Regulatory Mechanisms in Biosystems

ISSN 2519-8521 (Print)
ISSN 2520-2588 (Online)
Regul. Mech. Biosyst.

Pathomorphological aspects of cryptococcosis in domestic cats

O. Shchebentovska, K. Oriekhova, H. Blishch

Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies, Lviv, Ukraine

Article info

Received 24.08.2025
Received in revised form 12.10.2025
Accepted 09.11.2025

Stepan Gzhytskyi National University of Veterinary Medicine and Biotechnologies, Pekarska st., 50, Lviv, 79010, Ukraine.
Tel.: +38-067-701-81-46.
E-mail: schebentovskaolga@gmail.com

Shchebentovska, O., Oriekhova, K., & Blishch, H. (2025). Pathomorphological aspects of cryptococcosis in domestic cats. Regulatory Mechanisms in Biosystems, 16(4), e25192. doi:10.15421/0225192

Cryptococcosis is one of the most common mycotic infections in cats, which may affect the skin, mucous membranes of the upper respiratory tract, lungs, and central nervous system. Despite its high prevalence among cats in North America, Australia, and sporadic occurrence in Europe, there is no available information in Ukraine presenting case analyses of cryptococcosis in various animal species, likely due to the absence of timely diagnostic procedures for this disease. The etiological agents are *Cryptococcus neoformans* or *C. gattii* – encapsulated yeast-like fungi capable of surviving for prolonged periods in the environment, particularly in soil and avian excrement (especially that of pigeons). Infection typically occurs through the aerogenic route. The nasal cavity is the most common site of the primary infection, with possible hematogenous dissemination to the skin, eyes, and central nervous system. This article describes two cases of cryptococcosis in non-pedigree domestic cats that were treated at a veterinary clinic in Lviv (Ukraine) during 2024. According to the anamnesis, both cats were males, aged 5 and 7 years, kept indoors with free outdoor access. Rapid tests for FIV and FeLV were negative. Clinical examination of one cat revealed a solitary, firm, alopecic, left-sided cutaneous nodular lesion near the nasal wing, while the second cat presented with inspiratory dyspnea and mucopurulent nasal discharge. Cytological and histopathological examinations were performed for diagnostic verification. Fine-needle aspiration biopsies were collected from the affected skin area near the nasal wing and from the nasal mucosa, followed by hematoxylin and eosin staining. To improve yeast visualization, the PAS reaction, Heidenhain's Azan trichrome stain, and Grocott's methenamine silver stain were performed. Cytological smears stained with Romanowsky-Giemsa revealed numerous round cells forming clusters located among epithelial and leukocytic cells. *Cryptococcus* spp. cells possessed a well-defined capsule. In the PAS (McManus) reaction, the yeast cells stained bright red and were surrounded by a thick mucoid capsule. Application of Grocott's staining method clearly identified budding yeast cells, which appeared black in color. Thus, classical morphological features of cryptococcosis in domestic cats were identified through the use of cytological and histological diagnostic methods, once again emphasizing the importance of comprehensive morphological diagnostics for this infection.

Keywords: basidiomycetous fungi; cat; skin; fine-needle biopsy; histopathology.

Introduction

Cryptococcosis (torulosis, European blastomycosis, Busse-Buschke disease) is one of the most widespread systemic mycotic diseases being recorded in various animal species including cats, dogs, ferrets, horses, goats, sheep, bovine animals, reptiles, amphibians, and even fish (McGill et al., 2009; Danesi et al., 2021). According to McGill et al. (2009), cats are affected five to six times more frequently than dogs and approximately three times more frequently than horses. Cryptococcosis was first described in humans by Zenker and Freeman in 1861. The etiological agent, initially isolated from a human patient by Benham, was later characterized in greater detail. In 1916, Stoddard and Cutler established the association between cryptococcosis and mycotic infection, designating the fungus as *Torula histolytica*. In 1934, Benham concluded that the fungal agent of cryptococcosis exhibits numerous morphological variants but belongs to a single species. Redaelli subsequently described animal cases of the disease, which he considered to be European blastomycosis. According to Sanfelice (1895), similar lesions were also observed in horses in Italy. In 1904, Vuillemin detected cryptococci in pig lungs, while Frothingham (1902) described a yeast-like fungus in equine lungs. In 1912, Majer was the first to isolate *Cryptococcus neoformans* from tumor-like lesions on a horse's lip. Later, in 1935, Weidman and Ratcliffe described a case of generalized European blastomycosis in a cheetah from the Philadelphia Zoo that resulted in the animal's death. Research conducted over recent decades in multiple countries has confirmed a broad occurrence of cryptococcosis among both animals and humans (Barnett, 2010).

Cryptococcus neoformans is widespread in nature. It can be recovered from soil as well as from the skin of humans and animals. Extensive carrier status has been established among pigs and pigeons (Emmons, 1960; Hamilton & Goodley, 1996). The fungus predominantly infects humans and animals via the aerogenic route, through inhalation of basidiospores present in the environment. This is supported by the fact that cases of primary pulmonary cryptococcosis in humans, dogs, and cats are most frequent. The pathogen may also invade via the gastrointestinal tract, damaged skin, or mucous membranes.

The disease most often presents as focal lesions of the nasal cavity or eyes; pulmonary involvement is less common, although cases of meningoencephalomyelitis in animals have also been described in the literature. In cats and dogs, the nasal cavity is frequently the primary site of localization of *Cryptococcus* spp., which, upon contact with the mucous membrane, causes both localized and systemic infection (Malik et al., 1992; O'Brien et al., 2004; Caswell & Williams, 2007). From the upper respiratory tract, the pathogen may spread to the central nervous system through the cribriform plate, or to the lower respiratory tract and lungs (Martins et al., 2011). In cases of pulmonary infections, hematogenous dissemination may also occur via the mechanism of a so-called "leukocytic transport" (Caswell & Williams, 2007). Systemic cryptococcosis, as noted above, results from hematogenous dissemination of the pathogen and may manifest as meningoencephalomyelitis, uveitis, chorioretinitis, osteomyelitis, polyarthritis, generalized lymphadenitis, or lesions of parenchymal organs, including kidneys. Isolated systemic lymphadenitis in cats and dogs is rare (Costa et al., 2022). In histopathological studies of cats with systemic FeLV and feline infectious peritonitis, cryptococcosis has been identified among the main causes of ocular organ lesions (Wronski et al., 2023).

The pathogenic *Cryptococcus* species most frequently reported by Caswell & Williams (2007) are *C. neoformans* and *C. gattii*. Asymptomatic courses of infection during colonization of the respiratory tract by *Cryptococcus* spp. have been recorded much more frequently than cases with clinically apparent signs of disease (Malik et al., 1997; Connolly et al., 1999; Danesi et al., 2014). Specifically, asymptomatic

carriage of *C. gattii* has been identified in 4.3% of cats, 1.1% of dogs, and 2% of wild animals (mostly squirrels) in Colombia (Duncan et al., 2005; Bartlett et al., 2008). The incubation period ranges from one month to several years, and the source of infection often remains unknown.

According to Duncan et al. (2005), in most of the reported cases in cats, the course of the disease was subclinical. Cryptococcosis has been documented in cats of various ages, whereas in dogs it has most often been diagnosed in young individuals (Malik et al., 1992; McGill et al., 2009; Trivedi et al., 2011; Vercelli et al., 2021). According to Australian studies, cat breeds such as Siamese, Burmese, and Ragdoll demonstrated an increased susceptibility to infection; however, this trend was not confirmed in the United States (Malik et al., 1992; O'Brien et al., 2004; McGill et al., 2009; Sykes et al., 2010; Trivedi et al., 2011). A clear sex predisposition has also not been established, although most retrospective studies in cats indicate a predominance of disease among males (Malik et al., 1992; Flatland et al., 1996; Jacobs et al., 1997; Gerds-Grogan & Dayrell-Hart, 1997; Lester et al., 2004; McGill et al., 2009; Sykes et al., 2010). Seasonal variation in disease incidence among cats and dogs has likewise not been observed (McGill et al., 2009). Furthermore, lifestyle cannot be considered a risk factor, as the disease has been recorded in both domestic and stray or wild animals.

Pigeons are considered the natural reservoirs of *Cryptococcus* and are believed to play a key role in the global dissemination of the pathogen. They carry yeast cells on their beaks, feathers, and feet (Pal, 1989), while their excrement provides favorable conditions for fungal proliferation (Fortes et al., 2001).

The geographical range of *Cryptococcus* spp. in Europe is quite extensive: the pathogen has been detected in Austria, Belgium, Bosnia and Herzegovina, Denmark, France, Germany, Greece, Italy, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom (Lester et al., 2004; Nunes Rodrigues et al., 2020; Glavinić et al., 2024). Considering the sporadic nature of the disease in animals and the lack of its detection during routine laboratory diagnostics, most of the cases described in the literature concern isolated infections or reports involving a small number of animals (Castella et al., 2008; Nunes Rodrigues et al., 2020; Vercelli et al., 2021; Glavinić et al., 2024). The disease has been studied in greatest detail within retrospective research conducted in Canada, Australia, and the US (Stephen et al., 2002; O'Brien et al., 2004; Duncan et al., 2005, 2006; McGill et al., 2009; Sykes et al., 2010). No studies on the prevalence of cryptococcosis in cats and dogs have been conducted in Ukraine.

The genus *Cryptococcus* comprises at least 37 species (Sykes, 2022). In cats, the disease is caused by basidiomycetous yeasts belonging to the *C. neoformans* and *C. gattii* species complexes. According to the earlier classification, which was based on the antigenic properties of the capsular polysaccharide, five serotypes were distinguished: A, D, AD, B, and C (Takashima & Sugita, 2022). In the revised nomenclature, two main species associated with feline infections are recognized: *C. neoformans* (including the subspecies *C. n.* var. *grubii* – formerly serotype A – and *C. n.* var. *neoformans* – formerly serotype D) and *C. gattii* (formerly serotypes B and C).

In mammals, *Cryptococcus* usually exists in the yeast form and reproduces by budding within infected tissues. Under certain conditions, however, the pathogen can differentiate into other morphological forms, including chlamydospores, pseudohyphae, and true hyphae (Alspaugh et al., 2000; Lin & Heitman, 2006). *Cryptococcus* is capable of surviving inside phagocytic cells, particularly macrophages and neutrophils, and can disseminate through their activity (Urban et al., 2006; Trivedi et al., 2011).

The diagnosis of cryptococcosis relies on cytological and microbiological examination of representative tissue samples using cytological and microbiological methods, and, when necessary, histopathological research. Serological detection of cryptococcal antigen in biological fluids is also occasionally performed. The most informative diagnostic samples include nasal swabs, nasal lavages, aspirates from mass lesions, bronchoalveolar lavage, pleural fluid, cerebrospinal fluid, and urine (Sykes, 2022). Treatment approaches to cryptococcosis in dogs and cats are largely based on extrapolation from human medicine and the clinical experience of veterinarians, as studies on the efficacy of specific treatment protocols in veterinary practice are lacking. The aim of this research was to describe the morphological aspects of cryptococcosis in spontaneously infected domestic cats based on clinical, cytological, and histopathological examinations.

Materials and methods

All research procedures fully complied with ethical standards regarding the use of animals in experimental studies (Strasbourg, 1986; Kyiv, 2002). During 2024, two cases of suspected cryptococcosis in cats were recorded at the "Vetpraktik" clinic (Lviv, Ukraine). According to the anamnesis, both cats were non-pedigree males, aged 5 and 7 years, kept indoors with unrestricted outdoor access. Routine prophylactic treatments against ecto- and endoparasites as well as annual rabies vaccination were performed. Rapid diagnostic tests for FIV and FeLV were negative in both cats. Physical examination revealed a solitary alopecic nodular skin lesion on the left side near the nasal wing in one cat, and inspiratory dyspnea with mucopurulent nasal discharge in the other. For cytopathological examination, at least three cytological smears were prepared from affected tissues, air-dried, fixed in methanol, stained using the Romanowsky-Giemsa method, and examined under a Leica DM-2500 light microscope.

Fine-needle biopsies were obtained directly from the cutaneous nodule near the nasal wing and from the nasal mucosa for histopathological examination. Tissue samples were fixed in 10% aqueous neutral buffered formalin, rinsed, dehydrated through a graded series of alcohols, and embedded in paraffin following standard procedures. Paraffin blocks were sectioned at 7 µm thickness using an MS-2 sledge microtome. For light microscopy, deparaffinized sections were stained with Mayer's hematoxylin and eosin. Additionally, the PAS reaction according to McManus was applied: sections were oxidized in 0.5% aqueous periodic acid for 2 minutes, rinsed in distilled water, treated with Schiff's reagent for 10 minutes, and washed under running water for 10 minutes. Counterstaining was performed with Mayer's hematoxylin for 3 minutes, followed by rinsing, dehydration in alcohols, clearing in xylene, and mounting in a synthetic medium. The identified yeast cells demonstrated an intense PAS-positive reaction, staining purplish-red. Schiff's reagent was prepared according to the protocol described by Pearse (1960).

For Heidenhain's Azan trichrome staining, paraffin sections were deparaffinized in xylene, rehydrated to distilled water, and immersed in azocarmine in a Coplin jar at 56–60 °C for 45 minutes. The stained sections were rinsed in distilled water and differentiated in 0.1% aniline solution in 90% ethanol. Sections were then washed in 1% acetic acid in 96% ethanol for 0.5 minutes and placed in 5% aqueous phosphotungstic acid for 1 hour. Under microscopic control, connective tissue decolorization was monitored, after which the sections were quickly rinsed in distilled water and stained with aniline blue and orange G in acetic acid for 1 hour. They were then rinsed in distilled water, differentiated in 96% ethanol, cleared in xylene, and mounted in synthetic resin with a coverslip (Mulisch & Welsch, 2010).

The Grocott methenamine silver method was based on preliminary oxidation in 5% aqueous chromic acid, decolorization with sodium bisulfite, impregnation with methenamine silver, toning with 1% aqueous chloroauric acid, subsequent treatment with 5% aqueous sodium thiosulfate, dehydration, clearing in xylene, and mounting in synthetic resin (Mulisch & Welsch, 2010).

Light microscopy and microphotography of histological specimens were performed using a Leica DM-2500 microscope equipped with a Leica DFC 450 C digital camera.

Results

Examination of the cat with a left-sided cutaneous nodular lesion near the nose, measuring up to 1.5 cm in diameter and accompanied by alopecia, revealed that the lesion was immobile, unilateral, well-circumscribed, round, and non-painful (Fig. 1). According to the owners, the animal's activity level and appetite remained normal, and no deviations in its general condition were noted. The second cat had ex-

hibited bilateral mucopurulent nasal discharge and frequent sneezing over several months. Clinical examination revealed inspiratory dyspnea, however, thoracic radiography showed no pathological changes in the lower respiratory tract. Hematological and biochemical blood analysis demonstrated an increased number of segmented neutrophils and a slight elevation in total protein level. Antimicrobial therapy proved ineffective. Rhinoscopy revealed pink, granuloma-like formations within the nasal passages, from which biopsies were collected for histopathological examination.

Cytological examination of Romanowsky-Giemsa stained smears prepared from fine-needle biopsy specimens of the affected nasal wing and nasal mucosa revealed numerous yeast cells with well-defined capsules. Individual yeasts formed clusters located among epithelial and leukocytic cells (Figs. 2, 3).

Histological examination of the affected skin areas revealed focal perivascular lymphocytic-plasmacytic infiltration (Fig. 4a) and a large number of spherical yeast cells surrounded by capsules (Fig. 4b). A clear halo was visible among the yeast cells and their capsules.

Staining of biopsy material from the cutaneous lesion around the nasal wing and nasal cavity using the PAS reaction according to McManus (Fig. 5) and Heidenhain's Azan stain (Fig. 6) demonstrated massive diffuse infiltration with yeast cells that stained bright red (Fig. 5a, 5b). A morphological characteristic of the yeast forms of *Cryptococcus* spp. was the presence of a thick mucoid capsule (Fig. 5c, 5d). The majority of yeast cells were round or oval, ranging from 5 to 15 μm in diameter.

Fig. 1. Left-sided firm nodular lesion with alopecia up to 1.5 cm near the nasal wing in a cat

When the Grocott methenamine silver method was applied, yeast cells stained black, allowing clear identification of budding forms within the examined samples (Fig. 7a, 7b).

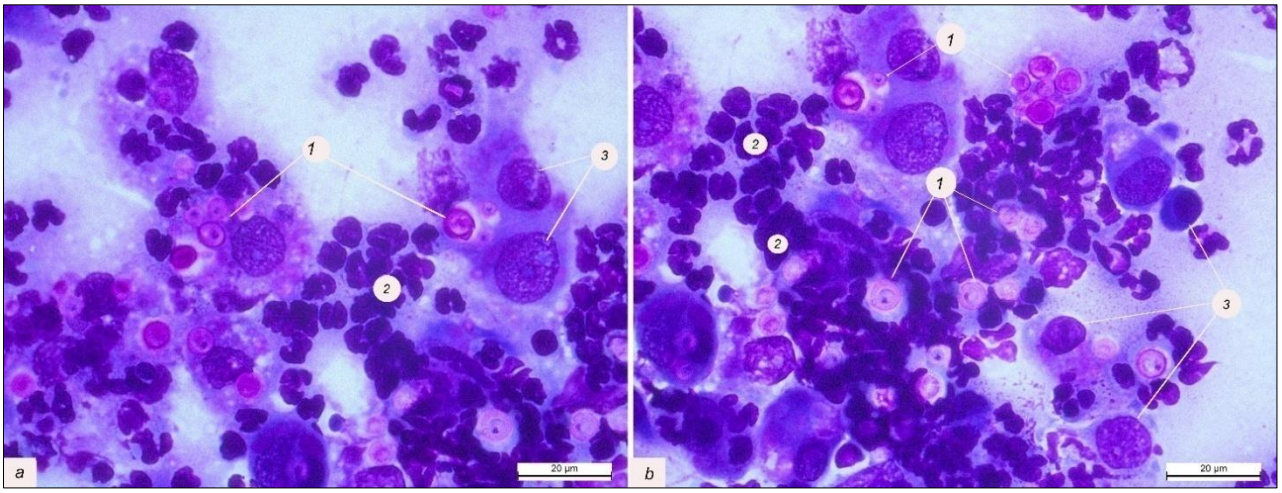

Fig. 2. Fine-needle biopsy from affected areas of the nasal cavity (*a*, *b*): numerous cryptococcal cells with distinct capsules (*1*) located among epithelial (*3*) and leukocytic (*2*) cells; Romanowsky-Giemsa stain

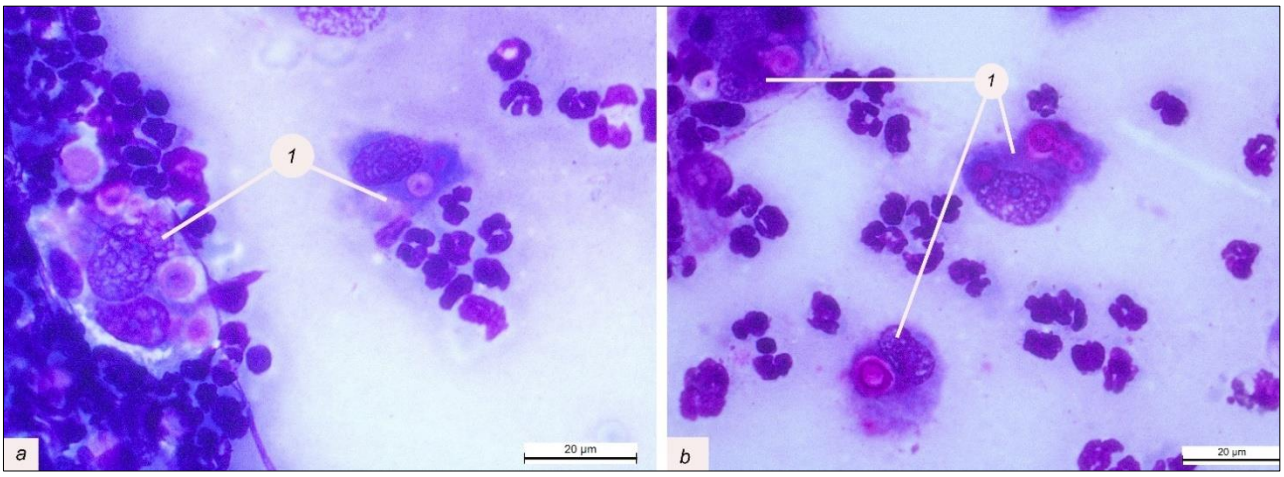

Fig. 3. Macrophages (*1*) phagocytizing *Cryptococcus* cells appearing as round encapsulated forms (*a*, *b*): fine-needle biopsy of nasal mucosa; Romanowsky-Giemsa stain

Thus, the application of cytological and histological diagnostic methods revealed numerous encapsulated yeast cells in the affected tissues that exhibited a positive PAS reaction and pleomorphic budding forms, enabling a definitive diagnosis of cryptococcosis.

Discussion

Retrospective studies conducted in various countries indicate that the most common clinical form of cryptococcosis in cats is the nasal

form, which is characterized by chronic, localized involvement of the soft tissues of the nasal cavity and skin, sometimes with extension to cartilage, bone tissue, and the submandibular lymph nodes (Malik et al., 1992; O'Brien et al., 2004; McGill et al., 2009). Clinically, this presents as swelling of the nasal and facial areas, deep ulcerative lesions with exudation, unilateral serous, mucopurulent, or hemorrhagic discharge, dyspnea, sneezing, and stertor. In some cases, nasopharyngeal granulomas mimicking polyps or tumors have been described (Malik et al., 1997; McEwan & Sykes, 2022). Additionally, other authors have reported proliferative and ulcerative lesions of the oral cavity and pharynx, as well as cases of otitis media and interna in cats with cryptococcosis (Beatty et al., 2000; Paulin et al., 2013; Nunes Rodrigues et al., 2020).

Clinical manifestations of cryptococcosis largely depend on the localization of the infection. Several clinical forms are therefore distinguished: nasal, neurological (which may develop as a complication of the nasal form or independently), cutaneous, and systemic. A chronic progressive course is typical of this disease; however, in cases involving the central nervous system or respiratory organs with associated pleural effusion, an acute course is also possible. According to findings (Vercelli et al., 2021), central nervous system involvement may lead to sudden blindness due to optic neuritis, seizures, and behavioral changes, which were observed in approximately one-third of the studied cats. In some cases, granulomatous encephalomyelitis also develops with mono- or multifocal lesions (Belluco et al., 2008; Sykes et al., 2010; Jacobson et al., 2022; Huang et al., 2023).

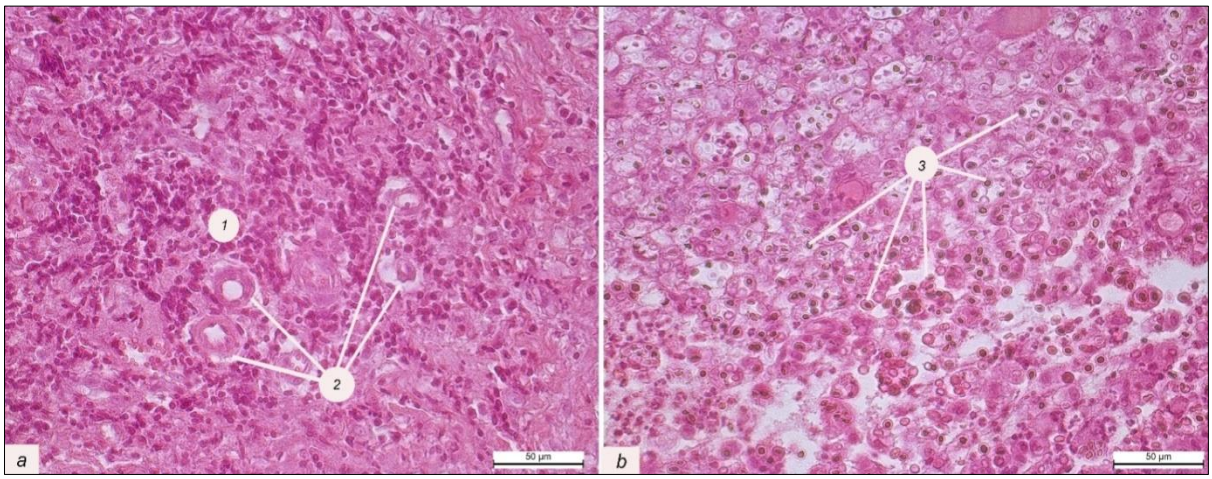

Fig. 4. Focal perivascular (*1*) lymphocytic–plasmacytic infiltration (*a*), vessels (*2*) and intensive (*b*) cryptococcal invasion (*3*); hematoxylin and eosin stain

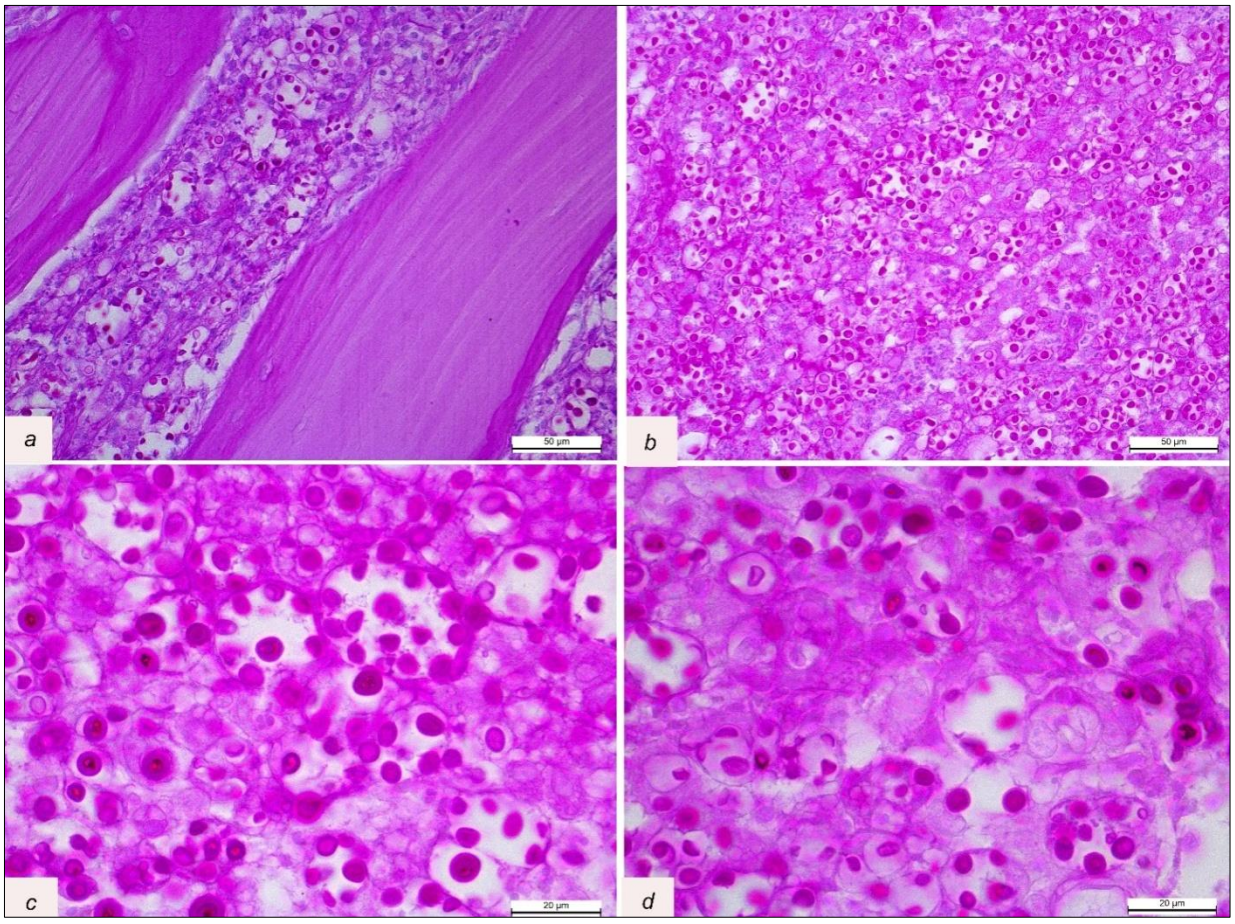

Fig. 5. Lesion around the nasal wing in a cat: *a*, *b* – massive diffuse proliferation of yeast cells; *c*, *d* – *Cryptococcus* spp. yeast cells with thick mucoid capsules; PAS reaction

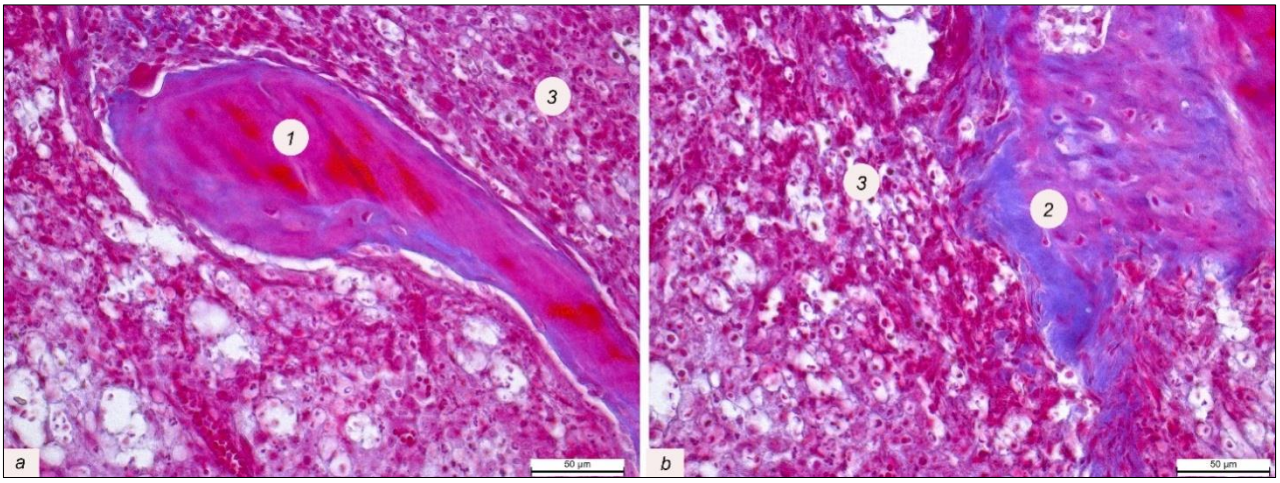

Fig. 6. Lesion around the nasal wing in a cat: *a*, *b* – diffuse proliferation of *Cryptococcus* spp. yeast cells; *1* – bone fragment, *2* – cartilage tissue, *3* – cryptococci; Heidenhain's Azan stain

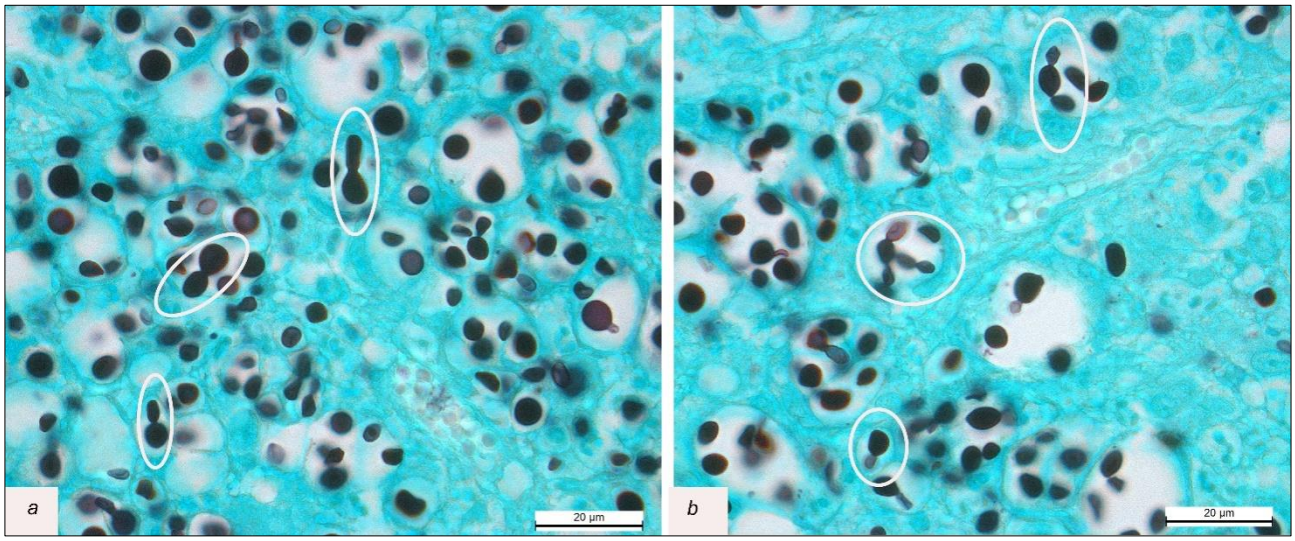

Fig. 7. Yeast cells (*a, b*) stained by Grocott's methenamine silver method: pleomorphic round and oval cryptococcal forms in the budding stage (indicated by circles)

The cutaneous form of cryptococcosis in cats and dogs, as reported by researchers (Myers et al., 2017; Nunes Rodrigues et al., 2020), is characterized by solitary or multiple lesions, where solitary foci represent direct inoculation, and multiple lesions result from hematogenous dissemination of infection. Our findings in cats were consistent with those of other authors, who observed the formation of small, predominantly alopecic, non-painful, and unilateral nodules on the skin.

Lower respiratory tract disease is often associated with the nasal form but may also occur independently, manifesting as pulmonary or mediastinal involvement. Clinically and radiographically, this may present with pleural effusion, though less commonly without it (Evans et al., 2018). In 2019, Newman & Schaible described a case of chronic lipoid pneumonia treated by lobectomy, with histopathological examination confirming a final diagnosis of cryptococcosis (Newman & Schaible, 2019).

Nodular lesions of the oral mucosa in cats with cryptococcosis have also been reported by other authors (Ferrari et al., 2023), while abdominal involvement with peritonitis was documented in a 13-year-old Ragdoll cat with chronic rhinitis and negative FIV and FeLV test results (Johnston et al., 2021; Teh et al., 2024). Post-mortem examination revealed generalized involvement of the thoracic organs (lungs, trachea, heart) and the central nervous system (Teh et al., 2024).

The role of immune status in the development of cryptococcosis remains controversial. Some studies have demonstrated a higher prevalence of infection in cats infected with FeLV or FIV (Gerds-Grogan & Dayrell-Hart, 1997; Jacobs et al., 1997), whereas other authors did not confirm this association (Malik et al., 1992; O'Brien et al., 2004, 2006; Norris et al., 2007; Sykes et al., 2010). Cats with FIV-cryptococcosis co-infection in certain studies did not have a poor prognosis, and several animals achieved full recovery (Graham et al., 2011; Trivedi et al., 2011). Although concurrent immunosuppressive conditions or opportunistic infections may influence the clinical course of the disease, the role of weakened immune response in pathogenesis remains debatable.

Thus, according to most researchers, cryptococcosis in cats predominantly presents in the nasal form, however, the clinical picture may vary from cutaneous and neurological manifestations to a systemic, generalized process. Although immune status may affect disease severity, the infection can also occur in clinically healthy cats without concurrent immunosuppressive conditions. Exceptionally rare localizations, such as in the abdominal or oral cavities, indicate the pathogen's ability for systemic dissemination and involvement of various organs. These findings highlight the importance of timely diagnosis and a comprehensive clinical approach that includes cytological, microbiological, and histopathological evaluation to accurately identify the cause of the disease and determine the optimal treatment strategy.

Conclusion

Timely cytological and histopathological examinations made it possible to confirm cases of cryptococcosis in cats, indicating the spread of this disease within the domestic animal population in Ukraine. During the diagnosis of fungal infections involving the nasal mucosa and perinasal skin, it is advisable to include cryptococcosis in the

differential diagnosis, particularly in cats, which represent a potential risk group. The obtained results may be used to clarify the epizootic situation and contribute to the development of effective approaches for early diagnosis and treatment.

Cryptococcosis in cats differs from other yeast mycoses by the presence of encapsulated *Cryptococcus* spp. cells, whose capsule, when stained with the PAS reaction, acquires an intense pink coloration, does not form mycelium and reproduces by budding. *Cryptococcus* species are also capable of producing localized skin lesions in a systemic way, while affecting the mucosa of the upper respiratory tract, lungs, and central nervous system. Molecular genetic methods are used for accurate species identification of *Cryptococcus* spp.

None of the authors have any personal or financial relationships with individuals or organizations that could inappropriately influence the content of this publication.

The authors express their gratitude to O. O. Zaitsev, Head of the Electron Microscopy Laboratory at Stepan Gzhytskyi Lviv National University of Veterinary Medicine and Biotechnologies, for technical and consultative assistance in preparing histological sections.

References

Alspaugh, J. A., Davidson, R. C., & Heitman, J. (2000). Morphogenesis of *Cryptococcus neoformans*. Contributions to Microbiology, 5, 217–238.

Barnett J. A. (2010). A history of research on yeasts 14: Medical yeasts part 2, *Cryptococcus neoformans*. Yeast, 27(11), 875–904.

Beatty, J. A., Barrs, V. R., Swinney, G. R., Martin, P. A., & Malik, R. (2000). Peripheral vestibular disease associated with cryptococcosis in three cats. Journal of Feline Medicine and Surgery, 2(1), 29–34.

Belluco, S., Thibaud, J. L., Guillot, J., Krockenberger, M. B., Wyers, M., Blot, S., & Colle, M. A. (2008). Spinal cryptococcoma in an immunocompetent cat. Journal of Comparative Pathology, 139(4), 246–251.

Castellá, G., Abarca, M. L., & Cabañes, F. J. (2008). Criptococosis y animales de compañía [Cryptococcosis and pets]. Revista Iberoamericana de Micologia, 25(1), 19–24.

Caswell, L. J., & Williams, K. J. (2007). Infectious diseases of the respiratory system. In: Maxie, M. G. (Ed.). Jubb, Kennedy and Palmer's pathology of domestic animals. Vol. 1. 5th ed. Elsevier, St. Louis. Pp. 579–650.

Connolly, J. H., Krockenberger, M. B., Malik, R., Canfield, P. J., Wigney, D. I., & Muir, D. B. (1999). Asymptomatic carriage of *Cryptococcus neoformans* in the nasal cavity of the koala (*Phascolarctos cinereus*). Medical Mycology, 37(5), 331–338.

Costa, P. P. C., Waller, S. B., Conte, C., Sanzo, G. L., Gaspar, L. F. J., de Oliveira Cavalcanti, G. A., de Borba, A. M., Dos Reis Gomes, A., de Faria, R. O., & Cleff, M. B. (2022). Cryptococcosis by *Cryptococcus* sp. causing lymphadenomegaly as a single sign in a cat. Mycopathologia, 187(5–6), 627–630.

Danesi, P., Falcaro, C., Schmertmann, L. J., de Miranda, L. H. M., Krockenberger, M., & Malik, R. (2021). Cryptococcus in wildlife and free-living mammals. Journal of Fungi, 7(1), 29.

Danesi, P., Fumari, C., Granato, A., Schivo, A., Otranto, D., Capelli, G., & Cafarchia, C. (2014). Molecular identity and prevalence of *Cryptococcus* spp. nasal carriage in asymptomatic feral cats in Italy. Medical Mycology, 52(7), 667–673.

Duncan, C., Stephen, C., & Campbell, J. (2006). Clinical characteristics and predictors of mortality for *Cryptococcus gattii* infection in dogs and cats of Southwestern British Columbia. The Canadian Veterinary Journal, 47(10), 993–998.

Duncan, C., Stephen, C., Lester, S., & Bartlett, K. H. (2005). Follow-up study of dogs and cats with asymptomatic *Cryptococcus gattii* infection or nasal colonization. Medical Mycology, 43(7), 663–666.

Emmons, C. W. (1960). Prevalence of *Cryptococcus neoformans* in pigeon habitats. Public Health Reports, 75(4), 362–364.

Evans, S. J. M., Jones, K., & Moore, A. R. (2018). Atypical morphology and disparate speciation in a case of feline cryptococcosis. Mycopathologia, 183(2), 479–484.

Ferrari, E., de P Secchin, C. R., & Santana, A. E. (2023). First report of oral cryptococcal osteomyelitis in a cat. Brazilian Journal of Microbiology, 54(2), 1315–1320.

Flatland, B., Greene, R. T., & Lappin, M. R. (1996). Clinical and serologic evaluation of cats with cryptococcosis. Journal of the American Veterinary Medical Association, 209(6), 1110–1113.

Fortes, S. T., Lazéra, M. S., Nishikawa, M. M., Macedo, R. C., & Wanke, B. (2001). First isolation of *Cryptococcus neoformans* var. *gattii* from a native jungle tree in the Brazilian Amazon rainforest. Mycoses, 44(5), 137–140.

Gerds-Grogan, S., & Dayrell-Hart, B. (1997). Feline cryptococcosis: A retrospective evaluation. Journal of the American Animal Hospital Association, 33(2), 118–122.

Glavinić, A., Šupić, J., Alić, A., Spahija, N., Maksimović, A., & Šunje-Rizvan, A. (2024). First case of feline cryptococcosis in Bosnia and Herzegovina. Journal of Feline Medicine and Surgery Open Reports, 10(2), 20551169241265248.

Graham, K. J., Brain, P. H., Spielman, D., Martin, P. A., Allan, G. S., & Malik, R. (2011). Concurrent infection with *Cryptococcus neoformans/gattii* species complex and *Mycobacterium avium* affecting the subcutis and bone of a pelvic limb in a cat. Journal of Feline Medicine and Surgery, 13(10), 776–780.

Hamilton, A. J., & Goodley, J. (1996). Virulence factors of *Cryptococcus neoformans*. Current Topics in Medical Mycology, 7(1), 19–42.

Huang, C. H., Chen, K. S., Chia, M. Y., Chiou, H. Y., & Shia, W. Y. (2023). Cryptococcal granulomas of basal ganglia due to *Cryptococcus neoformans* in a cat: A case report and literature review. The Journal of Veterinary Medical Science, 85(4), 412–416.

Jacobs, G. J., Medleau, L., Calvert, C., & Brown, J. (1997). Cryptococcal infection in cats: Factors influencing treatment outcome, and results of sequential serum antigen titers in 35 cats. Journal of Veterinary Internal Medicine, 11(1), 1–4.

Jacobson, E., Morton, J. M., Woerde, D. J., Thompson, M. F., Spillane, A. M., Tebb, A., Della Valle, Z., Birnie, G., & Malik, R. (2022). Clinical features, outcomes, and long-term survival times of cats and dogs with central nervous system cryptococcosis in Australia: 50 cases (2000–2020). Journal of the American Veterinary Medical Association, 261(2), 246–257.

Johnston, L., Mackay, B., King, T., Krockenberger, M. B., Malik, R., & Tebb, A. (2021). Abdominal cryptococcosis in dogs and cats: 38 cases (2000-2018). The Journal of Small Animal Practice, 62(1), 19–27.

Lester, S. J., Kowalewich, N. J., Bartlett, K. H., Krockenberger, M. B., Fairfax, T. M., & Malik, R. (2004). Clinicopathologic features of an unusual outbreak of cryptococcosis in dogs, cats, ferrets, and a bird: 38 cases (January to July 2003). Journal of the American Veterinary Medical Association, 225(11), 1716–1722.

Lin, X., & Heitman, J. (2006). The biology of the *Cryptococcus neoformans* species complex. Annual Review of Microbiology, 60, 69–105.

Malik, R., Martin, P., Wigney, D. I., Church, D. B., Bradley, W., Bellenger, C. R., Lamb, W. A., Barrs, V. R., Foster, S., Hemsley, S., Canfield, P. J., & Love, D. N. (1997). Nasopharyngeal cryptococcosis. Australian Veterinary Journal, 75(7), 483–488.

Malik, R., Wigney, D. I., Muir, D. B., Gregory, D. J., & Love, D. N. (1992). Cryptococcosis in cats: Clinical and mycological assessment of 29 cases and evaluation of treatment using orally administered fluconazole. Journal of Medical and Veterinary Mycology, 30(2), 133–144.

Martins, D. B., Zanette, R. A., França, R. T., Howes, F., Azevedo, M. I., Botton, S. A., Mazzanti, C., Lopes, S. T., & Santurio, J. M. (2011). Massive cryptococcal disseminated infection in an immunocompetent cat. Veterinary Dermatology, 22(2), 232–234.

McEwan, S. A., & Sykes, J. E. (2022). Nasopharyngeal cryptococcosis in a cat: Interlaboratory variation in cryptococcal antigen assay test results. Journal of Feline Medicine and Surgery Open Reports, 8(1), 20551169221074624.

McGill, S., Malik, R., Saul, N., Beetson, S., Secombe, C., Robertson, I., & Irwin, P. (2009). Cryptococcosis in domestic animals in Western Australia: A retrospective study from 1995–2006. Medical Mycology, 47(6), 625–639.

Mulisch, M. & Welsch, U. (2010). Romeis Mikroskopische Technik. Spektrum Akademischer Verlag, Heidelberg.

Myers, A., Meason-Smith, C., Mansell, J., Krockenberger, M., Peters-Kennedy, J., Ross Payne, H., & Rodrigues Hoffmann, A. (2017). Atypical cutaneous cryptococcosis in four cats in the USA. Veterinary Dermatology, 28(4), 405–e97.

Newman, R., & Schaible, M. (2019). Isolation of *Cryptococcus gattii* from feline chronic stage lipoid pneumonia. Medical Mycology Case Reports, 25, 19–21.

Norris, J. M., Bell, E. T., Hales, L., Toribio, J. A., White, J. D., Wigney, D. I., Baral, R. M., & Malik, R. (2007). Prevalence of feline immunodeficiency virus infection in domesticated and feral cats in Eastern Australia. Journal of Feline Medicine and Surgery, 9(4), 300–308.

Nunes Rodrigues, T. C., Stroobants, L. R., & Vandenabeele, S. I. (2020). Feline cutaneous nodular and ocular *Cryptococcus neoformans* in Belgium. Journal of Feline Medicine and Surgery Open Reports, 6(1), 2055116920912560.

O'Brien, C. R., Krockenberger, M. B., Martin, P., Wigney, D. I., & Malik, R. (2006). Long-term outcome of therapy for 59 cats and 11 dogs with cryptococcosis. Australian Veterinary Journal, 84(11), 384–392.

O'Brien, C. R., Krockenberger, M. B., Wigney, D. I., Martin, P., & Malik, R. (2004). Retrospective study of feline and canine cryptococcosis in Australia from 1981 to 2001: 195 cases. Medical Mycology, 42(5), 449–460.

Pal, M. (1989). *Cryptococcus neoformans* var. *neoformans* and munia birds. Mycoses, 32(5), 250–252.
Paulin, J., Morshed, M., & Armién, A. G. (2013). Otitis interna induced by *Cryptococcus neoformans* var. *grubii* in a cat. Veterinary Pathology, 50(2), 260–263.
Pearse, A. G. E. (1960). Histochemistry: Theoretical and applied. London.
Stephen, C., Lester, S., Black, W., Fyfe, M., & Raverty, S. (2002). Multispecies outbreak of cryptococcosis on Southern Vancouver Island, British Columbia. The Canadian Veterinary Journal, 43(10), 792–794.
Sykes, J. E. (2022). Greene's infectious diseases of the dog and cat. Elsevier Health Sciences.
Sykes, J. E., Sturges, B. K., Cannon, M. S., Gericota, B., Higgins, R. J., Trivedi, S. R., Dickinson, P. J., Vernau, K. M., Meyer, W., & Wisner, E. R. (2010). Clinical signs, imaging features, neuropathology, and outcome in cats and dogs with central nervous system cryptococcosis from California. Journal of Veterinary Internal Medicine, 24(6), 1427–1438.
Takashima, M., & Sugita, T. (2022). Taxonomy of pathogenic yeasts *Candida*, *Cryptococcus*, *Malassezia*, and *Trichosporon*. Medical Mycology Journal, 63(4), 119–132.
Teh, A., Pritchard, E., Donahoe, S. L., Malik, R., & Krockenberger, M. (2024). A case of disseminated cryptococcosis with abdominal involvement due to *Cryptococcus neoformans* species complex in a Ragdoll cat and false-negative cryptococcal antigen lateral flow tests due to the postzone phenomenon. Australian Veterinary Journal, 102(6), 306–312.
Trivedi, S. R., Sykes, J. E., Cannon, M. S., Wisner, E. R., Meyer, W., Sturges, B. K., Dickinson, P. J., & Johnson, L. R. (2011). Clinical features and epidemiology of cryptococcosis in cats and dogs in California: 93 cases (1988–2010). Journal of the American Veterinary Medical Association, 239(3), 357–369.
Urban, C. F., Lourido, S., & Zychlinsky, A. (2006). How do microbes evade neutrophil killing? Cellular Microbiology, 8(11), 1687–1696.
Vercelli, C., Peano, A., Piovano, G., Corona, A., Gambino, G., & Re, G. (2021). Diagnostic and therapeutic management of cryptococcosis in a kitten with practical considerations to veterinary pediatric therapeutic approach. Medical Mycology Case Reports, 32, 61–63.
Wronski, J. G., de Cecco, B. S., Raiter, J., Henker, L. C., de Lorenzo, C., Bandinelli, M. B., Driemeier, D., Pavarini, S. P., & Sonne, L. (2023). Ophthalmic and immunopathological characterization of systemic infectious diseases in cats. Veterinary Pathology, 60(3), 352–359.