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CASE REPORT

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Management of corneal epithelial defects in a population of mature chuck-will's-widows (Antrostomus carolinensis) in South Florida

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Abstract

Purpose: To describe ocular clinical findings, gross/histopathologic findings, and treatment regimens in a series of migratory chuck-will's-widows (Antrostomus carolinensis) (CWW) with corneal epithelial defects.

Methods: Seven CWW were presented to the South Florida Wildlife Center (SFWC). Four presented with bilateral (OU) corneal ulceration; two developed corneal ulceration OU; one had no ocular lesions. Treatment protocols for patients with corneal ulcers included the following: medical therapy only or medical therapy combined with an additional procedure. Four patients including the bird with no ocular lesions were euthanized, and one patient died. Their globes were submitted for histopathology. Two patients were released.

Results: Clinical findings prior to enucleation included superficial corneal ulceration with redundant epithelium persisting weeks to >1 month. On histopathology, epithelium in nonulcerated globes was remarkably thin; this was considered normal. Common histopathologic findings of ulcerated globes revealed epithelial and conjunctival attenuation with an acellular superficial stromal layer and hypercellular mid-stromal layer. One globe healed with medical therapy and cotton tip applicator debridement. Four globes healed by combination of medical therapy, equine amnion, nictitating membrane (NM) flap, and temporary tarsorrhaphy. No globes healed with diamond burr debridement or grid keratotomy.

Conclusions: Factors that may be contributing to these corneal epithelial defects include, but are not limited to, normally thin epithelium, exposure keratopathy, neurotrophic disease, epithelial turnover and inadequate stem cell recruitment, inherited/genetic causes, and unidentified infectious agents (eg, viral etiologies). Of the 12 eyes treated, one healed with medical therapy/cotton tip applicator debridement, and four healed with medical therapy/equine amnion/nictitating membrane flap/temporary tarsorrhaphy.

KEYWORDS

amnion, avian, chuck-will's-widow, corneal ulceration

1 | INTRODUCTION

The chuck-will's-widow (CWW) belongs to the family Caprimulgidae, colloquially known as Nightjars.[1] They are recognized for their crepuscular sustained onomatopoeic songs (chuck-will's-WID-dow)[2] and date back in written history to notes from the philosopher Aristotle (384 BC).[3] The Aristotle work *History of Animals* claimed that Nightjars would suckle milk from livestock under the cloak of night and that they were ultimately responsible for the development of livestock blindness.[4] This belief was held for nearly two millennia and was ultimately incorporated into the Nightjar nomenclature where the Latin words *capra* (nanny goat) and *mulgere* (to milk) were used for scientific classification.

Despite its long-standing presence in written literature, the CWW is a reclusive species and knowledge of its habits and migratory patterns exists in generalities. Their migratory range encompasses the Southern and Eastern United States, Middle America, and the Western Caribbean.[5,6] Several resident populations exist in Florida, Louisiana, and Texas. They forage aerially by flying several feet above the ground along the edges of woodlands and pastures. During flight, the rictal bristles lining their mouths serve to funnel insects into their large gaping bills.[7] It is unknown whether the CWW flies with open or partially closed eyelids, but during times of rest and/or defense, they have been observed to adopt a motionless horizontal position, keeping watch through partially closed eyelids.[4]

The CWW presents to the South Florida Wildlife Center (SFWC) with seasonal regularity. Trauma is the most common cause of presentation. Of the 200 CWW that passed through the doors of the SFWC between January 1, 2013, and December 31, 2018, 130 (65%) were thought to have suffered from trauma. Forty CWW (20%) presented with some form of ophthalmic disease including corneal ulceration, cataract, retinal detachment, and globe perforation. Superficial corneal ulceration was regularly noted. In all, 26 CWW (13%) with 42 ulcerated corneas were presented. A subset of these birds demonstrated persistent epithelial defects not responsive to medical therapy alone and inconsistently responsive to procedures including cotton-tipped applicator debridement, diamond burr keratectomy, and/or grid keratotomy. Of the ulcerated eyes, 23 (55%) healed and 19 (45%) did not heal despite treatment periods of up to 40 days. To date, three reports in the literature document treatment and resolution of superficial nonhealing ulcers in avian patients. These reports include a laughing kookaburra treated via debridement with a cotton tip applicator,[8] a peregrine falcon treated with 360° conjunctival flaps bilaterally,[9] and a Hyacinth Macaw whose ulcer was ultimately healed after prolonged treatment by diamond burr debridement and cyanoacrylate tissue adhesive application.[10]

The CWW is not typically suited to captivity due to its foraging habits; daily handling for tube- or hand-feeding is required. These birds are easily stressed and are prone to breaking primary feathers and development of mild-to-severe abrasions while waiting for their initial presenting issues to resolve, regardless of the use of sedation and environment. The birds are not deemed releasable until their corneal ulcers are healed; therefore, rapid and effective management strategies for these ulcers were sought. Humane euthanasia and natural death are common unwanted sequelae. This case series highlights a subset of CWWs that present to the SFWC with corneal ulcers, and the different methods used to encourage prompt healing. Historically, management strategies over the past 6 years have included medical therapy only, or medical therapy with cotton tip applicator, diamond burr debridement, and/or grid keratotomy. Nictitating membrane flap placement alone in years prior to the case series was unsuccessful (personal communication RLS). Most recently, a procedure combining placement of aseptically processed equine amnion disks with NM flap and temporary tarsorrhaphy has been utilized. Histopathology findings are reported for the cases in this series where treatment of corneal ulcers was unsuccessful, and for a case with no ocular lesions to demonstrate normal histologic anatomy.

2 | MATERIALS AND METHODS

Numerous doctors (Animal Eye Guys—RLS, TLO) (South Florida Wildlife Center—AGa, AGr, RMS) were involved in the examination, medical, and procedural management of the patients in this case series. Each patient was examined at least twice by a single board-certified veterinary ophthalmologist (RLS) and ophthalmology resident (TLO). All birds were examined by slit lamp biomicroscopy (Kowa SL-17) and indirect ophthalmoscopy with a 2.2D lens (Volk Optical IN.) and Welch Allyn 3.5V Finnoff Ocular Transilluminator.

All enucleated globes were fixed in formalin and submitted to the Comparative Ocular Pathology Laboratory of Wisconsin (COPLOW). The globes were routinely processed for histopathology and stained with hematoxylin and eosin stain.

3 | CASE SERIES

3.1 | Case 1

A mature CWW of unknown sex was presented to the SFWC for a possible wing fracture. Examination revealed an open left humeral fracture. No ocular injuries were noted. The patient was euthanized, and the eyes were collected for

documentation of histopathologic ocular features considered within normal limits for the species.

Histopathology of the globes notably revealed a corneal epithelium of a few cell layers thick and was considered the likely normal anatomic state of this species (Figure 1A).

3.2 | Case 2

A mature CWW of unknown gender was presented to the SFWC with a possible right-wing injury and missing tail feathers. On presentation, the right axillary region had a chronic deep laceration. Medical therapy was initiated for wound treatment and healing progressed uneventfully. Seven days after presentation, a superficial corneal ulceration with redundant epithelial edges occupying ~30% of the right (OD) corneal surface was noted. Medical therapy consisted of meloxicam (Ceva Animal Health) 1 mg/kg per os (PO) once daily (SID), doxycycline (compounded in-house) 5 mg/kg PO twice daily (BID), tobramycin (Bausch & Lomb) in both eyes (OU) BID, and avian serum (from in-house avian patients at the SFWC) OU three times daily (TID). Eight days later the corneal ulcer persisted; cotton tip applicator debridement was performed under topical 0.5% proparacaine (Amcon Laboratories) anesthesia (AGa). Diazepam (Lannett Company Inc) 1 mg/kg PO BID was initiated for sedation. The patient was evaluated five days later by Animal Eye Guys (AEG) (RLS); the corneal ulcer OD was nearly healed, and the left eye (OS) had developed a 2 × 3 mm superficial corneal ulcer with redundant epithelial edges. To limit patient handling and stress, all medications were discontinued except for HyCare lubricant (Acrivet Inc, Bausch & Lomb), which was applied OU TID. Four days later, the patient was examined, and the corneal ulcers were noted as healed with negative fluorescein stain retention OU. Shortly thereafter, the patient became agonal and nonresponsive to stimulus and was euthanized after 26 days in rehabilitation. A full necropsy was performed, and moderate-to-severe renal tubular gout tophi with renal tubular epithelial necrosis were seen on histopathology. Renal failure with resultant visceral gout was the documented cause of death.

Histopathology of both globes revealed focally extensive attenuation of the corneal epithelium (Figure 1B), mild conjunctival epithelium attenuation, and an intact Bowman's layer. Contrary to the final clinical examination findings, the OS cornea demonstrated multifocal regions of epithelial nonattachment associated with the area of epithelial attenuation. The reason for this disparity is unknown.

3.3 | Case 3

A mature male CWW was presented to the SFWC "unable to fly." On presentation, the patient was bright, alert, and responsive with a body condition score (BCS) of 3/5. The patient was able to fly but had right elbow/radius/ulnar swelling and tired quickly. Radiographs revealed soft tissue swelling without fractures. Superficial corneal ulcers of unknown diameter were present OU. The patient was placed on neopolygram (Bausch & Lomb) OU TID, avian serum OU TID, and meloxicam 1 mg/kg PO SID. Three days later, the ulcers remained present, and cotton tip applicator debridement was performed OU under topical 0.5% proparacaine anesthesia (AGa). The topical antibiotic was changed to tobramycin OU TID due to mild perceived patient discomfort associated with neopolygram administration. Eight days later, the corneal ulcers persisted, and diamond burr debridement (Algerbrush II 3.5-mm medium grit round diamond burr; Ambler Surgical) was performed OU under topical 0.5% proparacaine anesthesia (AGr). Size of corneal ulceration postprocedure was not documented. Medical therapy was continued with the addition of diazepam 1 mg/kg PO BID. Fifteen days later, the corneal ulcers persisted, and diamond burr debridement was repeated OU (TLO). The patient was moved outdoors due to agitation but was later observed flying into the aviary walls causing hemorrhagic discharge from the beak and broken

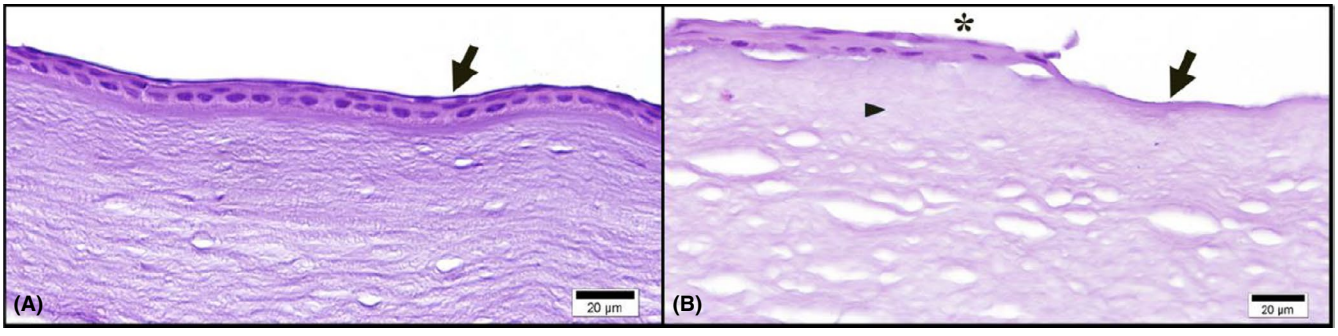

FIGURE 1 Selected histopathology photographs comparing the corneal epithelium of nonulcerated and ulcerated chuck-will's-widow corneas. A, Corneal section from a CWW that died unrelated to ophthalmic disease. The epithelium (arrow) is only 1-2 cell layers thick and is considered the normal anatomic state of the species, and (B) corneal section from a CWW with axial corneal ulceration (arrow) with disorganized epithelium (asterisk) and mild stromal edema (arrowhead). H&E stain

primary feather tips. Medical therapy was decreased to avian serum OU SID, HyCare OU SID, and meloxicam 1 mg/kg PO SID to reduce handling. The self-trauma and patient agitation stopped when handling became limited. Two weeks after the second diamond burr procedure, the superficial ulcers with redundant epithelial edges persisted OU. A grid keratotomy was performed under topical 0.5% proparacaine anesthesia OU (TLO). Doxycycline 5 mg/kg PO BID was added to the medical therapy plan. Three days later, the left elbow was observed to have a degloving injury. Ultimately, the corneal ulcers never healed, and due to stress and injuries, the patient was euthanized 40 days after presentation.

Histopathology of both globes demonstrated an axial focally extensive area of corneal ulceration with adjacent attenuated and disorganized epithelium. The underlying corneal stroma had a superficial acellular layer and mid-stromal hypercellular layer. Multifocal breaks in Bowman's layer were present and were suspected to be a result of the diamond burr procedure.

3.4 | Case 4

A mature CWW of unknown gender was presented to the SFWC with nonspecific clinical signs. On presentation, the patient was dull with a BCS of 2/5. Open wounds were present over the left shoulder. The OD was noted to have hemorrhage adjacent to the pecten, and the OS had a questionable PLR. Medical therapy was initiated by the SFWC and included flurbiprofen OU BID, tobramycin OU BID, meloxicam 1 mg/kg PO SID, and ciprofloxacin 15 mg/kg PO BID. Therapy was purposefully broad to cover for possible mild uveitis and pinpoint corneal ulceration not easily detected without slit lamp biomicroscopy. Thirteen days after presentation, the patient was noted to have superficial corneal ulcers with redundant epithelium OU. Diamond burr debridement was performed under topical 0.5% proparacaine anesthesia OU (RLS), flurbiprofen was discontinued, and avian serum was added OU. Due to persistence of the corneal ulcers and self-inflicted keel wounds, the patient was euthanized 26 days after presentation.

Histopathology of both globes demonstrated an axial focally extensive area of corneal ulceration with adjacent attenuated and disorganized epithelium. The underlying corneal stroma had a superficial acellular layer and mid-stromal hypercellular layer. Multifocal breaks in Bowman's layer were present and were suspected to be a result of the diamond burr procedures. Additionally, the conjunctival substantia propria demonstrated focal infiltration by histiocytes with large clear vacuoles.

3.5 | Case 5

A mature CWW of unknown sex was presented to the SFWC with missing tail feathers and blood in the glottis. The patient was noted to have pinpoint superficial corneal ulcers OU. Tobramycin OU BID, avian serum OU SID, meloxicam 1 mg/kg PO SID, and doxycycline 10 mg/kg PO SID were initiated. The ulcer diameters were noted to expand over the next several days OU. Three days after presentation, the patient was evaluated at AEG. It was elected to perform amnion disk placement/NM flap/temporary tarsorrhaphy OS (RLS). The authors considered performing the procedure OU concurrently, but decided to proceed unilaterally due to the possible additional stress of rendering the patient temporarily nonvisual. The procedure was performed as follows: The corneal and conjunctival surfaces were cleansed to remove debris and exudates. Topical 0.5% proparacaine anesthesia was applied. A 7-0 prolene suture (Ethicon) was pre-positioned through the dorsotemporal eyelid and conjunctival fornix, full thickness through the leading margin of the NM, and lastly returned through the dorsotemporal conjunctival fornix and eyelid. A 15-mm acellular xenograph equine amniotic membrane disk (Tendril; Seed Biotech) was applied directly to the corneal surface without further suturing/adhesion. The nictitating membrane flap was then pulled over the amnion disk and corneal surface into the desired position and secured in the dorsotemporal fornix. Lastly, a 7-0 prolene single temporary tarsorrhaphy horizontal mattress suture was placed through the temporal aspect of the superior and inferior eyelids. Stents were not utilized, as the sutures placed for the NM flap and temporary tarsorrhaphy did not appear to be under significant strain. Medical therapy was continued without change. Fourteen days post-procedure, the patient was reevaluated at AEG. The NM palpebral surface was observed to be mildly hyperemic. Release of the temporary tarsorrhaphy and NM flap revealed a partially degenerated amnion disk (removed) and that the corneal ulcer OS was healed. The NM was observed to glide freely across the globe. Images of this process can be found in Figure 2. The corneal ulcer OD persisted, and the same procedure combination was performed OD (RLS). Seven days after the OS was observed to be healed, a new pinpoint corneal ulcer was observed OS and was treated with HyCare lubricant TID. Fourteen days post-procedure OD, release of the temporary tarsorrhaphy and NM flap revealed a partially degenerated amnion disk (removed) and that the corneal ulcer OD was healed. The NM palpebral surface was observed to be mildly hyperemic and was observed to glide freely across the globe. The corneal ulcer OS was also healed. The patient was released 40 days after presentation.

3.6 | Case 6

A mature CWW of unknown sex was presented to the SFWC with missing tail feathers and a wound in its bottom palate.

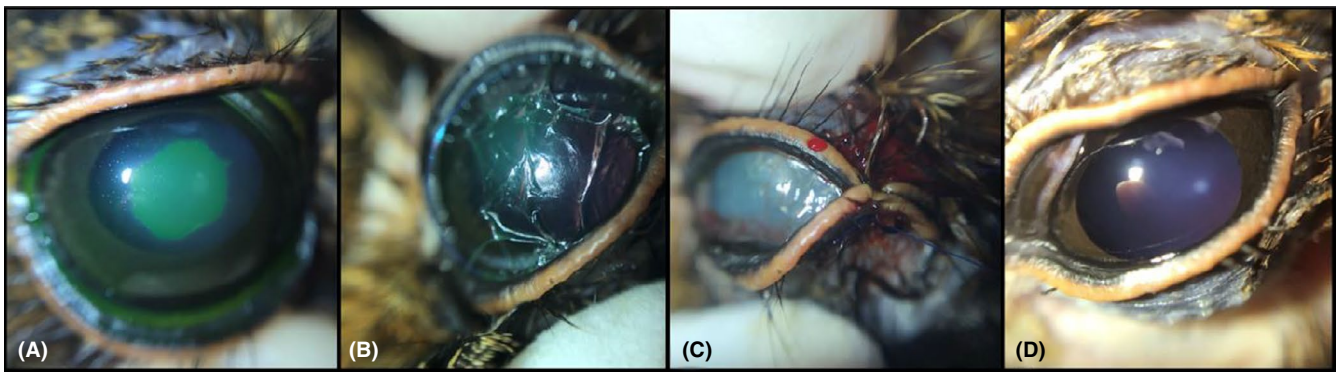

FIGURE 2 Selected photographs in chronologic sequence for the treatment of a superficial corneal ulceration in a chuck-will's-widow using an acellular xenograph equine amniotic membrane disc, nictitating membrane flap, and temporary tarsorrhaphy. A, A superficial 3 × 3 mm superficial corneal ulcer is observed axially after fluorescein stain application. B, A 15-mm disk of equine amnion (Tendril) covers the surface of the cornea after being manipulated with a cotton tip applicator. No hydration of the amnion disk was performed. C, A third eyelid flap was placed over the amnion followed by a temporal temporary tarsorrhaphy using 7-0 prolene, and (D) 2 wk post-procedure, the corneal surface is clear and ulcer free immediately after taking down the third eyelid flap and temporary tarsorrhaphy

The patient was bright, alert, and responsive with a BCS of 2/5. Superficial corneal ulcers 6 × 7 mm with redundant epithelial edges were nearly symmetrical OU. Tobramycin OU BID, avian serum OU SID, meloxicam 1 mg/kg PO SID, and doxycycline 10 mg/kg PO SID therapy were initiated. Three days after presentation, the patient was evaluated at AEG. It was elected to perform amnion disk placement/NM flap/temporary tarsorrhaphy OS (RLS) in a similar manner as described in Case 5. Medical therapy was continued without change. Fourteen days post-procedure, the patient was reevaluated at AEG. The NM palpebral surface was observed to be mildly hyperemic and partially retracted. Release of the temporary tarsorrhaphy and NM flap revealed a partially degenerated amnion disk (removed). The corneal ulcer OS was healed, and the NM was observed to glide freely across the globe. The corneal ulcer OD persisted (Figure 3), and the same procedure combination was performed OD (RLS). Over the next two weeks, the patient developed pressure sores on both hocks and developed an open wound on the left carpus, which were successfully medically managed by the SFWC. Fifteen days post-procedure, the NM palpebral surface was observed to be mildly hyperemic. Release of the temporary tarsorrhaphy and NM flap revealed that the corneal ulcer OD was healed, and the NM was observed glide freely across the globe. The patient was released 32 days after presentation.

FIGURE 3 Characteristic appearance of a chronic superficial corneal ulcer in a CWW. This image was taken of the OD from Case 6 seventeen days post-presentation, and immediately prior to amnion, NM membrane flap, and temporary tarsorrhaphy placement. No corneal vascularization was present

3.7 | Case 7

A mature male CWW was presented to the SFWC after being found in an airport janitorial closet. On presentation, the patient was bright, alert, and responsive with a BCS of 3/5. The patient was able to fly, had a small bruise on the left caudal hock, and had superficial corneal ulceration with redundant epithelial edges OU, occupying an estimated 60% of the OD and 30% of the OS corneal surface. The ulcers were debrided with cotton tip applicators, and a carpal wrap was placed by SFWC staff. Over the course of the next week, the patient was treated with meloxicam 1 mg/kg PO SID, doxycycline 5 mg/kg PO BID, diazepam 1 mg/kg PO BID, tobramycin OU TID, and homologous avian serum OU four times daily (QID). After seven days, the corneal ulcers were largely unchanged. AEG was contacted. A diamond burr debridement was performed OD, and a grid keratotomy with a 27-gauge needle was performed OS under topical 0.5% proparacaine anesthesia (RLS). Following the debridement

and keratotomy, multiple ophthalmic examinations were performed, and the ulcers remained unhealed after 19 days. The ulcers maintained a superficial and noninfected appearance on each examination. The patient developed a self-inflicted decubital ulcer on the dorsal right elbow and a keel degloving injury. To reduce catching and handling, the SFWC reduced therapy to avian serum SID OU in the morning and HyCare lubricant SID OU in the evening and moved the patient to an outdoor enclosure. The patient died after 26 days in rehabilitation. Cause of death is unknown.

Histopathology of the right globe revealed an axial focally extensive area of corneal ulceration with adjacent attenuated and disorganized epithelium. The underlying corneal stroma had a superficial acellular layer and mid-stromal hypercellular layer. Multifocal breaks in Bowman's layer were present and were suspected to be a result of the diamond burr procedure. The conjunctival substantia propria and episcleral tissues demonstrated focal infiltration by histiocytes. The left globe had similar histologic features, with the addition of slight epithelial downgrowth into the superficial corneal stroma, consistent with grid keratotomy lines, and presence of septate pigmented fungal hyphae. Fungal culture could not be performed due to globe fixation, and genus remains unknown.

4 | DISCUSSION

In this case series, we detail the clinical findings for a subset of chuck-will's-widow birds presented to the South Florida Wildlife Center with corneal ulcers. Clinical appearance of these ulcers was similar among this population of birds and was characterized by superficial ulceration with redundant epithelium (Figure 3). Collaboration with the SFWC highlighted the difficulties of keeping species, even temporarily for rehabilitation, that do not do well in a captive environment. The CWW is one such species, and persistence of corneal ulcers in a portion of this population has prevented release, and ultimately contributed to loss of life.

Avian ophthalmic disorders are highly variable and are related but not limited to the species, anatomic conformation, environmental factors, and lifestyle (eg, free living vs captive). A report by Murphy et al (1982) estimated 15% of birds presented to veterinary hospitals and wildlife rehabilitation centers had ocular lesions.[11] This is consistent with the CWW population presented to the SFWC over the past 6 years, where 20% were noted to have some form of ophthalmic disease. In raptors and wild birds of prey, ocular trauma is reported as the most common etiology of ocular disease.[11,12] Corneal disease in these species is a relatively infrequent cause of post-traumatic euthanasia in birds.[13] Aside from the percentage of birds presented for veterinary care, observation of ocular lesions in free-living birds is rare and reported consistently around 2% across species.[14,15] This includes families and orders in the Strisores clade, which Caprimulgiformes belong to.[15] The low percentage reported may be due to overall low numbers of ophthalmic disease or high incidence of death in the wild following ocular disease or trauma.[14,15] For the CWW in this series, cause of presentation was not always readily apparent, though injuries in some birds on presentation were suggestive of trauma.

The underlying cause for the refractory nature of these corneal ulcerations in a subset of CWW is unknown and may be multi-factorial. While in captivity for rehabilitation, these CWW were observed to commonly keep their palpebral fissures fully open, as opposed to the partial closure observed in the wild during periods of rest and vigilance. Development of corneal ulceration due to prolonged corneal exposure is one of the primary underlying etiologies suspected by the authors. Other contributing etiologies include repeated mechanical trauma, inherited/genetic factors, and viral contributions. The exceptionally thin corneal epithelium present in the normal anatomic state may be a contributory factor that exacerbates the underlying etiology. A report in a Great Horned Owl with chronic ulcerative keratitis identified a novel alphaherpesvirus, and resolution of the ulcer occurred post-diamond burr debridement and anti-viral therapy with topical cidofovir.[16] However, this case had recurrence of chronic corneal ulceration for years in conjunction with keratitis and papillary conjunctivitis. It is possible that a different viral etiology was present in the CWWs of the present case series but given the resolution of corneal ulcers without anti-viral therapy and lack of viral inclusions seen on histopathology, a viral etiology is considered less likely. Viral polymerase chain reaction (PCR) was not performed on any sample due to limited funding.

Resolution of superficial corneal ulcerations in the CWW has been a long-standing challenge for rehabilitation centers in South Florida (personal communication with Dr Jessica Martinez DACVO at Pelican Harbor Seabird Station). Ulcers over the years have inconsistently responded to medical therapy alone, and medical therapy combined with cotton tip applicator debridement, diamond burr keratectomy, and/or grid keratotomy. Consideration to superficial keratectomy has been given, but efforts to avoid general anesthesia in a species already prone to significant morbidity in captivity have precluded attempts with this procedure. The authors also recognize the limited expertise available in many centers for avian anesthesia and ophthalmic microsurgery and aimed to identify a successful method of corneal ulcer healing that could be replicated without the need for advanced training. Time until healing has been highly variable and given the difficulty of keeping CWW in captivity for even short periods of time, other modes of therapy were sought. Recently, the combination of placing acellular amniotic membrane over the wound, followed by NM flap and temporary tarsorrhaphy, has yielded promising results. All eyes in this case series that underwent

the procedure combination were healed within 2 weeks. Since completion of this manuscript, an additional two CWW (four eyes) have been treated with this procedure. In these cases, both eyes were treated at the same time, which rendered the birds largely nonvisual during the treatment period. SFWC staff noted that birds appeared to have minimal vision from the nasal aspect of the globes. Vision obscuration did not notably increase patient stress in captivity or lead to more destructive behavior. The NM flaps/temporary tarsorrhaphies were taken down after 1 week, and all ulcers were healed. This brings the total number of eyes treated with this procedure combination to eight, with 100% success within 1-2 weeks.

Consistent resolution of these superficial ulcers has been observed only with the combination of amnion, NM flap, and temporary tarsorrhaphy placement. Diamond burr debridement and grid keratotomy were performed due to persistence of the ulcers, and similar clinical appearance to spontaneous chronic corneal epithelial defects (SCCEDs) reported in dogs. However, these procedures have failed repeatedly to consistently aid healing of superficial corneal ulcers in the CWW population, and histopathology from the birds that died in this case series did not reveal a prominent superficial stromal hyaline acellular zone, which is the characteristic of the disorder in canine patients.[17] Fungal hyphae were noted on histopathology in the grid keratotomy site of Case 7 in this series. This is the only case where an infectious agent was noted, and while fungal hyphae have been suggested to impede healing via production of anti-angiogenic factors,[18,19] given the lack of corneal vascularization in all cases, it is unlikely that this factor was responsible for the prevention of ulcer healing alone. It is also possible that the grid keratotomy for an already nonhealing ulcer created an environment that encouraged fungal adhesion (eg, grid keratotomy tracks).

The amniotic membrane sample used in Cases 5 and 6 is a dehydrated amniotic membrane product of equine origin. Amniotic membrane is a biologic tissue that has been used for the treatment of a variety of ocular surface diseases. It possesses anti-microbial, anti-immunogenic, and anti-angiogenic properties. Amnion has been used to facilitate the migration, differentiation, and adhesion of epithelial cells through extracellular matrix proteins and stromal matrix growth factors.[20-22] It has also been shown to control apoptosis of the corneal epithelium, temper corneal scarring via suppression of transforming growth factor-B signaling,[23] and decrease corneal inflammation through production of proteins that inhibit pro-inflammatory cytokine activity.[20-22,24]

Reports of amnion for ophthalmic wound healing in the veterinary literature primarily detail the use of cryopreserved samples. These reports include a case series for two dogs and a cat,[25] transplantation for corneal ulceration and keratomalacia in horses,[26] and the use of amnion for corneal surface reconstruction after corneolimbal squamous cell carcinoma resection in horses.[27] Kim et al (2009) were the first to detail the use of a freeze-dried amniotic membrane product for the treatment of superficial corneal ulcers in canines.[22] Freeze-dried amnion (FD-AM) eliminates advanced storage requirements, and although some of the biochemical properties of amnion can be reduced during the preservation process, FD-AM retains biochemical properties.[28] Collagen, fibronectin, and laminin-5 are retained, and the basal lamina and basement membrane remain intact.[29] The results published by Kim et al (2009) demonstrated that FD-AM enhanced corneal epithelial wound healing when compared to nictitating membrane and contact lens use alone.[25] To the authors' knowledge, the current case series is the first to present the use of a dehydrated equine amnion product as adjunctive treatment for corneal ulceration in an avian species.

The NM is well developed, thin, and highly mobile in avians,[30] including the CWW. Other literature sources suggest that due to the important role that the NM plays in distributing tear film, in addition to being under voluntary pyramidalis muscle control via CN VI, that NM flaps should not be performed in avian species.[31] While the reasoning behind this recommendation is understood by the authors, it was elected to proceed with NM flaps to assure that the amnion disks placed remained relatively immobile. Temporary tarsorrhaphy and amnion disk placement without NM flap were considered, but the eyelids of the CWW fit loosely over the globe and it was unclear whether the disk would remain centered as desired over the ulceration. The NM flap eliminated the possibility of blinking friction/eyelid movement that temporary tarsorrhaphy alone may have contributed. The birds in this case series retained full function of their NMs once the flaps were released.

The authors suggest that management strategies for these ulcers in the future should continue to evolve. The combination of equine amnion, NM flap, and temporary tarsorrhaphy has been successful in the limited number of cases treated. This treatment requires a level of expertise that may be taught at wildlife rehabilitation centers, though depending on the source of amnion, it may be cost-prohibitive. In the future, we plan to continue this procedure combination while searching for the least amount of time required for the NM flap and temporary tarsorrhaphy to be in place for healing. Amnion and temporary tarsorrhaphy without NM flap, or temporary tarsorrhaphy alone may also be explored, as it would be ideal to eliminate NM involvement. Bandage contact lenses, with or without amnion, may also be attempted in combination with the above procedures. It should be noted that 2/6 CWW in this series developed corneal ulcers after presentation, and 1/6 developed an additional ulcer after the procedure combination had been taken down. For CWW that present without corneal ulceration, prophylactic temporary tarsorrhaphy procedures may be considered on a case-by-case basis in order to reduce the chances of ulcer development while undergoing rehabilitation for other injuries.

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