

Treatment and follow-up

Prior to surgery four horses (Case 2–5) were treated with topical corticosteroids (dexamethasone disodium phosphate 0.1 %)[k] and hypertonic eye ointment. One horse received topical antibiotics and hypertonic eye ointment instead of corticosteroids. In all horses, no complications were noted during surgery.

Horse 1 showed no signs of ocular discomfort postoperatively and was treated topically with gentamicin[l] and acetylcysteine[m] four times daily via the SPL. Meloxicam (Metacam)[n] was administered orally for 10 days post-operatively. The SPL was removed after 2 weeks and the horse was discharged from the equine clinic. Topical treatment was continued by the owner for one week. Corneal oedema decreased in the following period and the flap showed no signs of dehiscence. The horse had a follow-up ophthalmic examination at the equine clinic 5 months postoperatively and showed a decrease in corneal oedema and the pigmented flap was fully adhered to the cornea (Figure 1).

Horse 2 showed mild ocular discomfort the first 2 days after surgery and was topically treated with gentamicin[l], acetylcysteine[m] four times daily and atropine[o] once daily via the SPL. Meloxicam[n] was administered orally for 8 days and the horse was discharged 8 days after surgery. The owner continued treatment after discharge for 2 weeks (Figure 2). The SPL was removed by the referring veterinarian 3 weeks postoperatively. The referring veterinarian re-examined the horse 7 months postoperatively. The horse showed no signs of discomfort or complaints of an impairment in vision. The flap was fully adhered to the cornea and no corneal oedema was seen.

Horse 3 showed mild to severe ocular discomfort after surgery and had mucopurulent discharge. The initial treatment consisted

Table 1 Breed, age in years, gender, duration of complaints, ophthalmic examination results and intra-ocular pressure in the affected eye of the 5 horses

	Breed	Age (yr)	Gender	Duration complaints	Ophthalmic examination	IOP (mmHg)
Horse 1	QH	1	stallion	2 weeks	Vertical band corneal oedema	-
Horse 2	Irish Cob	2	gelding	2 weeks	Vertical band corneal oedema	-
Horse 3	Hanoverian	11	gelding	2 weeks	Severe diffuse bullous corneal oedema	31
Horse 4	Appaloosa	-	mare	2 days	Horizontal band corneal oedema	17
Horse 5	DWB	13	gelding	2 weeks	Vertical band bullous corneal oedema	8

of topical gentamicin[l], acetylcysteine[m] and atropine[o] six times daily via the SPL. Meloxicam[n] was administered orally for 14 days. Six days postoperatively a fluorescein positive corneal ulceration was seen ventral to the flap. A corneal swab was taken for bacterial culture and sensitivity testing which showed a methicillin resistant *Staphylococcus aureus* (MRSA), antibiotics were switched to chloramphenicol[p]. Autologous serum was added to the topical treatment. Multiple vessels were progressing from the flap to the central part of the cornea. As corneal oedema decreased ophthalmic examinations suggested that an anterior uveitis could not be ruled out and therefore ketorolac[i] was also added to the treatment. Five weeks after surgery the horse was discharged with the advice to continue treatment with atropine[o] and ketorolac[i] for 2 weeks. The horse had regular re-check examinations at the equine clinic. Six months postoperatively the horse was comfortable without topical medication. The flap was fully adhered to the cornea and corneal oedema was decreased (Figure 3).

Horse 4 showed no signs of ocular discomfort after surgery and was treated topically with gentamicin[l] and acetylcysteine[m] six times daily via the SPL. Oral meloxicam[n] was administered for 20 days postoperatively. Ten days after surgery a sudden increase in corneal oedema was seen and intra-ocular pressure increased to 38 mmHg. Therefore, dorzolamide and timolol[i] was added to the topical treatment. The horse had regular re-check examinations at the equine clinic. Two months postoperatively corneal oedema decreased and treatment with dorzolamide and timolol[i] twice daily was continued (Figure 4).

In horse 5 it was decided to take a bacterial culture prior to surgery and results were in 2 days after surgery showing MRSA. Topical antibiotics in this horse were switched to chloramphenicol[p] as initial treatment consisted of gentamicin[l] and acetylcysteine[m] via the SPL. Oral meloxicam[n] was administered for 5 days postoperatively. The horse showed mild ocular discomfort the first 2 days after surgery and no signs of infection or dehiscence of the flap were seen. The horse was discharged 2 weeks after surgery after removal of the SPL. The owners continued treatment for one week. A re-examination was performed at the equine clinic 4 months postoperatively. The horse showed no signs of discomfort and a decrease in corneal oedema was seen (Figure 5).

Histopathology

In two horses (Case 1, 3), the excised corneal samples harvested during keratectomy were send in for histopathology. Results for Case 1 showed normal squamous epithelial cells with local ballooning degeneration. In the subepithelial and stromal part of the cornea signs of oedema were seen and 1 to 2 neutrophils without signs for pathogens. It could be concluded that the cornea showed signs of oedema without a clear cause. Case 2 also showed normal squamous epithelial cells with increased space between the collagen fibres, as is often seen in cases with oedema. No other abnormalities were found.

Discussion

This case series describes the clinical presentation and ultrasonographic examinations of five horses with unilateral, band shaped or diffuse corneal oedema without signs of ocular discomfort. Surgical treatment, consisting of a superficial keratectomy and a Gunderson inlay flap, resulted in a decrease of corneal oedema in all 5 horses with the longest follow-up period being 7 months. At time of last follow-up, none of the horses showed signs of ocular discomfort. All horses had improved vision postoperatively and showed no vision loss. One horse still relies on topical medication to maintain a normal intra-ocular pressure.

This case series proves that superficial keratectomy and Gunderson inlay flap is a valuable treatment method for horses with endothelial corneal oedema and adds to the existing literature (*Scherrer* et al. 2017).

In all horses an endothelial dysfunction was suspected to be the cause of the corneal oedema, due to the severity of the oedema. The subacute onset of the complaints, no signs of ocular discomfort and unresponsiveness to medical treatment could further substantiate this presumptive diagnosis. It was impossible to differentiate between a primary or secondary endothelial disorder in all horses. On the list of differential diagnoses are blunt trauma, Descemet's membrane detachment (DMD), idiopathic primary oedema, endothelial immune-mediated keratitis, anterior uveitis and glaucoma (*Scherrer* et al. 2017, *Gilger* 2017, *Gilger* et al. 2005).
Horse 3 showed signs of a keratouveitis in the post-operative period, which responded well to anti-inflammatory medication. *Scherrer et al*. 2017 also reported cases of keratouveitis in the post-operative period, which responded well to medication. It was suspected that the uveitis was secondary to the corneal disease, although a primary uveitis could not be ruled out (*Scherrer* et al. 2017). In this case the topical medication was discontinued completely and the horse is currently without medication.

Horse 4 had a history of equine recurrent uveitis but did not show signs of an active uveitis at the time of presentation. However, the horse was still on topical medication and vitreal debris was visible on ultrasonographic examination. After surgery topical medication to lower the intra-ocular pressure was temporarily stopped which possibly could explain the sudden increase in corneal oedema, especially since the horse showed a decrease in oedema when medication was introduced again. A premature DMD was suspected on ultrasonographic examination as well because of focal hyperechoic irregular endothelial lining, although postoperatively this was not visualised again. The possible effects of uveitis, and/or the premature DMD glaucoma cannot be ignored as a cause of the corneal oedema in this case. In the other 3 cases no definitive cause of the corneal oedema could be determined.

Horses are known to be carriers of methicillin resistant *Staphylococcus aureus* (MRSA) (*Boyle* et al. 2017). However, prevalence at the conjunctival surface in healthy horses is currently not known. One of the horses (Case 3) developed ulcerative keratitis ventral to the conjunctival graft 6 days after the procedure and MRSA was subsequently found following culture and sensitivity testing and topical treatment was adjusted. Following horse 3 we therefore elected culture and sensitivity testing prior to the procedure in horse 5, and another MRSA was cultured. We adjusted medical treatment management

Fig. 1 Case 1 showing a vertical band of local corneal oedema preoperatively and 5 days postoperatively and reduction of the oedema 5 months postoperatively.

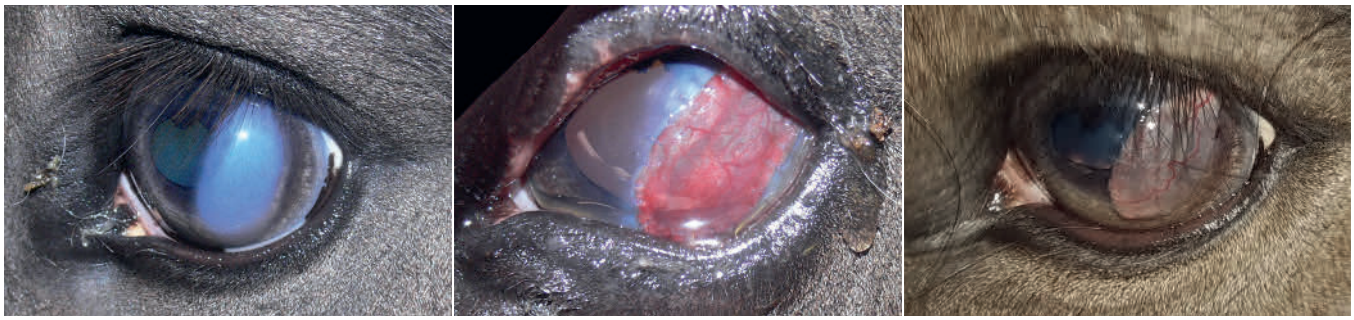

Fig. 2 Case 2 showing local vertical band shaped corneal oedema pre-operatively and clinical presentation 2 days and 7 months post-operatively

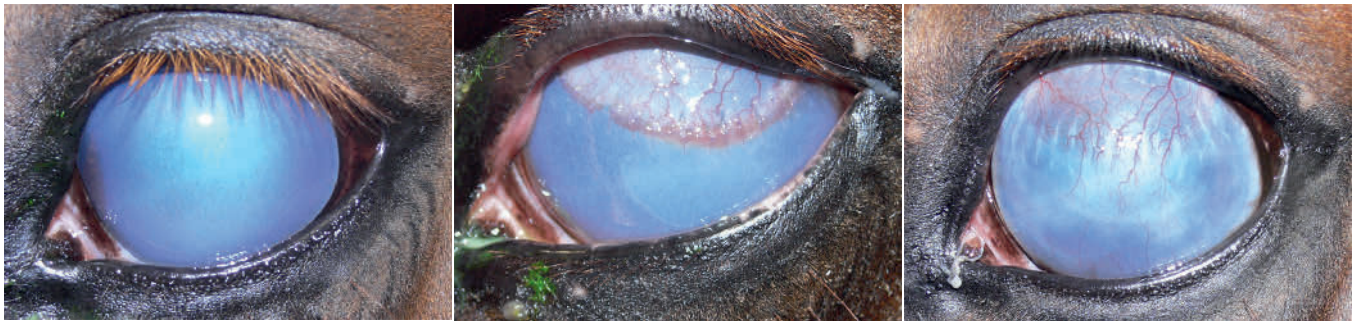

Fig. 3 Case 3 clinical presentation of diffuse bullous corneal oedema preoperatively, 7 days and 6 months post-operatively

Fig. 4 Case 4 presented with local horizontal band shaped corneal oedema preoperatively, clinical presentation 1 day and 2 months post-operatively

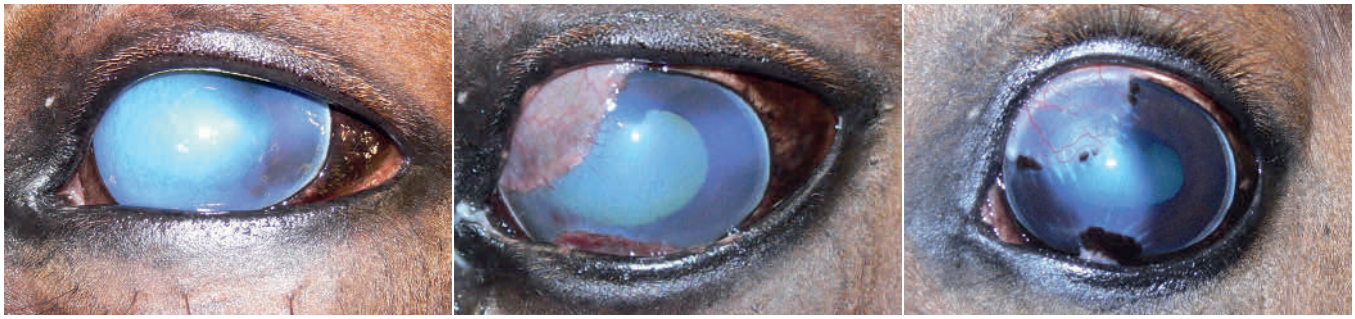

Fig. 5 Case 5 showing diffuse bullous corneal oedema pre-operatively and at 3 days and 4 months post-operatively

and this case did not develop any complications after surgery. Culture and sensitivity testing prior to performing a surgical procedure on an intact cornea might be a validated option to ensure a suitable treatment strategy after the procedure and possibly prevent complications from occurring.

Risk factors for a Descemet's membrane detachment (DMD) are currently unknown and further research should be done to determine the effects of intra-ocular inflammatory processes on endothelial cells and the DM (*Slenter* et al. 2020). As abovementioned, suspicion of a premature DMD was raised in one horse (Case 4) on ultrasonographic examination, however when repeating the examination 13 days after surgery this could not be confirmed. Based on this case, one cannot conclude that surgery might have had a preventive effect on the progression of the premature detachment, or that medical treatment and the decrease in IOP and subsequent corneal oedema is a more plausible explanation. This being said, prevention of DMD is very important and surgical treatment presented in this case series might play a role. Further evaluation of this treatment path in DMD cases is necessary.

All horses were treated with topical corticosteroids and hypertonic medication prior to surgery and no improvements were seen. Medical treatment for corneal oedema of suspected primary endothelial origin could consist of topical corticosteroids in absence of corneal ulcerations. The effect of hyperosmotic agents is considered questionable, however, they might aid in reducing bullae formation. Furthermore, in case of ocular discomfort or signs of local inflammation, topical anti-inflammatory medication such as ketorolac might be considered. *O'Leary* et al. 2021 described three horses with corneal hydrops in which early recognition and therapeutic intervention gave excellent results. After 7 to 10 days of topical medication clear improvement was seen in these horses. This might suggest that topical treatment could be carried out for at least one week before considering surgical treatment, unless the disease progresses, the horse shows ocular discomfort or rupture of bullae causes corneal ulceration.

Scherrer et al. 2017 suggested two theories for resolution of the corneal oedema even when the keratectomy and flap only occupy a small portion of the cornea. One theory is that blood vessels from the conjunctival graft remove excess fluid in the surrounding cornea. The other theory is that with placing the conjunctival graft the remaining normal function of endothelial cells can be restored (*Scherrer* et al. 2017). In this study the horse with diffuse oedema (Case 3) showed a multitude of blood vessels growing from the dorsally orientated graft towards the central and ventral aspect of the cornea. At six months following surgery these protruding vessels had retracted and the cornea oedema was reduced.

Two horses in this study were young horses, respectively 1 year (Case 1) and 2 years of age (Case 2). *O'Leary* et al. 2021 recently described a case series of 3 young horses of 2,5 years and 1 year old with a per acute onset of corneal hydrops (*O'Leary* et al. 2021). These horses showed severe unilateral corneal oedema with intrastromal bullae and anterior bulging of the corneal contour. In our study Case 2 developed a similar corneal hydrops with anterior bulging of the corneal contour. In the study performed by *O'Leary* et al. a traumatic Descemet's membrane rupture was suspected, however no advanced imaging was done to confirm this suspicion. In our study none of the horses had a definitive diagnosis of Descemet's membrane detachment and in none of the cases trauma was mentioned in the patient history although this cannot be completely excluded. In theory, small disruptions of the DM can be missed by conventional ocular ultrasound and other advanced techniques could be used to confirm DMD or DM rupture (*Slenter* et al. 2020). To confirm DM rupture, optical coherence tomography or ultrasound biomicroscopy could be used (*Rodriguez Galarza* et al. 2020). Both techniques are not available in our current clinical situation.

All horses in the study of *O'Leary* et al. 2021 had an excellent outcome with medical management. In our study, the corneal oedema of 2 horses progressed despite medical treatment. Corneal cross-linking and/or tamponade with temporary tarsorrhaphy might have been other viable options.

Due to the retrospective nature of this study, intra-ocular pressure was not recorded in 2 cases which is a limitation of this study. Obtained measurements were compared to the healthy eye if possible. One horse (Case 5) showed a decreased pressure in the affected eye which is not readily explained since an artificial increase in pressure would be more likely caused by the oedema (*Micheau*, 2017). However, in cats and dogs

Table 2 Ultrasonographic measurements and additional findings of the affected eye with corneal oedema and the healthy contralateral eye.

	Globe diameter (affected eye)	Corneal thickness (edema)	Corneal thickness (healthy)	Descemet's membrane	Other abnormalities
Case 1	35 mm	2.5 mm	0.6 mm	Normal	None
Case 2	38 mm	2.0 mm	0.7 mm	Normal	Bilateral posterior capsular cataract and vitreal degeneration
Case 3	45 mm	2.5 mm	1.2 mm	Normal	Mild increase in aqueous humor in posterior chamber, bilateral cataract and vitreal degeneration
Case 4	43 mm	2.6 mm	0.8 mm	Suspicion of premature detachment	Suspected of uveitis due to amount of fibrin in vitreum
Case 4*	41 mm	1.4 mm	0.9 mm	Normal	Persistent evidence of uveitis due to vitreal debris
Case 5	43 mm	2.0 mm	0.8 mm	Normal	Bilateral mild cortical cataract and mild vitreal degeneration

with corneal pathology a decrease in IOP is occasionally described when using an indirect measurement method to determine IOP (*von Spiessen* et al. 2015). The horse in Case 5 did not show signs of inflammation in the anterior segment of the eye.

Case 4 was presented while the horse was still being treated with medication to lower the intra-ocular pressure, this could explain the normal pressure at time of presentation and increase in pressure when medication was temporarily stopped.

In conclusion, superficial keratectomy and a Gunderson inlay flap is considered a valuable surgical treatment option in cases of suspected endothelial oedema when medical treatment is unsuccessful, or the severity deems surgical treatment necessary. Progressive corneal oedema with bullae formation, persistent corneal ulceration or ocular discomfort are other indications for surgical treatment. Ultrasonography as an advanced imaging modality is considered useful to further discriminate between possible differential diagnoses for corneal oedema, especially when the oedema is severe and diffuse. Culture and sensitivity testing prior to performing corneal surgery might be useful in electing a tailored postoperative medical treatment strategy in horses, even when infectious keratitis is not present or suspected, given the MRSA carrier status. Future studies are necessary to further understand the possible causes of endothelial corneal oedema (e.g. endotheliitis) and the relation to Descemet's membrane detachments. Further research could also aid in a better understanding on how keratectomy and conjunctival inlay grafts could prevent progression of the disease process.

Manufacturers' addresses

[a] SL-15, Kowa Optimed, Inc., Torrance, CA, USA.
[b] Welch Allyn, Skaneateles falls, NY 13153 USA.
[c] Tonovet Icare Finland Oy, Äyritie 22/Tuike FI-01510 Vantaa, Finland
[d] Vétoquinol BV, Postbus 3191, 5203 DD 's-Hertogenbosch, The Netherlands.
[e] Philips Medical Imaging and Healthcare, Eindhoven, The Netherlands
[f] Vicryl Ethicon, Johnson & Johnsen Consumer BV Postbus 188 3800 AD Amersfoort, The Netherlands
[g] Eye Lavage Kit/SPL Mila International Inc. 7984 Tanners Gate Lane, Florence, Kentucky 41042 USA
[h] Ethilon Ethicon, Johnson & Johnsen Consumer BV Postbus 188 3800 AD Amersfoort, The Netherlands
[i] Dorzolamidehydrochloride 20 mg/ml, timololmaleaat 5 mg/ml RVG 1056Mylan, Bunschoten, The Netherlands.
[i] Ketorolac 5 mg/ml, Acular, Allergan Pharmaceuticals Ireland Castlebar Road Westport Co. Mayo, Ireland.
[k] Dexamethasone disodium phosphate 0.1 %, Allergan Pharmaceuticals Ireland Castlebar Road Westport Co. Mayo, Ireland.
[l] Soligental (gentamicine eye drops), Virbac, Hermesweg 15, 3771 ND, Barneveld, The Netherlands.
[m] Acetylcysteine 100 mg/ml, Veterinary Medicine Pharmacy, Yalelaan 106, 3584 CX, Utrecht, The Netherlands.
[n] Boehringer Ingelheim Vetmedica GmbH, 55216 Ingelheim/Rhein, Germany.
[o] Atropine Sulphate eye drops, 5 mg/ml, Veterinary Medicine Pharmacy, Yalelaan 106, 3584 CX, Utrecht, The Netherlands.
[p] Chloramphenicol eye drops, 5 mg/ml, Teva Nederlands B.V., Swensweg 5, 2031 GA, Haarlem, the Netherlands.

Conflict of interest statement

No conflicts of interest have been declared.

Ethical animal research

Ethical review not applicable for this retrospective case series.

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Authorship

H. Hermans and E. M. S. Visser managed the clinical cases and prepared the manuscript. I. J. M. Slenter was the main surgeon performing the surgeries and critically reviewed the manuscript. S. Veraa performed and contributed to the description of the ultrasonographic examinations and critically reviewed the manuscript. All authors approved the final manuscript.

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