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Equine keratomycoses in California from 1987 to 2010 (47 cases)

Z. REED[†], S. M. THOMASY^{§,*}, K. L. GOOD[§], D. J. MAGGS[§], K. G. MAGDESIAN[‡], N. PUSTERLA[‡], and S. R. HOLLINGSWORTH[§]

[†]William R. Pritchard Veterinary Medical Teaching Hospital, School of Veterinary Medicine, University of California, Davis, Davis, CA 95616, USA

[§]Department of Surgical and Radiological Sciences, School of Veterinary Medicine, University of California, Davis, Davis, CA 95616, USA

[‡]Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California, Davis, Davis, CA 95616, USA

Summary

Reasons for Performing Study—Equine keratomycosis in the western United States has received little study, likely due to its low prevalence.

Objectives—To determine clinical features, predominant fungal isolates, treatment modalities, and outcomes of horses with keratomycosis in California and compare these with results from different geographic regions.

Methods—Records of horses presented to the University of California-Davis Veterinary Medical Teaching Hospital (UCD-VMTH) with confirmed keratomycosis between 1987 and 2010 were reviewed for this retrospective study. Information retrieved from the record included signalment, ophthalmic examination findings, treatment prior to and following presentation, visual outcome, and ocular survival.

Results—A total of 48 eyes of 47 horses met inclusion criteria and comprised 2% of cases presented to the UCD-VMTH ophthalmology service. Prior to presentation, 20 horses (43%) received at least one topically administered anti-inflammatory medication. Keratomycosis was confirmed by fungal culture in 38 horses (81%), by histopathology in 2 horses (4%) or by cytology in 7 horses (15%). Forty-four isolates were identified in the 38 horses cultured; *Aspergillus* was the most common isolate (64%) and a novel isolate, *Papulospora*, was identified in 2 horses. Treatment consisted of medications only (73%), medical and surgical treatment (25%), or immediate enucleation (2%). Globe retention was 77% and vision retention was 53%. Corneal perforation was significantly associated with loss of vision ($P < 0.001$).

Conclusions—Keratomycosis is relatively uncommon in horses presented for ophthalmic conditions at UCD-VMTH. Corneal perforation was a negative prognostic indicator for vision in this population of northern Californian horses.

Keywords

horse; fungal keratitis; keratomycosis; *Aspergillus*; corticosteroids

*Corresponding author: Sara Thomasy, Department of Surgical and Radiological Sciences, School of Veterinary Medicine, University of California, Davis, West Health Sciences Dr. Davis, California 95616, USA. Phone: 530-752-0926, Fax: 530-752-3708, smthomasy@ucdavis.edu.

Dr. Reed's current address is VCA West Los Angeles Animal Hospital, Los Angeles, CA 90025, USA.

Authors' declaration of interests

No competing interests have been declared.

Introduction

Keratomycosis is a common cause of corneal disease in equine patients and can result in vision or globe loss. Aggressive medical management, sometimes in combination with surgery, is required to achieve a functional outcome in affected horses. Success rates for vision retention in equine keratomycosis vary from approximately 50% [1-4] to 90% or greater [5, 6]. However, the wide variation in clinical appearance, progression, and response to treatment among individual patients complicates diagnosis, management, and prognostication for horses with keratomycosis [1, 3-5, 7-10].

Fungal organisms are a normal component of the equine conjunctival microflora and external environment [5, 11, 12], but regional differences exist regarding presence and type of fungi within the conjunctival microflora [12-14]. In addition, *in vitro* susceptibility patterns of fungi associated with keratomycosis vary geographically [15-17]. Equine keratomycosis appears to be more common in warm, humid environments and most studies examining this syndrome were performed in the southern and central United States [4, 5, 16, 18]. Keratomycosis is also more common in humans residing in the southern United States with fungi accounting for 35% of microbial keratitis in Florida versus 8% in San Francisco and 1% in New York [19]. In addition to climatic variation in prevalence of equine and human keratomycosis, the causative fungal organism also varies regionally. For example, *Aspergillus* and *Fusarium* spp. are found most commonly in horses with keratomycosis from Florida [5], while *Aspergillus* and *Candida* spp. are most common in the northeastern United States [15]. Filamentous fungi such as *Fusarium* spp. are also more common in human and equine keratomycosis from the southern United States while non-filamentous fungi, such as *Candida* spp. are more frequent in human and equine keratomycosis in the northern United States [5, 15, 19].

To the authors' knowledge, an investigation of equine keratomycosis in the western United States - where conditions are not believed to favour keratomycosis - has not been performed. Therefore, the purpose of this study was to retrospectively assess and report signalment, history, diagnostic testing, treatment, and outcome for horses diagnosed with keratomycosis at a single teaching hospital in the western USA.

Materials and Methods

Retrospective Study

Medical records of horses presented to the University of California-Davis Veterinary Medical Teaching Hospital (UCD-VMTH) from January 1, 1987 until December 31, 2010 were electronically searched for patients diagnosed with keratomycosis. Search terms included "fungal keratitis", "keratomycosis", "Aspergillus and cornea", or "ulcerative keratitis". Following electronic retrieval, each record was individually reviewed to ensure that it met all inclusion criteria. A horse was considered to have keratomycosis only when fungal hyphae or yeast were seen on cytologic examination of corneal scrapings, fungal elements or yeast were seen on histologic examination of excised tissue, and/or fungus was cultured from corneal scrapings. Information retrieved from the electronic medical record included the horse's sex, breed, age, location of residence, and month of presentation, along with history of ophthalmic disease, treatment immediately prior to presentation, clinical diagnoses, ophthalmic examination findings, medical treatment provided, surgical procedures performed, visual outcome, and ocular survival. Based on the findings from the ophthalmic examination, each horse's clinical diagnosis could be placed into 3 categories - superficial ulcerative keratitis, stromal ulcerative keratitis, and stromal abscess. Superficial ulcerative keratitis was defined as an ulcerated cornea with no stromal loss or malacia and cellular infiltrate in the anterior 50% of the cornea. Stromal ulcerative keratitis was defined

as an ulcerated cornea with stromal loss and/or malacia and/or cellular infiltrate beyond the anterior 50% of the cornea. Stromal abscess was defined as a non-ulcerated cornea with stromal cellular infiltrate. Favourable visual outcome was defined as functional vision in the affected eye based on degree of corneal scarring and response to a menacing gesture. Ocular survival was defined as retention of a cosmetically-acceptable, pain-free globe.

All horses seen at the UCD VMTH during the same period served as the reference population. Month of presentation was used to determine the season of presentation with the seasons defined as spring (March, April, May), summer (June, July, August), autumn (September, October, November) and winter (December, January, February). A Student's *t*-test was used to determine the effect of age on globe retention. The chi-square test was used to assess the effect on visual outcome of a number of variables: presentation during autumn versus other seasons, presence or absence of concurrent bacterial keratitis, topical treatment with corticosteroids, corneal stromal malacia, corneal stromal loss, corneal perforation, surgical treatment, topical treatment with greater than one antifungal agent, topical treatment with the most common antifungal agent, miconazole, and topical treatment with an NSAID. A Mann-Whitney rank sum test was used to determine the effect of surgery on treatment and hospitalisation time. Comparisons and probabilities were determined using commercial software (Microsoft Office Excel 2007, Redmond, WA) and an interactive chi-square calculator [20]. For each chi-square test, odds ratios (OR) and 95% confidence intervals (CI) were determined using StatXact 8 (Cytel Software Corporation, Cambridge, MA). If any of expected values for the Chi-square test were less than 5, then a Fisher's exact test was performed using StatXact 8 (Cytel Software Corporation, Cambridge, MA). For all analyses, a *P* value of < 0.05 was considered significant.

Results

Signalment and History

Keratomycosis was diagnosed in 48 eyes of 47 horses presented to UCD-VMTH in the 24-year study period. Horses with keratomycosis comprised 1.98% of equine ophthalmology admissions and 0.04% of total UCD-VMTH equine admissions. Twenty-two mares (46.8%), 20 geldings (42.6%), and 5 stallions (10.6%) were diagnosed with keratomycosis. Breeds most commonly affected with keratomycosis were Quarter Horse (*n* = 18; 38%), Thoroughbred (*n* = 11; 23%), Paint (*n* = 4; 9%) and Arabian (*n* = 4; 9%). Other breeds affected were Thoroughbred-Quarter Horse cross (*n* = 2), unknown pony breed (*n* = 2), and Tennessee Walker, Morgan, Lipizzaner, Dutch Warmblood, French Trotter, Oldenburg, Appaloosa, and Norwegian Fjord horses (*n* = 1 each). Horses with keratomycosis ranged widely in age (1.2 to 25.9 years) with a median age of 12 years. The most common month of presentation for horses with keratomycosis was October (*n* = 8; 17%) followed by August, September, and November (*n* = 5 each; 11%), March, May, and July (*n* = 4 each; 9%), January, February, and April (*n* = 3 each; 6%), December (*n* = 2; 4%), and June (*n* = 1; 2%). Autumn was the most common season of presentation (38.3%) followed by spring (23.4%), summer (21.3%) and winter (17.0%). Forty-three horses (91%) resided in northern California, 3 horses (6%) resided in southern California and one horse (2%) resided in Nevada.

Keratomycosis was confirmed in the left eye of 24 horses (51%), the right eye of 22 horses (47%), and in both eyes of one horse (2%). Thirty of 47 eyes (64%) were diagnosed with stromal ulcerative keratitis, 10 eyes (21%) were diagnosed with stromal abscess, and 7 eyes (15%) were diagnosed with superficial ulcerative keratitis; one eye could not be categorised due to an insufficient description. Prior to presentation, 15 horses (32%) were diagnosed with ocular conditions, including chronic uveitis (*n* = 6), ulcerative keratitis (*n* = 4), corneal oedema (*n* = 4), eosinophilic keratitis (*n* = 3), cataracts (*n* = 2), blocked nasolacrimal duct (*n*

= 1), or conjunctivitis (n = 1). Prior to presentation, 20/45 horses (43%) had received at least one topically or subconjunctivally administered anti-inflammatory medication, including a corticosteroid (n = 18), non-steroidal anti-inflammatory drugs (NSAIDs; n = 1), or both (n = 1); for 2 horses, history regarding topical administration of corticosteroids was not reported (Table 1). Fifteen horses (75%) received a single topically administered anti-inflammatory medication, and 5 horses (25%) received 2 (n = 4) or 3 (n = 1) topically or subconjunctivally administered anti-inflammatory medications. Ten of the 15 horses (67%) with previously diagnosed ocular conditions were receiving one or more topically administered anti-inflammatory medication prior to presentation. Pre-existing ocular conditions that were treated with a topically administered anti-inflammatory medications included chronic uveitis (n = 6), eosinophilic keratitis (n = 3), cataracts (n = 2), blocked nasolacrimal duct (n = 1), or conjunctivitis (n = 1). At presentation, 32/47 horses (68%) were receiving systemically administered anti-inflammatory medications (Table 1); 25 horses were receiving one and 7 horses were receiving 2 systemically administered anti-inflammatory medications.

At presentation, 8/47 horses (17%) were receiving at least one antifungal agent topically with 7 (88%) horses receiving one topically administered antifungal agent and one horse (12%) receiving 2 topically administered antifungal agents; one horse was receiving an antifungal agent systemically (Table 1). At presentation, 40/47 horses (85%) were receiving at least one topically administered antibiotic with 23 horses (57.5%) receiving one topically administered antibiotic and 17 horses (42%) receiving 2 (n = 13) or 3 (n = 4) topically administered antibiotics; 3 horses (6%) were receiving systemically administered antibiotics. At presentation, 30/47 horses (64%) were receiving topically administered atropine and 5 horses (11%) were receiving other topically administered treatments.

Diagnosis

Keratomycosis was confirmed by culture of corneal scrapings or biopsies in 38 horses (81%), by histopathology in 2 horses (4%) and by cytology in 7 horses (15%). Fungal culture was performed in 45/47 horses (96%) and 84% of cultures resulted in identification of one or more organisms (Table 2). Forty-four fungal isolates were identified in the study population; a single isolate was found in 33/38 horses (87%); 2 fungi were isolated from 4 horses and one horse had 3 fungi isolated. *Aspergillus* spp. (n = 28, 64%) were the most common isolates followed by *Fusarium* and *Rhizopus* spp. (n = 3 each; 7%). *Rhizopus* spp. were always found with another fungi, including *Aspergillus* and *Graphium*. *Papulaspora* spp., - a filamentous fungi - were responsible for 2 cases of equine keratomycosis and a distinctive brown-black appearance to the superficial plaques was noted in the affected eyes of both horses (Fig 1). One horse with *Papulaspora* keratomycosis had facial nerve paralysis secondary to equine protozoal myeloencephalitis. For 10 isolates, antifungal susceptibility testing by broth dilution [21, 22] was performed by the Fungal Testing Laboratory at The University of Texas Health Science Center at San Antonio (Table 3). Aerobic bacterial culture was performed on samples from 39/47 horses (83%) with at least one genus of bacteria identified in 15/39 horses (38%); (Table 2). A single bacterial isolate was found in 9/15 horses (60%) while 2 (n = 5) or 3 (n = 1) isolates were identified from the remaining 6 horses (40%). A total of 22 bacteria were isolated; *Pseudomonas* and *Staphylococcus* (n = 5 each; 23%) were the most commonly isolated bacteria followed by *Streptococcus* (n = 3; 14%).

Treatment

Following examination and diagnostic testing, medical management was instituted in 46/47 horses (98%). Specific treatment records were unavailable for one horse, and one horse was enucleated immediately upon presentation. Thirty-four of 46 horses (74%) received medical treatment only with a median treatment time of 46 (range 7–90) days. The remaining 12

horses (26%) underwent surgery in addition to medical treatment and had a median treatment time of 37 (range 8–64) days. There was no significant difference in treatment time (Mann-Whitney rank sum test; $P = 0.147$) for horses receiving medical versus medical and surgical therapy. Surgical procedures included conjunctival pedicle flap ($n = 8$), 360° conjunctival graft ($n = 2$), keratectomy ($n = 1$), and penetrating keratoplasty with corneal transplantation ($n = 1$). One horse had a conjunctival pedicle flap with a second surgery to stabilise the graft; another horse had 2 conjunctival pedicle flap surgeries. Median (range) time to surgery following first visit was 1.5 (0–14) days. Median (range) duration of hospitalisation was not significantly different between horses receiving medical (12; 0–44 days) versus medical and surgical (11.5; 6–60 days) treatment (Mann-Whitney rank sum test; $P = 0.91$).

Topical therapy was initiated via subpalpebral lavage in 33/34 horses (97%) receiving medical treatment and in all 12 horses that received medical and surgical treatment. Topically applied antifungal agents were administered to all 45 horses with 30 horses (67%) receiving one topically administered antifungal agent while 15 horses (33%) received 2 ($n = 14$) or 3 ($n = 1$) topically administered antifungal agents (Table 1). Frequency of administration varied from every 2 to 6 h. Antifungal medications were administered systemically to 14/45 horses (31%; Table 1). Antibiotics were topically or subconjunctivally administered to 44/45 horses (98%) with 13 horses (30%) receiving one topically administered antibiotic while 31 horses (70%) received 2 ($n = 19$), 3 ($n = 10$), 4 ($n = 1$) or 5 ($n = 1$) topically or subconjunctivally administered antibiotics. Antibiotics were given systemically to 11/45 horses (23%) with a single systemic antibiotic administered to 9 horses (82%), while 2 horses (18%) received 2 systemic antibiotics. Forty-four of 45 horses (94%) received atropine topically. Autologous serum was topically administered to 23/45 horses (51%). Nonsteroidal anti-inflammatory drugs were given topically to 11/45 (23%) horses with 11 horses (92%) receiving a single topical NSAID and one horse receiving 2 topical NSAIDs (Table 1); NSAIDs were administered systemically to all 45 horses (Table 1). Eleven of 47 horses (24%) were administered other topical treatments.

Outcome

Globes were retained in 37/47 horses (77%); 11/48 eyes (23%) were enucleated. Age did not have a significant effect on globe retention (Student's t -test, $P = 0.250$). The fungal organism was identified in 9/11 enucleated globes as *Aspergillus* ($n = 8$) or *Fusarium* ($n = 1$). Twenty-seven of 37 eyes (73%) were evaluated for vision after completion of treatment; 20 eyes (74%) were assessed as retaining vision and 7 eyes (26%) were assessed as blind. Thus, at least 53% of horses retained some vision. Presentation during autumn versus other seasons, presence or absence of concurrent bacterial keratitis, topical treatment with corticosteroids, corneal stromal malacia, corneal stromal loss, surgical treatment, topical treatment with miconazole, and topical treatment with an NSAID did not have a significant effect on visual outcome (Supplementary Item 1). However, all 10 eyes with corneal perforation were enucleated ($n = 9$) or lost vision ($n = 1$) and corneal perforation was significantly associated with a negative visual outcome ($P < 0.001$; Supplementary Item 1).

Discussion

Equine keratomycosis appears to be an uncommon ophthalmic condition in northern California comprising only 2% of equine patients presented to the UCD-VMTH Ophthalmology Service. The paucity of cases at UCD-VMTH may reflect a low occurrence of this disease in northern California due to climatic conditions. Equine keratomycosis is more common in the humid eastern United States and Canada where it comprised 7% of equine ophthalmology visits in Florida and Ontario [1, 5]. Interestingly, in Cordoba, Spain, which has a climate similar to that in northern California, a relatively high rate (8.6%) of

keratomycosis was reported among equine patients [23]. Human keratomycosis is also more common in humid climates, like south Florida, compared to the more temperate climate of northern California [19]. At the UCD-VMTH, horses with keratomycosis were presented in all months with autumn being the most common season of presentation. Multiple studies have documented a propensity for equine and human keratomycosis in autumn and summer months in the northern hemisphere [1, 3, 4, 7, 17, 24]. In Florida, the majority of equine keratomycosis cases present in late autumn and winter, which are typically the driest seasons of the year [5]. Geography and climate influence the type and amount of fungal species observed, which may account, at least in part, for the regional variation seen in frequency and season of presentation of equine keratomycosis [7, 13, 15, 25].

The present study demonstrated that nearly 50% of horses presented to UCD-VMTH for equine keratomycosis had received topically administered corticosteroids. Of these, half had previous ophthalmic conditions, such as uveitis, eosinophilic keratitis, and conjunctivitis that are typically treated with corticosteroids. Corticosteroids may predispose to corneal infection for several reasons, including delaying epithelialisation allowing increased opportunity for infection, disruption of phagocyte mobilisation and function, and inhibition of vascularisation and fibroblast infiltration into the cornea [26-29]. Topical administration of corticosteroids has been shown to enhance experimentally-induced *Candida albicans* keratitis in rabbits [26,31]. Thus, judicious topical use of corticosteroids in equine patients and frequent monitoring for corneal ulceration are required to decrease the risk of keratomycosis. Nevertheless, topical administration of steroid did not have a significant effect on visual outcome in horses with keratomycosis in the present study. Two other retrospective studies evaluating equine keratomycosis also reported no difference in globe retention or degree of scarring in horses with or without a history of topical administration of corticosteroids [4,23]. This is surprising given that experimental and clinical studies have demonstrated that fungi behave more aggressively and penetrate deeper into the cornea when corticosteroids are used [32]. Corticosteroids also reduce the efficacy of some antifungal medications and may interact with fungal organisms to block antifungal activity [31]. However, a recent study demonstrated that topical antibiotic-steroid combinations decreased rather than increased the conjunctival fungal flora in normal horses [11]. The lack of statistical significance in some of these studies may be partially due to small number of horses included, as Gaarder and colleagues did note a trend between lack of corticosteroid use and increased likelihood of vision retention [4].

Forty-four fungal isolates were identified from 38 horses in the present study. Consistent with previous studies, *Aspergillus* was most common accounting for 64% of isolates [1, 5, 15]. At UCD-VMTH, *A. flavus* was the most common species and represented nearly half of *Aspergillus* isolates, as observed in previous studies [1, 33]. *Fusarium*, *Rhizopus*, and *Candida* were the next most common genera from northern California comprising 7%, 7%, and 5% of isolates, respectively. In Florida and the northeastern United States, *Fusarium* (30% of total isolates) and *Candida* (10% of total isolates) are the second most common genera, respectively [5, 15]. Interestingly, *Rhizopus* spp. were only detected with other fungi including *Aspergillus* and *Graphium*. *Rhizopus* has been isolated in a horse with external ocular disease and from humans with keratomycosis in India [34, 35]. Since different fungal isolates display variable sensitivity to antifungal medications, it is important to choose an antifungal medication with activity against *Aspergillus* for initial treatment of equine keratomycosis in northern California.

In the present study, the most common topically applied antifungal agents were miconazole, natamycin, and voriconazole. Nearly half of all horses treated at UCD-VMTH received topically administered miconazole, though all horses receiving this antifungal were treated prior to 2004. In the northeastern United States, only one-quarter of fungal isolates were

susceptible to miconazole [15], while 69% of fungal isolates from Wisconsin [24] and between 77–100% of fungal isolates from Florida [16, 24] were susceptible. These data suggest that regional variation in drug susceptibility exists. Unfortunately, susceptibility to miconazole was not evaluated for any of the fungal isolates from UCD-VMTH patients. The present study showed all tested isolates were sensitive (67%) or intermediately sensitive (33%) to natamycin. Natamycin – a polyene antifungal antibiotic - is predominantly fungicidal and is the preferred treatment for *Fusarium* keratitis [2, 36], but its major disadvantage is its poor penetration through intact corneal epithelium [37]. Given that nearly 80% of eyes with keratomycosis in the present study were ulcerated, natamycin appears to have potential for initial treatment of equine keratomycosis in northern California based on the small number of isolates tested. Eight of 9 (89%) isolates tested including all 5 *Aspergillus* isolates tested in the present study were sensitive to voriconazole, a new triazole antifungal which has excellent corneal penetration in horses following topical administration [38] and a broader spectrum than other triazoles. A recent study found voriconazole to be the most effective antifungal agent for initial treatment of equine keratomycosis caused by *Aspergillus* or *Fusarium* spp. in the midwestern and southern United States [36], and it appears to have potential for initial treatment of equine keratomycosis in northern California based on the small number of isolates tested in the present study.

Interestingly, 2 cases of keratomycosis in our study were due to *Papulaspora* species, a bulbiferous hyphomycete [39]. One species was identified as *P. sepedonioides* using DNA sequencing; the second *Papulaspora* isolate was not speciated. To the authors' knowledge, *P. sepedonioides* has never been recovered from a horse with keratomycosis. *Papulaspora equi* was the causative organism in an unspecified ocular infection of a horse from Alabama [39]. In addition, *Papulaspora immersa* has been isolated from horse manure demonstrating its presence in the equine environment [39]. Both horses with *Papulaspora* in the present study had superficial plaques that were brown-black in appearance (Fig 1). One horse with *Papulaspora* in the present study had facial nerve paralysis secondary to equine protozoal myeloencephalitis. Exposure keratitis secondary to lagophthalmos may have caused ulceration or disruption of the corneal epithelium and subsequent opportunistic infection with *Papulaspora*. In the present study susceptibility data for *Papulaspora* (Table 3) were derived using breakpoints established for *Aspergillus* since they are both filamentous fungi (B. Byrne, personal communication, January 4, 2011); both isolates were susceptible to natamycin and voriconazole while one isolate was susceptible to posaconazole, itraconazole, and fluconazole but resistant to amphotericin B. Both horses with *Papulaspora* in the present study were treated with topical voriconazole and retained vision. One horse was also treated with a superficial keratectomy and topical amphotericin B until it was discontinued when susceptibility results showed that the *Papulaspora* isolate was resistant to amphotericin B.

In the present study, approximately 90% of horses were treated with topically administered antibiotics prior to referral or as part of treatment at UCD-VMTH. Greater than one-third of horses with keratomycosis in this study had a concurrent bacterial infection, which is similar to previous studies from Florida and Spain [5,23]. In humans, topically administered antibiotics may shift normal conjunctival flora from primarily Gram-positive bacterial organisms to fungal and Gram-negative organisms [40,41]. However, topical treatment with antibiotics or antibiotic-steroid combinations decreased the number of bacterial and fungal microorganisms in the conjunctiva of normal horses [11]. Thus, concurrent topical antibiotic administration is recommended for horses with keratomycosis in northern California to prevent or treat concurrent bacterial infection. The most common bacterial isolates in this study were *Pseudomonas*, *Staphylococcus*, and *Streptococcus* species, which are the most frequently isolated organisms in equine bacterial keratitis [42]. Despite the relatively high

rate of bacterial infection, there was no significant difference in visual outcome in the present study for horses with or without concurrent bacterial keratitis.

Vision retention for horses with keratomycosis was approximately 50% in this study, similar to previous reports of 53–64% [1-4,23]. While a few studies report positive visual outcomes of 75% or greater [5-7], a guarded prognosis for vision is advisable for equine patients with keratomycosis due to the risk of extensive corneal scarring, uncontrollable uveitis, and globe rupture, which can occur despite aggressive treatment. Corneal perforation was associated with at least a 4-fold increase in risk for enucleation or vision loss and owners should be advised of a poor visual prognosis for keratomycosis with corneal perforation. Visual outcome in this study was not significantly different for horses treated with medications and surgery versus those treated solely with medications. This observation contrasts with an Ontario study that noted improved visual outcomes in horses that received both medical and surgical treatment [1]. In the present study, a trend ($P = 0.147$) towards less hospitalisation time was noted in patients treated surgically compared to patients receiving medications only. Depending on the technique performed, surgical treatment may decrease fungal mass, increase drug penetration, suppress collagenolysis, or provide fibrovascular support to the devitalised cornea, but it may also add expense and increase the risk of complications for the patient during and after general anaesthesia. The risks and benefits of surgical intervention for equine patients with keratomycosis must be carefully considered before advising clients.

In conclusion, keratomycosis is relatively uncommon in horses presented for ophthalmic conditions at UCD-VMTH. This study found *Aspergillus* to be the most common isolate and identified, for the first time, *Papulaspora* spp. in 2 horses with keratomycosis. Miconazole, natamycin and voriconazole were the most commonly used medications for the treatment of equine keratomycosis in northern California. Corneal perforation was a negative prognostic indicator for vision in this population of horses with keratomycosis.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Fig 1.

A) Left eye of a 25 year old Arabian gelding from which *Papulaspora sepedonioides* was isolated. B) Right eye of a 25 year old Paint mare from which an unidentified *Papulaspora* species was isolated. Note the distinctive brown-black appearance of the superficial plaques in both affected eyes.

TABLE 1

Antifungal and anti-inflammatory medications administered prior to and following presentation to 47 and 45 horses, respectively, diagnosed with keratomycosis at the UCD-VMTH (1987–2010).

Medication	Route	No. of horses receiving this drug prior to presentation	No. of horses receiving this drug following presentation
Antifungal agents			
Miconazole	Topical	5	20
Natamycin	Topical	1	15
Fluconazole	Topical/Oral	1/1	11/13
Voriconazole	Topical	0	12
Amphotericin B	Topical	0	2
Itraconazole	Topical/Oral	0/0	1/1
Unnamed agent	Topical	2	0
Anti-inflammatory agents			
Dexamethasone with antibiotic	Topical	13	0
Hydrocortisone with antibiotic	Topical	3	0
Dexamethasone	Topical/Oral	1/1	0
Prednisolone acetate	Topical	1	0
Methylprednisolone acetate	Subconjunctival	1	0
Unnamed agent	Topical/Subconjunctival/Oral	3/1/1	0/0/0
Flurbiprofen	Topical	1	11
Diclofenac	Topical	1	1
Flunixin meglumine	Oral	26	42
Phenylbutazone	Oral	10	15
Aspirin	Oral	1	0
Ketoprofen	Oral	0	1
Metamizole	Oral	0	1

TABLE 2

Frequency of fungal and bacterial isolates from 38 and 15 horses, respectively, diagnosed with keratomycosis at the UCD-VMTH (1987–2010).

Fungal organism	No. isolates (Percent isolates)	Bacterial organism	No. isolates (Percent isolates)
<i>Aspergillus</i> spp.	28 (63.6)	<i>Pseudomonas</i> spp.	5 (22.7)
<i>Aspergillus flavus</i>	13 (29.5)	<i>Staphylococcus</i> spp.	5 (22.7)
<i>Aspergillus fumigatus</i>	9 (20.4)	<i>Streptococcus</i> spp.	3 (13.6)
<i>Aspergillus niger</i>	1 (2.3)	<i>Streptococcus equi</i> zooepidemicus	2 (9.1)
<i>Aspergillus</i> spp. (unidentified)	5 (11.4)	<i>Streptococcus alpha</i>	1 (4.5)
<i>Fusarium</i> spp.	3 (6.8)	<i>Stentrophomonas maltophilia</i>	2 (9.1)
<i>Rhizopus</i> spp.	3 (6.8)	<i>Aerococcus viridans</i>	1 (4.5)
<i>Papulaspora</i> spp.	2 (4.5)	<i>Escherichia coli</i>	1 (4.5)
<i>Scedosporium apiospermum</i>	2 (4.5)	<i>Flavobacterium odoratum</i>	1 (4.5)
<i>Candida albicans</i>	2 (4.5)	<i>Granulicatella adiacens</i>	1 (4.5)
<i>Cryptococcus albidus</i>	1 (2.3)	<i>Micrococcus</i> spp.	1 (4.5)
<i>Graphium</i> spp.	1 (2.3)	<i>Providencia rettgeri</i>	1 (4.5)
<i>Paecilomyces</i> spp.	1 (2.3)	<i>Streptomyces</i> spp.	1 (4.5)
<i>Scytalidium</i> spp.	1 (2.3)		
Total	44 (100)	Total	22 (100)

TABLE 3

Antifungal susceptibility of fungi cultured from 10 horses diagnosed with keratomycosis at the UCD-VMTH (1987–2010).

Organism	Vor	Pos	Itra	Flu	Ket	Nat	Amph	Casp	5-Flu
<i>Aspergillus</i> spp									
Resistant	0/5	0/4	0/4	5/5	0/1	0/4	0/0	0/0	0/0
Sensitive	5/5	4/4	1/4	0/5	1/1	2/4	0/0	0/0	0/0
Intermediate	0/5	0/4	3/4	0/5	0/1	2/4	0/0	0/0	0/0
<i>Papulaspora</i> spp									
Resistant	0/2	0/1	0/1	0/1	0/0	0/2	1/1	0/0	0/0
Sensitive	2/2	1/1	1/1	1/1	0/0	2/2	0/1	0/0	0/0
Intermediate	0/2	0/1	0/1	0/1	0/0	0/2	0/1	0/0	0/0
<i>Candida albicans</i>									
Resistant	0/1	0/1	0/1	0/1	0/0	0/0	0/1	0/1	0/1
Sensitive	1/1	1/1	1/1	1/1	0/0	0/0	1/1	1/1	1/1
Intermediate	0/1	0/1	0/1	0/1	0/0	0/0	0/1	0/1	0/1
<i>Cryptococcus albidus</i>									
Resistant	1/1	1/1	1/1	1/1	1/1	0/0	0/1	1/1	1/1
Sensitive	0/1	0/1	0/1	0/1	0/1	0/0	1/1	0/1	0/1
Intermediate	0/1	0/1	0/1	0/1	0/1	0/0	0/1	0/1	0/1
Total	9	7	7	8	2	6	3	2	2
Resistant	11%	14%	14%	75%	50%	0%	33%	50%	50%
Sensitive	89%	86%	43%	25%	50%	67%	67%	50%	50%
Intermediate	0%	0%	43%	0%	0%	33%	0%	0%	0%

Vor = Voriconazole, Pos = Posaconazole, Itra = Itraconazole, Flu = Fluconazole, Ket = Ketoconazole, Nat = Natamycin, Amph = Amphotericin B, Casp = Caspofungin, 5-Flu = 5-Flucytosine