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RESEARCH ARTICLE

Global Bibliometric Research on a Neglected Food-Borne Parasite: *Taenia solium*

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ABSTRACT

This study analyzes publications on *Taenia solium*, the pork tapeworm, using Web of Science data from 2000-2023. It aims to characterize scientific production, distribution of contributions, and thematic research characteristics, exploring trends, prominent journals, affiliations, and global contributions to better understand this neglected tropical disease. For this bibliometric study, articles related to *Taenia solium*, published from January 1st, 2000, to September 30th, 2023, were extracted from the Web of Science Core Collection database. The analysis encompassed an exploration of the scholarly output's evolution and an examination of the diverse subject areas covered in the corpus of research. The data were systematically analyzed using the Bibliometrix 2.0 package within the RStudio application, providing a robust and comprehensive evaluation of the research landscape surrounding *Taenia solium* during the specified timeframe. An extensive analysis was conducted on a total of 4.167 articles published from 2000 to 2023. In the realm of average citations, 2018 emerged as a peak year. The journals contributing significantly to this body of work fell within the categories of tropical medicine and veterinary science. While the United States led in productivity with 896 articles, noteworthy attention is drawn to the endemic nature of *Taenia solium* in countries like India (748 articles), Brazil (615 articles). It's worth noting, however, that some endemic regions in Africa (285 articles) and Oceania (72 articles) exhibited comparatively lower participation in research efforts. This comprehensive examination aids researchers in gaining insights into its temporal evolution, providing a global audience with structured information to discern both the key areas of focus and potential research gaps. This emphasis becomes especially crucial in the context of developing endemic countries, where the encouragement of robust research practices can significantly contribute to advancing our understanding of *Taenia solium*.

INTRODUCTION

Neglected tropical diseases are a group of infectious diseases that primarily affect populations in tropical regions. They are characterised by their prevalence in poor communities where access to adequate healthcare, sanitation and education is limited (García et al., 2003). Efforts to address these diseases include preventive measures, community-based interventions, mass drug administration and research into improved diagnostics and treatments. International organisations, governments and non-governmental organisations collaborate to control and eliminate these diseases, reducing the suffering experienced by affected communities (García et al., 2000; Rajshekhar et al., 2003; Torgerson et al., 2015; Boelaert et al., 2016; WHO, 2023). Neglected tropical diseases primarily consist of parasitic infections, including foodborne trematodiases, dengue fever, Chagas disease, leprosy, draconculiasis, schistosomiasis, trypanosomiasis, leishmaniasis, onchocerciasis, lymphatic filariasis, soil-transmitted helminthiases and taeniasis/cysticercosis (Mondiale de la et al., 2016; Gripper and Welburn, 2017; WHO, 2023)

Taenia solium, commonly known as the pork tapeworm, is a parasitic flatworm that has long been a cause for concern in the fields of medicine and veterinary science. This article explores the intricacies of *Taenia solium*, examining its life cycle, its impact on human health, and the measures taken to prevent and control it.

The life cycle of *Taenia solium* is complex and involves both humans and pigs. Humans become infected by ingesting undercooked pork containing cysticerci, which are the larval stage of the tapeworm. Once ingested, these larvae develop into adult tapeworms in the small intestine, where they can grow to several metres in length. These adult tapeworms then release eggs into the host's faeces, perpetuating the cycle (Deckers et al., 2010; Rajshekhar et al., 2003; Debacq et al., 2017).

The impact of *Taenia solium* on human health is significant. Infection with the adult tapeworm can result in gastrointestinal symptoms, including abdominal pain, nausea and weight loss (Mondiale et al., 2016; Willingham & Engels, 2006). However, more severe consequences arise from the presence of cysticerci in tissues, particularly in the brain, which can lead to a condition called neurocysticercosis. This condition can manifest as seizures, headaches and more severe neurological complications, posing a substantial public health threat in endemic regions (García et al., 2000; García et al., 2020; Fonseca et al., 2020; Bustos et al., 2021; Rubio et al., 2022).

Preventing and controlling *Taenia solium* infection requires a multifaceted approach. This includes public health education campaigns emphasising the importance of proper pork cooking techniques, improved sanitation practices and regular deworming in both humans and pigs (García et al., 2003; De Coster et al., 2018; Larkins et al., 2022). Additionally, rigorous meat inspection and surveillance programmes are essential for identifying infected animals before they enter the food supply chain.

Despite the challenges posed by *Taenia solium*, significant progress has been made in recent years. Research efforts have improved our understanding of the parasite's biology, while international collaborations have contributed to the development of more effective control strategies. The use of antiparasitic drugs for deworming, alongside improved sanitation practices and meat inspection, has demonstrated potential in reducing the prevalence of *Taenia solium* in certain regions (Coral-Almeida et al., 2015; Engels & Zhou, 2020).

However, *Taenia solium* remains a formidable foe in the realm of public health. While progress has been made, ongoing research and collaborative efforts are necessary to further unravel the complexities of this parasite and implement sustainable prevention and control measures. Vigilance, education and international cooperation are essential to mitigate the impact of *Taenia solium* on global health.

Publication reviews conducted at regular intervals reveal trends and progress in a scientific field. The most frequently used method for this purpose is bibliometric analysis (Yıldız, 2020; Tokur, & Alkan, 2024).

Our study makes a significant contribution to existing knowledge as it is the first to analyse Web of Science data on *Taenia solium*. While another previous study (González-Alcaide et al., 2023) used MEDLINE data to perform a similar analysis, our strategy of focusing on Web of Science offers new insights into *Taenia solium*. Our study aims to complement and build on the results of the aforementioned study by utilising untapped databases to improve the overall understanding of this neglected tropical disease. This study aims to describe research on *Taenia solium* by examining the development of scientific output, the distribution of contributions by nationality and the distinguishing characteristics of thematic research on this subject.

MATERIALS AND METHODS

Design of the study

This study employs a descriptive bibliometric approach to analyse *Taenia solium* research, evaluating the characteristics and impact of scientific publications within this field. It defines a typology of published *Taenia solium* research, covering biomedical, epidemiological and socio-behavioural dimensions. The Web of Science (WoS) database provides a comprehensive view of the current knowledge landscape and promotes interdisciplinary collaboration. The analysis aims to identify knowledge gaps in the literature and highlight areas for further research. This will inform future research directions and provide a more comprehensive understanding of *Taenia solium* and related challenges. Acknowledging the absence of a state-of-the-art overview, the study contributes to the field by providing a typology of research and identifying key knowledge gaps. WoS is a comprehensive database covering various fields of science.

Data selections

The Web of Science database was chosen as the primary data source due to its widespread use in the health sciences and its dominance in the English language. The chosen MESH (Medical Subject Headings) keywords were applied to extract results from the Science Citation Index Expanded, providing a comprehensive and relevant dataset for the study: ([MeSH Terms] OR "*Taenia*"[Title]) AND *solium*[Title], "cysticercosis"[MeSH Terms] OR Cysticercosis[Title], and also Cysticercosis[Title] OR Cysticercoses[Title] OR “Coenuri Infection*”[Title] OR Coenurosis[Title] OR Coenuroses[Title] OR “Coenurus cerebralis Infection*”[Title] OR “Cysticercus cellulosae Infection*”[Title] OR “*Taenia solium* Cysticercosis”[Title] OR “*Taenia solium* Cysticercoses”[Title] OR Neurocysticercosis[Title] OR Neurocysticercoses[Title] OR Neurocoenurosis[Title] OR Neurocoenuroses[Title] OR “Central Nervous System Cysticercosis”[Title] OR “CNS Cysticercosis”[Title] OR “CNS Cysticercoses”[Title] OR “Brain Cysticercosis”[Title] OR “Cerebral Coenurosis”[Title] OR “Cerebral Coenuroses”[Title] OR “Cerebral Cysticercosis”[Title] OR “Cerebral Cysticercoses”[Title].

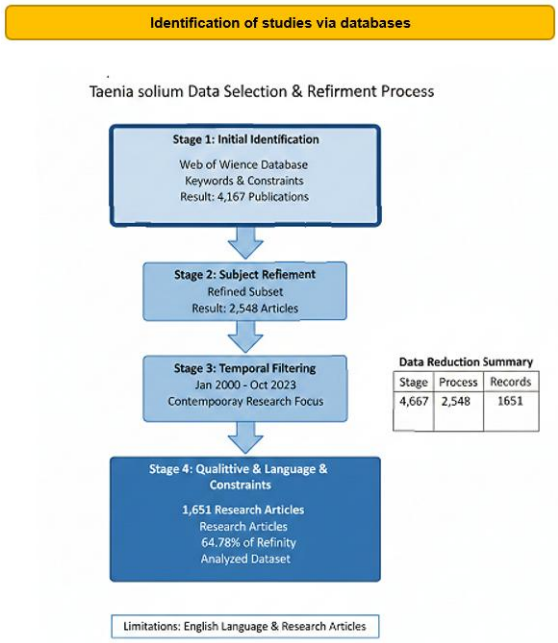
Time span

The study covers the period from January 1, 2000, to October 31, 2023, providing a comprehensive analysis of *Taenia solium* research trends and developments.

Inclusion criteria and flowchart

This study employed a multi-step process to identify and refine a dataset for a thorough analysis of *Taenia solium* publications. The initial search involved using specific keywords and constraints within the Web of Science database to identify 4,167 publications. To narrow the focus, this was refined to a subset of 2,548 articles. The study focused on contemporary and relevant research, selecting the time span from 1 January 2000 to 31 October 2023. This enabled a closer examination of recent developments and aligned with the study's objective of providing insights into the latest trends and advancements related to *Taenia solium*. The final sample consisted of 1,651 research articles, accounting for 64.78% of the initial dataset. The study's limitations, such as the use of specific search keywords and the inclusion of English-language publications only, were intentional decisions

made to ensure the relevance and quality of the selected articles (**Flowchart**).



Appendix. Flowchart

Exploring data and visualizing networks

Bibliometric maps are visual tools that illustrate the relationships, affiliations and connections between different scientific fields or research topics. Data were analysed using plain text, Excel files and 99% consensus files, with discrepancies in publications excluded. This study examined various bibliometric data, such as publication characteristics, the journals with the highest publication numbers, the leading institutions/universities in terms of publications, the temporal distribution of publications, the countries with the most cited and published works, H-indexes, frequently used keywords and keyword density. The analysis was conducted using Excel and the Bibliometrix R package (Aria et al., 2021; Çelik et al., 2023; Alkan and Tokur, 2023).

Bibliometrix is an open-source tool for quantitative scientometric and bibliometric research. It offers various routines for importing bibliographic data from different databases. Developed using the R statistical computing and graphics language, Bibliometrix is flexible and easy to automate, and can be integrated with other R statistical packages. It is used for science mapping and synthesising past research findings, which is crucial for advancing research. Bibliometrics provides a structured analysis of large bodies of information, inferring trends over time, identifying shifts in disciplinary boundaries, and highlighting prolific scholars and institutions. It also shows the 'big picture' of existing research (Aria et al., 2021).

Additionally, keyword co-occurrence analysis was visualised using Vosviewer 1.6.20 (Van Eck, & Waltman, 2011).

RESULTS

Main information

A total of 4,167 publications were identified, 2,548 of which were articles. The dataset spans from 2000 to 2023 and shows a notable increase in publications in recent years, particularly in 2006, 2016, 2019 and 2020. This indicates a diverse distribution of publications over time. Since 2000, 1,651 publications (64.78%) have been published, forming the focus of our analysis.

Examining the dataset from 2000 to 2023 reveals varying trends in scholarly article publication, highlighting the dynamic nature of scientific output (Figure 1). During this period, 443 journals published 1,651 articles, with a negative annual growth rate of 1.58%. These documents have an average age of 11.6 years and an average of 16.96 citations per document. The dataset comprises 17,295 references involving 5,850 authors, with an average of 6.29 co-authors per document. Of these, 36.04% were international collaborations.

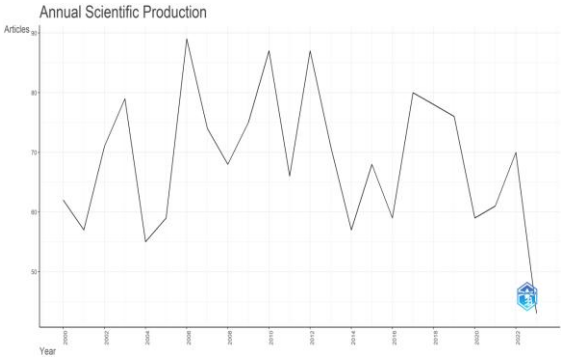


Figure 1. Annual scientific production for *Taenia solium*

A decline in the average total number of citations per article over time reflects a decrease in the average number of citations received by studies. The annual average total number of citations initially rose, reaching its peak around 2015, followed by a decline. In contrast, the cumulative total number of citable years showed a steady increase on an annual basis (Figure 2 and Table 1).

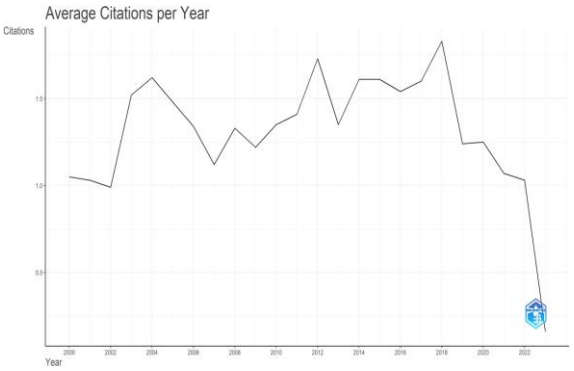


Figure 2. Average article citation per year for *Taenia solium*

Table 1. Average citations per year

Year	Mean Total Citations per article	Number of citations	Mean Total Citations per year	Citable years
2023	0.16	43.00	0.16	1
2022	2.06	70.00	1.03	2
2021	3.2	61.00	1.07	3
2020	5.02	59.00	1.25	4
2019	6.2	76.00	1.24	5
2018	11	78.00	1.83	6
2017	11.19	80.00	1.60	7
2016	12.29	59.00	1.54	8
2015	14.47	68.00	1.61	9
2014	16.14	57.00	1.61	10
2013	14.87	71.00	1.35	11
2012	20.75	87.00	1.73	12
2011	18.3	66.00	1.41	13
2010	18.91	87.00	1.35	14
2009	18.29	75.00	1.22	15
2008	21.26	68.00	1.33	16
2007	19.03	74.00	1.12	17
2006	24.09	89.00	1.34	18
2005	28.1	59.00	1.48	19
2004	32.4	55.00	1.62	20
2003	31.87	79.00	1.52	21
2002	21.76	71.00	0.99	22
2001	23.75	57.00	1.03	23
2000	25.21	62.00	1.05	24

Journals

The dataset highlights key top journals in the *Taenia solium* literature, with key publications found in PLOS Neglected Tropical Diseases, American Journal of Tropical Medicine and Hygiene, Veterinary Parasitology, Arquivos de Neuro-Psiquiatria, and Acta Tropica (Table 2).

Table 2. The prominent journals in on *T. solium* literature

Sources	Articles	Sources	Articles
Plos Neglected Tropical Diseases	81	Journal of Child Neurology	14
American Journal of Tropical Medicine and Hygiene	78	Journal of Helminthology	14
Veterinary Parasitology	56	World Neurosurgery	14
Arquivos De Neuro-Psiquiatria	54	Neurology	13
Acta Tropica	52	Pesquisa Veterinaria Brasileira	13
Transactions of The Royal Society of Tropical Medicine And Hygiene	45	Bmc Infectious Diseases	12
Parasitology Research	32	Infection And Immunity	12
Tropical Medicine & International Health	28	Journal of Clinical Microbiology	12
Parasitology International	24	Journal of The Neurological Sciences	12
Parasitology	21	Clinical Neurology and Neurosurgery	11
Revista de Neurologia	20	International Journal for Parasitology	11
Parasites & Vectors	19	Journal of Parasitology	11
Epilepsia	17	Pathogens and Global Health	11
Experimental Parasitology	17	Annals of Indian Academy of Neurology	10
Neurology India	17	Emerging Infectious Diseases	10
Preventive Veterinary Medicine	17	Journal of Travel Medicine	10
Tropical Animal Health and Production	16	Pathogens	10
Clinical Infectious Diseases	14	Semina-Ciencias Agrarias	10

In this study, the Bibliometrix software was used to analyse the number of publications, which indicates researcher productivity, and the total citation values, which reflect scientific impact. Within the scope of the analysis, the h-index (Hirsch, 2005), which establishes the balance between publications and citations, and the g-index (Nocera et al.,2024), which gives weight to highly cited studies, were calculated. The m-index, normalised according to academic age, and the first publication year (FPY) data were used to present the trajectory of scientific productivity over time from a holistic perspective. These data are summarised in Table 3.

Table 3. The prominent journals' local impact

Journal name	h_index	g_index	m_index	TC	NP	SYP
Plos Neglected Tropical Diseases	26	37	1.625	1679	81	2008
American Journal of Tropical Medicine And Hygiene	24	34	1.043	1447	78	2001
Veterinary Parasitology	24	36	1	1461	56	2000
Acta Tropica	23	40	1	1653	52	2001
Transactions of The Royal Society of Tropical Medicine and Hygiene	18	31	0.75	1009	45	2000
Parasitology International	16	23	0.889	566	24	2006
Epilepsia	14	17	0.609	764	17	2001
Tropical Medicine & International Health	14	22	0.583	539	28	2000
Arquivos de Neuro-Psiquiatria	13	19	0.542	525	54	2000
Neurology	12	13	0.5	815	13	2000
Parasitology	12	18	0.632	329	21	2005
Journal of Clinical Microbiology	11	12	0.458	513	12	2000
Parasites & Vectors	11	17	0.846	315	19	2011
Parasitology Research	11	17	0.458	343	32	2000
Clinical Infectious Diseases	10	14	0.455	357	14	2002
Experimental Parasitology	10	14	0.455	219	17	2002
Infection and Immunity	10	12	0.435	533	12	2001
International Journal for Parasitology	10	11	0.455	621	11	2002
Preventive Veterinary Medicine	9	16	0.529	280	17	2007
Vaccine	9	9	0.391	345	9	2001
American Journal of Neuroradiology	8	9	0.333	181	9	2000
Annals of Tropical Medicine and Parasitology	8	9	0.364	165	9	2002
Pathogens and Global Health	8	11	0.667	408	11	2012
Acta Neurologica Scandinavica	7	7	0.333	139	7	2003
Emerging Infectious Diseases	7	10	0.318	433	10	2002

**TC: Total Citations, NP: Number of Publications, SYP: Starting Year of Publication*

The substantial article counts, h-index, m-index and g-indexes of the top journals highlight their significant role in promoting research and advancements in these fields (Table 3). The most productive journals in our study were high-impact publications (Quarter 1, according to the Journal Citation Reports' 2022 edition's journal impact factor rankings), alongside other journals with varying levels of visibility (Quadrants 2 and 3). Notably, the number of journals nominated in the fourth quarter and listed in the Emerging Source Citation Index was relatively limited. Figure 3 shows the majority of journals' production over time.

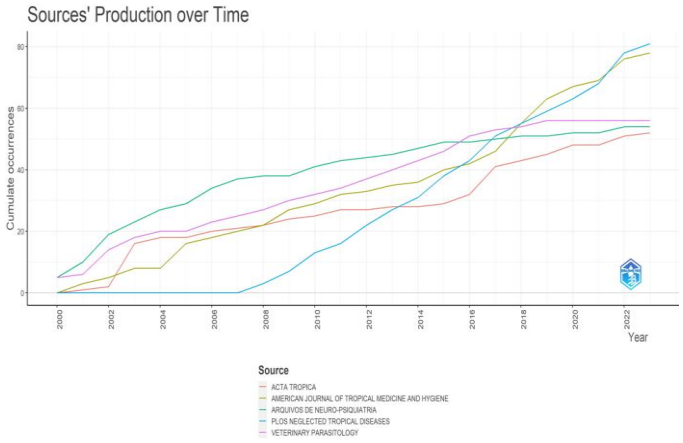


Figure 3. Mostly publishing journals's production over time for *Taenia solium*

Affiliations

The dataset reveals the distribution of articles contributed by various academic and research institutions, indicating that Peru and Mexico lead the way in terms of research output. Specifically, Universidad Peruana Cayetano Heredia in Peru and Universidad Nacional Autónoma de México in Mexico have contributed 239 and 238 articles respectively. Additionally, the Universidade de São Paulo in Brazil has made a significant contribution of 126 articles. Figure 4 shows the affiliations with the highest number of articles and Figure 5 shows the number of articles of these affiliates over the years.

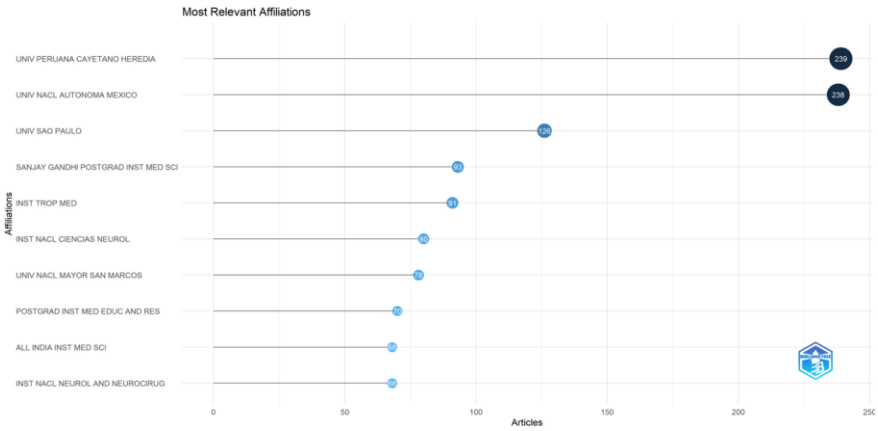


Figure 4. Most relevant affiliations for *Taenia solium*

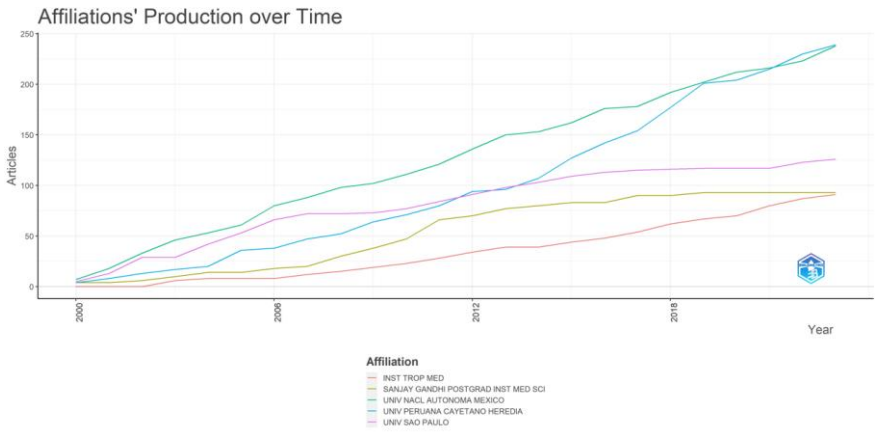


Figure 5. Affiliations' production over time for *Taenia solium*

Countries

Figure 6 displays the distribution of publication numbers on a world map**.** Figure 7 shows the countries' production over time. The dataset shows how publications are distributed across different countries. The USA is the top contributor, with 896 articles. India and Brazil followed closely behind with 748 and 615 articles, respectively. Mexico and Peru also made significant contributions with 560 and 545 articles respectively. North America, led primarily by the USA and Canada, contributed a total of 967 articles. Asia, significantly influenced by India and China, contributed a notable 902 articles. South America, led by Brazil, Peru and Ecuador, contributed 787 articles in total. Europe, including Belgium, the UK and France, contributed 844 articles. Africa contributed 285 articles and Oceania contributed 72 (Figure 7).

The USA has the highest number of citations to scientific output on *Taenia solium*, with a total of 5,773. India and Mexico also received a high number of citations, with 3,708 and 3,695, respectively. Table 4 provides an overview of the top 25 most cited countries in this context.

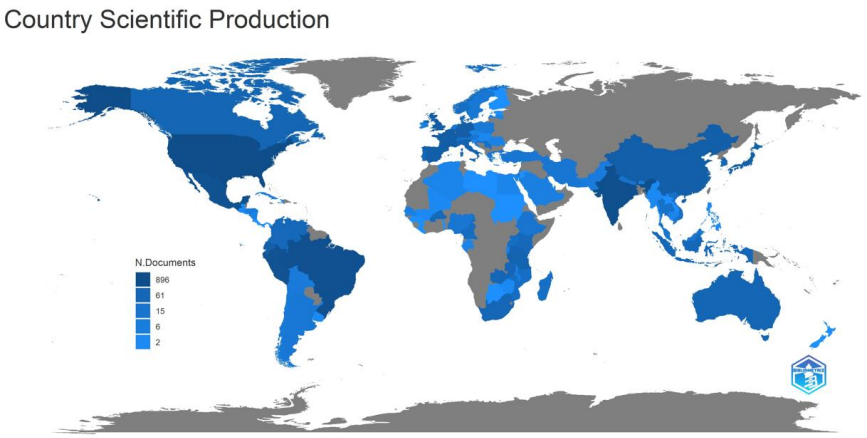


Figure 6. Countries' production over time for Taenia solium.

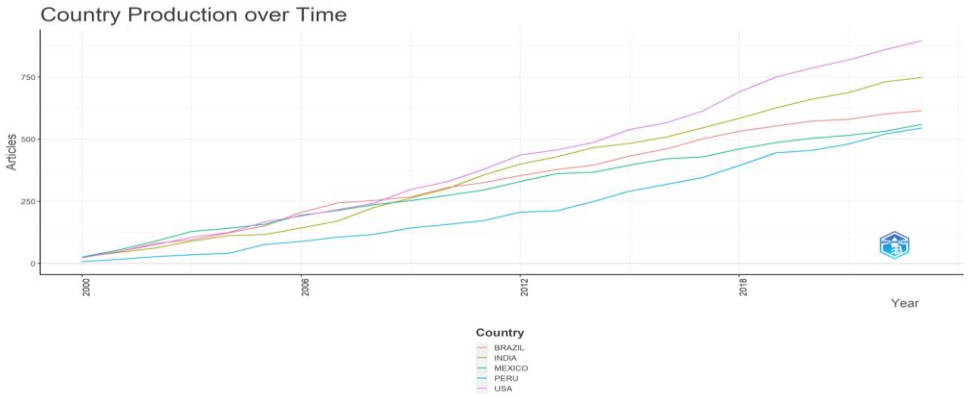


Figure 7. Countries' scientific production for Taenia solium (* Numbers represent the scientific production based on the corresponding author's country. International collaborative papers are attributed to a single country to avoid duplicate counting).

Keyword Co-occurrence Analysis

Keyword co-occurrence analysis visualised with Vosviewer 1.6.20. In total, 2069 different keywords were used in publications on *Taenia solium*. 149 of them were used at least 5 times, and 60 of them were used at least 10 times.

Upon examining the data in Figure 8 and Table 5, it is observed that the keywords with the highest frequency are neurocysticercosis (n=559, TLS=798), cysticercosis (n=414, TLS=812) and *Taenia solium* (n=363, TLS=812). These core concepts are followed by epilepsy (n=109, TLS=247), ELISA (n=71, TLS=179), Taenia saginata (n=70, TLS=171), albendazole (n=65, TLS=139), diagnosis (n=64, TLS=136), epidemiology (n=52, TLS=144) and taeniasis (n=51, TLS=132). The studies also included Taenia crassiceps (n=49, TLS=70), prevalence (n=41, TLS=131), bovine cysticercosis (n=37, TLS=66), seizures (n=37, TLS=92), magnetic resonance imaging (n=36, TLS=69), hydrocephalus (n=34, TLS=56) and porcine cysticercosis (n=28, TLS=52). In the context of animal husbandry and risk factors, pigs (n=27, TLS=77), pig (n=26, TLS=81), praziquantel (n=26, TLS=76), risk factors (n=25, TLS=84), cerebrospinal fluid (n=24, TLS=43), cattle (n=22, TLS=59), seroprevalence (n=22, TLS=57), meat inspection (n=21, TLS=52) and zoonosis (n=20, TLS=55) are recorded. In terms of geographical distribution, Peru (n=19, TLS=65), Mexico (n=16, TLS=45), Tanzania (n=14, TLS=44), Brazil (n=13, TLS=34), India (n=11, TLS=28) and Zambia (n=10, TLS=29) stand out. Other important technical and clinical terms include vaccination (n=18, TLS=49), control (n=17, TLS=43), cysticercus cellulosae (n=16, TLS=34), MRI (n=16, TLS=18), treatment (n=16, TLS=38), parasite (n=15, TLS=31), public health (n=15, TLS=38), brain (n=14, TLS=32), enzyme-linked immunosorbent assay (n=14, TLS=40), immunodiagnosis (n=13, TLS=32), serology (n=13, TLS=45) and *Taenia* (n=12, TLS=18). At the end of the list are computed tomography (n=11, TLS=31), cysticercus (n=11, TLS=11), cysticercus bovis (n=11, TLS=30), neuroendoscopy (n=11, TLS=15), parasitic infection (n=11, TLS=15), serodiagnosis (n=11, TLS=20), swine (n=11, TLS=32), taeniosis (n=11, TLS=35), vaccine (n=11, TLS=31), western blot (n=11, TLS=36), antigen (n=10, TLS=33), central nervous system (n=10, TLS=24), PCR (n=10, TLS=20), Taenia hydatigena (n=10, TLS=22) and zoonoses (n=10, TLS=31).

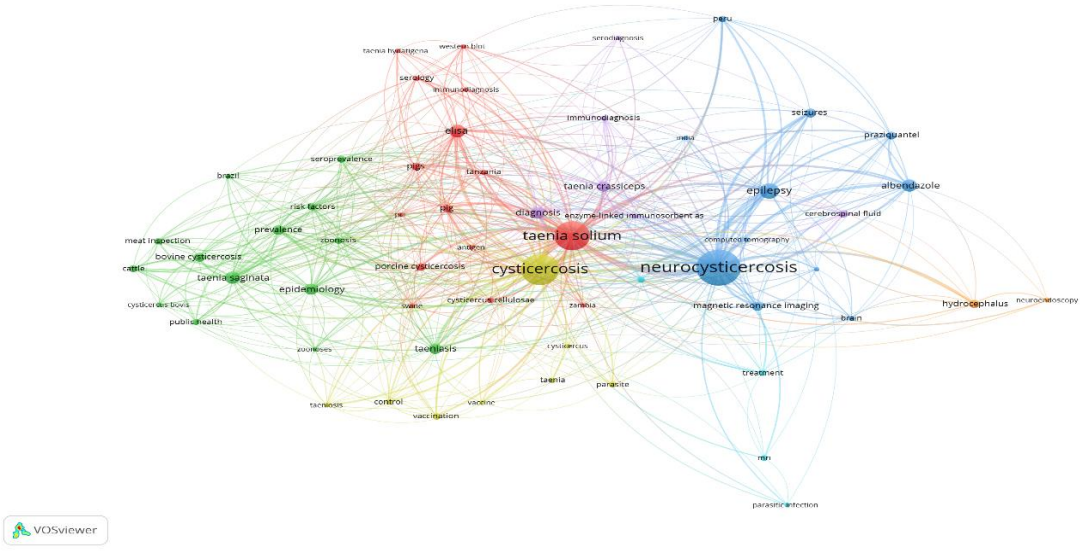


Figure 8. Keyword Co-occurrence Analysis.

Table 5. Keyword co-occurrence analysis and total link strength

Keyword	Number of occurrences	Total link strength
Neurocysticercosis	559	798
Cysticercosis	414	812
Taenia solium	363	812
Epilepsy	109	247
ELISA	71	179
Taenia saginata	70	171
Albendazole	65	139
Diagnosis	64	136
Epidemiology	52	144
Taeniasis	51	132
Taenia crassiceps	49	70
Prevalence	41	131
Bovine cysticercosis	37	66
Seizures	37	92
Magnetic resonance İmaging	36	69
Hydrocephalus	34	56
Porcine cysticercosis	28	52
Pigs	27	77
Pig	26	81
Praziquantel	26	76
Risk factors	25	84
Cerebrospinal fluid	24	43
Cattle	22	59
Seroprevalence	22	57
Meat inspection	21	52
Zoonosis	20	55
Peru	19	65
Vaccination	18	49
Control	17	43
Cysticercus cellulosae	16	34
Mexico	16	45
Mrı	16	18
Treatment	16	38
Parasite	15	31
Public health	15	38
Brain	14	32
Enzyme-linked İmmunosorbent assay	14	40
Tanzania	14	44
Brazil	13	34
İmmunodiagnosis	13	32
Serology	13	45
Taenia	12	18
Computed tomography	11	31
Cysticercus	11	11
Cysticercus bovis	11	30
Neuroendoscopy	11	15
Parasitic infection	11	15
Serodiagnosis	11	20
Swine	11	32
Taeniosis	11	35

DISCUSSION AND CONCLUSION

In recent years, scientists have become interested in bibliometric analysis, a method based on the extensive collection and evaluation of data (Fakhar et al., 2021). This analytical method utilises various bibliometric indicators to evaluate research trends in specific fields, including medicine and health sciences. In parasitology, bibliometric analysis is critical for systematically mapping the vast scientific literature, revealing which parasite species or diseases are the focus of research, identifying global research trends and highlighting gaps in academic studies objectively. This method can provide strategic guidance, particularly when visualising collaboration networks between countries and institutions within the 'One Health' framework. It can help to direct limited resources towards areas with the greatest public health impact, identify the most effective publication channels and improve understanding of the molecular-level transformation of the field's historical development process (Ekici et al., 2022).

This study focuses on global research trends related to *Taenia solium*, an often-overlooked foodborne disease. Our bibliometric analysis of *Taenia solium* research from 2000 to 2023 revealed fluctuations in the annual number of articles published, which mirrored the findings of another bibliometric analysis of *Taenia solium* (Gonzalez-Alcaide et al., 2023). The most prolific years during this

period were 2006, 2010, and 2012. The average number of citations peaked in 2004, 2012 and 2018. The observed decline in the average number of citations per article in recent years may be partly due to newer publications having had less time to accumulate citations. It may also be due to the field's natural maturation and diversification.

Journals are crucial instruments for disseminating research within the relevant scientific community. The influence of a journal is evident in its ability to convey published research to the relevant segment of society (Fakhar et al., 2021). When top journals are assessed based on the volume of published articles, it becomes evident that impact factors do not dictate the rankings. This analysis subscribes to the perspective that the impact factor of articles published in a journal may not inherently reflect the quality of those articles (Fakhar et al., 2021). In our bibliometric analysis, PLOS Neglected Tropical Diseases emerged as the leading journal for publishing articles on *Taenia solium* during this timeframe, with an h-index of 26. Notably, the journal demonstrates a commendable commitment to addressing this issue, aligning well with its stated aim and scope. In addition, journal visibility, indexing coverage, and open-access policies may substantially influence publication and citation patterns observed in bibliometric analyses.

Taeniasis and cysticercosis, which are caused by infection with the *Taenia solium* parasite, have been identified as neglected tropical diseases. They are now included in the World Health Organization's (WHO) new roadmap for intensified control measures by 2030 (WHO, 2020; WHO, 2023). Recognised as the leading causes of death among all foodborne parasitic diseases, taeniasis and cysticercosis are estimated to have caused a global burden of approximately 2.8 million disability-adjusted life years in 2015 (Garcia and Del Brutto, 2020; WHO, 2020; WHO, 2023). However, it is important to note that these estimates may be conservative due to limited data availability. The impact of taeniasis and cysticercosis extends beyond health to include social costs, as individuals with epilepsy often experience discrimination and stigmatisation. Additionally, there are economic costs incurred for treating infected individuals, and their ability to work is affected.

Our data show that the majority of *Taenia solium* publications originate from the United States. The research output on *Taenia solium* is much more extensive in the United States than in Europe and Asia. Several factors may contribute to this difference. The significant budget allocated by the USA specifically for this disease, coupled with the influx of immigrants, particularly from endemic countries (González-Alcaide et al., 2018), may indicate increased research attention to neurocysticercosis in the country rather than reflecting local transmission dynamics directly. However, this connection should be interpreted with caution, as further evidence is required. The increase in research funding in the USA and its high research output may reflect the strength of its research infrastructure and international collaborations rather than providing direct evidence of migration-related transmission.

Research funding levels in countries such as Peru, Mexico, Brazil and India appear to be associated with research productivity on this topic. However, this relationship should be interpreted with caution given the analytical limitations of bibliometric studies. However, this relationship should be interpreted with caution, given the analytical limitations of bibliometric studies. Research quality and output are not always directly linked to financing, as other factors such as institutional support, research focus and collaboration networks are also important.

The main factor guiding research efforts is the budget that countries allocate to diseases that impose a significant economic burden (WHO, 2023). The findings of this bibliometric analysis reveal that the majority of funding organisations are based in countries dealing with the challenges posed by *Taenia solium*. This highlights the need for cost-effective, comprehensive and collaborative studies spanning multiple countries, focusing specifically on preventive measures against *Taenia solium*.

A noteworthy finding of the analysis of scientific production by institutions is that the highest levels of production (more than 100 articles) are achieved by institutions in regions endemic for *Taenia solium*, as well as by some research-intensive countries. Here, 'research-intensive countries' refers to nations with well-established research infrastructures and sustained funding mechanisms rather than to endemic countries.

Notable research output was also observed at Universidad Nacional Autónoma de México (238 articles) and the University of São Paulo (126 articles), following the lead of Universidad Peruana Cayetano Heredia (239 articles). The high productivity of these institutions may be influenced by their long-standing research programmes, their role as regional reference centres and their sustained international collaborations focused on *Taenia solium*.

Beyond publication volume, *Taenia solium* research has largely focused on neurocysticercosis, epidemiology, diagnostics and control strategies. In contrast, relatively few studies have addressed the socio-economic impacts, the implementation of research and integrated One Health approaches. This highlights important gaps and potential areas for future research. Despite the epidemiological relevance of *Taenia solium* in African countries, their limited contribution to the literature may reflect structural challenges such as restricted research funding, limited infrastructure and underrepresentation in major indexing databases. Closing the gap between these regions and fostering stronger research collaborations with African institutions could significantly improve research output and coverage.

In conclusion, this bibliometric analysis offers a thorough overview of the scientific landscape of *Taenia solium* research between 1 January 2000 and 31 October 2023. The study reveals intriguing patterns in publication trends, institutional contributions and the global distribution of research efforts. Compared with previous bibliometric analyses (e.g. González-Alcaide et al., 2023), this study extends the temporal coverage and provides updated insights into institutional productivity, funding patterns and thematic research gaps. Further research should address the underrepresentation of certain regions and research themes, particularly the socio-economic impact and One Health strategies, in order to strengthen the overall body of knowledge surrounding *Taenia solium*.

LIMITATIONS

The primary limitation of this study is its reliance on the Web of Science database for bibliographic data, which could result in pertinent publications being excluded from the analysis. This is particularly pertinent for research originating in endemic countries and published in languages other than English, as this may not be adequately represented in the dataset.

This is particularly true of research conducted in endemic regions and published in languages other than English. Such research is generally underrepresented,

leading to a systematic bias in research outputs from low- and middle-income countries. Evidence generated locally is often published in unindexed regional journals or appears in grey literature, which is outside the scope of this bibliometric analysis. This includes national surveillance data, theses and technical reports from organisations such as the WHO and FAO.

Furthermore, internal biases in bibliometric metrics, such as time lag and citation window effects, may influence identified publication trends, given that it takes time for new publications to receive citations. When interpreting research impact, potential distortions arising from self-citation and institutional citation biases should also be considered. Despite our rigorous search strategy, the absence of certain keywords or differences in data reporting related to affiliated institutions may affect the comprehensiveness of the findings. Additionally, this study does not account for external factors such as policy changes, funding fluctuations or the interdisciplinary nature of *Taenia solium* research, which spans medicine, veterinary science and public health. Additionally, as this is a bibliometric analysis, content analysis has not been included.

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Ethical Declaration
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Conflict of Interest
The authors declare that they have no competing interests.

Authorship contributions
Conceptualization, Funding acquisition, Investigation, Methodology, Formal analysis, Data curation, Writing–original draft, Writing–review & editing: S.A., Visualization, Writing – review & editing: S. K. A, Formal analysis, Writing–review & editing: M. E. A.

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RESEARCH ARTICLE

Histopathological Evaluation of Intestinal *Eimeria* and *Ogmocotyle*-like Trematode Infections in Slaughtered Dromedary Camels

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ABSTRACT

Camelus dromedarius is a resilient, desert-adapted species; however, it remains susceptible to gastrointestinal parasitic infections that often go undiagnosed in clinically healthy individuals. This study investigated the occurrence, anatomical distribution, and histopathological impact of protozoan and helminth parasites in the small intestinal segments (duodenum, jejunum, and ileum) of 14 asymptomatic dromedaries slaughtered in Blida, Algeria. Histopathological analyses revealed subacute catarrhal enteritis, villous atrophy, epithelial degeneration, and inflammatory infiltration. Sexual stages of *Eimeria cameli* and *Eimeria dromedarii* were frequently identified, particularly within the crypts of Lieberkühn and villous epithelium, respectively. Overall, 78.57% of animals were found to be parasitized, with *E. cameli* present in 57.14%, and one individual harboring both species. Morphometric and Periodic Acid–Schiff (PAS) staining supported the identification of distinct developmental stages of both species. Notably, *Ogmocotyle*-like trematodes were detected in the duodenum of two camels, representing the first report of such organisms in this host. These flukes were associated with focal epithelial necrosis, eosinophilic infiltration, and luminal debris, underscoring their pathological significance. Despite the absence of molecular confirmation, histopathology, histochemistry, and morphometric analysis collectively enabled a detailed characterization of these infections. These findings highlight the importance of post-mortem surveillance and accurate parasitic identification in camels. Future studies should incorporate molecular tools to enhance species-level resolution and explore host–parasite immunological dynamics.

INTRODUCTION

The domesticated one-humped (*Camelus dromedarius*) and two-humped *(Camelus bactrianus*) camels serve as essential resources for transportation, meat and milk production, and cultural practices across arid regions such as North Africa and the Middle East (Faye and Konuspayeva, 2012; Mohandesan et al., 2017). Despite their remarkable physiological adaptations to desert conditions, camels remain susceptible to various infectious diseases, including gastrointestinal parasitic infections (Sazmand and Joachim, 2017; Dubey and Schuster, 2018).

Among these, coccidiosis caused by *Eimeria* spp. is a notable protozoan disease with both pathological and economic implications. While infected camels may show nonspecific signs such as diarrhea, weight loss, and reduced productivity, subclinical infections particularly in adults, are frequent and often overlooked despite active oocyst shedding (Parsani et al., 2008; Kheirandish

et al., 2012; Bouragba et al., 2020). The main *Eimeria* species identified in dromedaries include *E. cameli, E. dromedarii, E. rajasthani*, and *E. pellerdyi*, with *E. cameli* being the most frequently reported (Hussein et al., 1987; El-Khabaz et al., 2019).

Histological identification of *Eimeria* developmental stages—such as microgamonts, macrogamonts, and oocysts—offers critical insight into the localization and progression of infection within the intestinal mucosa. However, misidentification remains a challenge in camelid coccidiosis literature, with some studies inaccurately classifying species or developmental forms (Luna, 1968; Dubey, 2019).

In addition to protozoan infections, helminthic parasites—especially trematodes—have occasionally been reported in camels. The most common species include *Fasciola hepatica*, *Paramphistomum* spp., and *Schistosoma* spp (Parsani et al., 2008). However, data on trematodes from the family Notocotylidae, such as *Ogmocotyle*, are lacking, and such organisms have not been previously documented in camels.

This study aimed to investigate the occurrence, anatomical distribution, and histopathological effects of protozoan and helminthic parasites in the small intestines of clinically healthy, slaughtered dromedary camels. By integrating histopathological, histomorphometric, and semi-quantitative techniques, we provide novel findings on the distribution of *Eimeria* species and report, for the first time, an *Ogmocotyle*-like trematode infection in this host species.

MATERIALS AND METHODS

Animals and Sample Collection

This study was designed as an exploratory, abattoir-based investigation. The study was conducted on 14 clinically healthy dromedary camels (*Camelus dromedarius*) comprising 10 females and 4 males, aged between 6 and 14 years. The animals belonged to two local Algerian breeds: *Saharaoui* (n = 9) and *Targui* (n = 5) and were slaughtered at the Blida municipal abattoir. From each camel, approximately 10 cm-long tissue segments were collected from the duodenum, jejunum, and ileum. All samples were macroscopically examined for visible pathological alterations and immediately fixed in 10% neutral-buffered formalin for 72 hours.

Histopathological and Histochemical Procedures

Formalin-fixed samples were processed using an automated tissue processor (Leica TP1020, Germany), embedded in paraffin (Thermo Shandon EG1150H, Germany), and sectioned at 5 µm thickness using a rotary microtome (Shandon AS325, Germany). Sections were stained with hematoxylin and eosin (H&E) for general histopathological evaluation (Luna, 1968). For detection of glycogen, glycoprotein, and mono/polysaccharide contents within parasitic structures, selected sections were stained with Periodic Acid–Schiff (PAS) reagent (Bioptica AUS240, Italy).

Histomorphometric Analysis

Morphometric evaluation of parasitic developmental stages was performed as described by Dubey and Schuster (2018). Ten representative microgamonts, macrogamonts, and oocysts per slide were randomly selected, photographed under 1000× magnification, and measured using ImageJ software (NIH, USA). Results were expressed as mean ± standard deviation (SD).

Semi-Quantitative Scoring of Histopathological Lesions

Histological evaluation was performed on H&E- and PAS-stained sections. Lesions were scored semi-quantitatively based on the severity of villous atrophy, epithelial degeneration or necrosis, crypt/glandular changes, hemorrhage, hyperemia, and inflammatory infiltration. Ten random microscopic fields per intestinal segment were examined at 20× magnification. Lesion severity was graded as follows: 0 = none, 1 = mild, 2 = moderate, and 3 = severe, according to Dubey (2018). Mild lesions were defined as focal alterations affecting a limited portion of the examined field, moderate lesions as multifocal or more extensive changes, and severe lesions as diffuse or widespread alterations with marked disruption of tissue architecture.

Statistical Analysis

Differences in histopathological lesion scores among intestinal segments were analyzed using two-way analysis of variance (ANOVA), followed by Tukey's *post hoc* test. A p-value of < 0.05 was considered statistically significant. All statistical analyses were performed using GraphPad Prism version 8.0 (GraphPad Software Inc., USA).

Ethics Statement

The methodology protocols of the present study followed the ethical concepts in animal experimentation, recommended by FELASA and approved by the Algerian Ministry of Higher Education and Scientific Research (Executive Decree 10-90 supplementing the Algerian government decree 04-82) and the AASEA (45/DGLPAG/DVA.SDA.14).

RESULTS

Macroscopic Observations

All examined intestinal segments (duodenum, jejunum, and ileum) displayed varying degrees of wall thickening. Multiple small, whitish to yellowish pinpoint lesions were observed on the mucosal surfaces, particularly in the jejunum and ileum (Fig. 1A–B).

Histopathological Findings

Microscopic examination revealed subacute catarrhal enteritis across all intestinal regions. Key findings included villous atrophy, mucosal hyperemia, epithelial degeneration and necrosis, inflammatory infiltration, and occasional hemorrhages (Fig. 1C–F; Table 1). Developmental stages of coccidian parasites—namely, microgamonts, macrogamonts, and oocysts—were frequently detected, with the ileum showing the highest parasitic burden.

Eimeria cameli was widely distributed in the lamina propria and submucosa, particularly within the crypts of Lieberkühn. In contrast, *E. dromedarii* was confined to the villous epithelium (Table 1; Fig. 1A–D). Infections with *E. dromedarii* and *Ogmocotyle*-like trematodes were associated with pronounced epithelial disruption, necrotic debris accumulation, and dense inflammatory infiltrates in the duodenum (Fig. 1E-F).

Inflammatory responses consisted primarily of lymphocytes and macrophages, with moderate eosinophil presence and occasional plasma cells and neutrophils. The ileum exhibited the most intense inflammation (96.4%), particularly in camels infected with *E. cameli* (Fig. 2; Fig. 3A–B). Trematode-associated lesions featured eosinophil-rich infiltrates and extensive necrosis of the columnar epithelium in the duodenum.

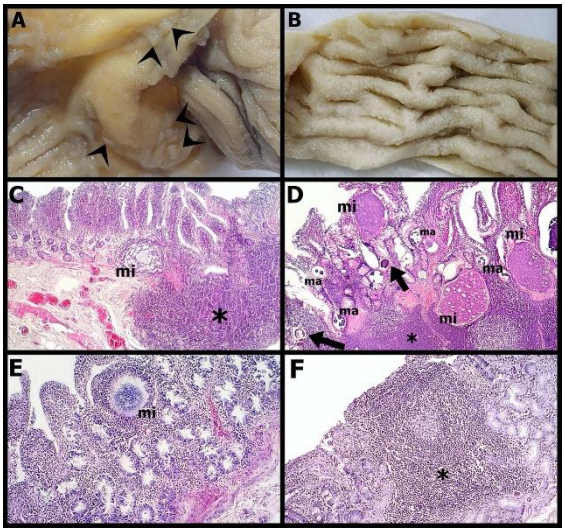

Figure 1. Macroscopic and histopathologic images of *Eimeria cameli*. A, B) Macroscopic view of pinhead-sized whitish foci (arrowhead) and thickening of the intestine in formalin fixed small intestinal section. C, D) Large microgamonts (mi), macrogamonts (ma), and oocysts (arrow) of *Eimeria cameli* in lamina propria and submucosa, with mild to severe mononuclear cell infiltration (asterisk) and congestion in the ileum. Hematoxylin and eosin staining. Magnification: x100. E) Villous atrophy with large microgamonts (mi) of *Eimeria cameli* in lamina propria in jejunum. Hematoxylin and eosin staining. Magnification: x100. F) Villous atrophy, necrotic cell surrounded with inflammatory cell infiltration (asterisk) in the duodenum. Hematoxylin and eosin staining. Magnification: x100.

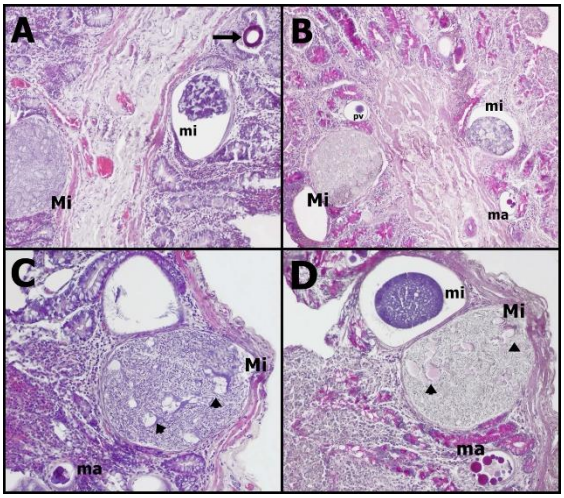

Figure 2. Different developmental stages of *Eimeria cameli* in the small intestine of naturally infected dromedaries A, C) Hematoxylin and eosin staining. Magnification: x200. B, D) Periodic Acid–Schiff reaction with hematoxylin counterstaining. Magnification: x200. Early microgamont located in large parasitophorous vacuoles (pv). Large microgamonts (mi), large microgamonts with PAS-positive amorphous material vacuoles (arrowheads) (mi), early macrogamont containing PAS-positive amylopectin granules (ma) and oocyst (arrow) in the submucosa.

Vascular changes included mild-to-moderate hyperemia across all segments, while focal hemorrhages were typically observed around small vessels. Statistical analysis revealed significant differences in lesion severity between intestinal segments ($p < 0.05$) (Table 1).

Table 1. Lesions (Mean±Standard Error) counted totally and separately within different gut parts.

Histopathological findings MEAN±SE, N=*14*	DUODENUM	JEJUNUM	ILEUM	ALL PARTS
Villus epithelium	50±8.69	57.69±5.2	55.76±7.57	54.76±4.01
Inflammation	82.14±7.14	83.92±4.97	96.42±2.42	83.37±4.03
Necrosis/deg	30.35±8.76	85.0±9.34	95.0±7.62	70,11 ± 8,57
Hemorrhage	25.0±6.93	25.0±8.28	23.21±7.62	25±4.49
Hyperemia	51.78±8.87	64.28±8.16	73.21±7.62	63.09±4.83
Total lesions	47.85±10.06	65.32±12.15	54.36±14.26	59,26±10.80

Parasite Identification and Distribution

Parasitic infection was detected in 11 of 14 animals (78.6%). Of these, 8 camels (57.1%) harbored *E. cameli*, while one Targui-breed camel (7.1%) exhibited co-infection with both *E. cameli* and *E. dromedarii*. Sexual developmental stages were observed in different regions: *E. cameli* primarily in the jejunum and ileum, and *E. dromedarii* localized to the ileum (Fig. 3A–D).

Morphometric analysis indicated mean diameters of 38.3 ± 11.3 µm for *E. cameli* microgamonts and 83.7 ± 12.6 µm for macrogamonts. PAS staining revealed intracellular amylopectin granules in mature macrogamonts. Truncate-shaped oocysts measured 102.7 ± 16.3 µm in length with a wall thickness of 13.6 µm.

Eimeria dromedarii microgamonts and macrogamonts had average dimensions of 65.8 ± 5.5 µm and 81.0 ± 6.1 µm, respectively. Oocysts were elongate-oval and measured 74.5 ± 6.4 µm. PAS-positive features such as wall-forming bodies in macrogamonts and basophilic nuclei in microgamonts were clearly evident (Fig. 3A–D).

Interestingly, *Ogmocotyle*-like trematodes were identified in the duodenum of two female Saharaoui camels (14.3%). These trematodes exhibited a single oral sucker and lacked a ventral sucker, consistent with members of the Notocotylidae family. Based on morphological features and anatomical location, they were tentatively classified as *Ogmocotyle*-like species (Fig. 3E–F).

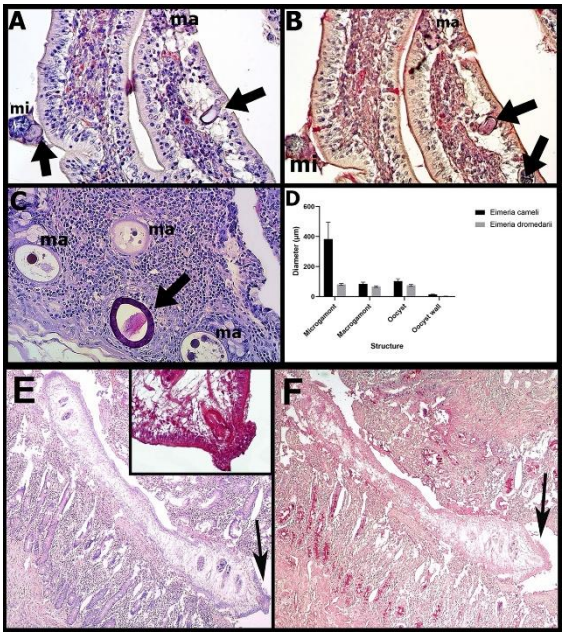

Figure 3. Different developmental stages of *Eimeria dromedarii* and *Eimeria cameli* in naturally co-infected dromedary. A) *Eimeria dromedarii* microgamonts (mi), macrogamonts (ma) and oocyst (arrow) in the ileum. Hematoxylin and eosin staining. Magnification: x200 B) *Eimeria dromedarii* microgamonts (mi), macrogamonts (ma) and oocyst (arrow) in the villous epithelium of the ileal segment of the small intestine. PAS staining. Magnification: x200. C) *Eimeria cameli* macrogamonts (ma) and oocyst (arrow) in the ileal submucosa. Hematoxylin and eosin staining. Magnification: x200. D) Comparison between *Eimeria dromedarii* and *Eimeria cameli* sexual developmental stages diameter. E-F) *Ogmocotyle*-like structures in the duodenal part of the small intestine. E) Oral sucker (arrow and inset panel) of trematode and necrotic debris around the parasite. Hematoxylin and eosin staining. Magnification: x40. F) Oral sucker (arrow) of trematode and necrotic debris around the parasite. Periodic Acid–Schiff reaction with hematoxylin counterstaining. Magnification: x40.

DISCUSSION AND CONCLUSION

Although *Camelus dromedarius* exhibits remarkable physiological resilience to extreme desert conditions, it remains susceptible to gastrointestinal parasitic infections, many of which are subclinical yet capable of inducing significant histopathological changes (Sazmand and Joachim, 2017; Dubey and Schuster, 2018; Bouragba et al., 2020). This study provides novel insights into the occurrence, distribution, and tissue-level pathology associated with coccidian (*Eimeria cameli, E. dromedarii*) and helminthic (*Ogmocotyle*-like) infections in asymptomatic dromedary camels, underscoring the importance of routine subclinical surveillance in camel health management. Although *Ogmocotyle*-like trematodes have not been previously documented in camels in Algeria, their detection in this study may reflect environmental contamination, interaction with migratory wildlife, or indirect transmission via intermediate hosts shared across regional ecosystems. Further molecular and ecological studies are warranted to elucidate their origin and transmission pathways.

Eimeria cameli was the most frequently identified species, detected in over half of the animals, followed by *E. dromedarii*, which—although less prevalent—was associated with pronounced epithelial damage, particularly in the ileum. These findings are in line with previous studies reporting that *E. cameli* predominantly localizes within the crypts of Lieberkühn, whereas *E. dromedarii* targets the villous epithelium (Hussein et al., 1987; Kheirandish et al., 2012; El-Khabaz et al., 2019). The morphometric analysis corroborated established morphological characteristics, and the PAS staining highlighted amylopectin granules in mature gamonts—an often-overlooked diagnostic feature (Dubey and Schuster, 2018).

Histopathologically, lesions such as villous atrophy, crypt damage, epithelial necrosis, and eosinophilic and mononuclear infiltration were consistently observed in sections containing parasitic developmental stages, supporting a spatial association between parasite presence and mucosal injury. Similar alterations have been reported in experimental coccidiosis models, where intracellular parasite replication leads to epithelial disruption, inflammation, and regenerative failure (Parsani et al., 2008; Dubey, 2018). Semi-quantitative scoring in this study revealed significant differences in lesion severity among intestinal segments, reinforcing the concept of region-specific parasitic tropism along the gut. Although *Eimeria* spp. are classically regarded as epithelial parasites, their endogenous stages are often closely associated with crypt epithelium, and in heavily affected tissues they may appear to extend into deeper mucosal compartments because of crypt involvement and distortion of local mucosal architecture.

One of the most notable findings of this investigation was the detection of an *Ogmocotyle*-like trematode in the duodenum of two camels. To the best of our knowledge, this represents the first report of a notocotylid trematode in *C. dromedarius*. Members of this family have previously been recorded in yaks, Japanese macaques, and Korean water deer, where they are known to inhabit the small intestine and induce mucopurulent enteritis (Bandyopadhyay et al., 2010; Choe et al., 2011; Iwaki et al., 2012; Junker et al., 2015). The observed morphology, including the presence of a single oral sucker and the absence of a ventral sucker, together with the associated epithelial necrosis and eosinophilic infiltration, highlights their pathological relevance and suggests a broader host range than previously recognized.

The presence of these flukes in camels may reflect environmental exposure through shared pastures, migratory birds, or undocumented wildlife interactions. Further studies are needed to clarify their transmission dynamics, host range, and epidemiological significance in Algerian camel production systems.

Beyond direct tissue damage, coccidian infections have been implicated in modulating host immunity, particularly by dampening pro-inflammatory cytokine responses and facilitating microbial imbalance (Zhao et al., 2018). Although cytokine profiling was beyond the scope of this study, the histological evidence of immune cell infiltration, especially in *E. cameli*-infected ileal segments, supports active host-parasite interaction and indicates the potential for future immunopathological investigation.

Misidentification of *Eimeria* species has historically led to taxonomic confusion in camelids (Dubey and Schuster, 2018). This study addresses that limitation by integrating histopathological, morphometric, and histochemical techniques to accurately identify parasite species and developmental stages. To our knowledge, this is the first study reporting histomorphometric and PAS-based characterization of Eimeria developmental stages in naturally infected camels combined with semi-quantitative lesion scoring. However, the parasite identifications presented here should be regarded as morphology-based,

and definitive species-level confirmation, particularly for the *Ogmocotyle*-like trematodes, will require additional morphological and/or molecular characterization. Future studies incorporating such approaches are recommended to strengthen taxonomic resolution and better elucidate parasite diversity.

Collectively, these findings reveal a significant and underappreciated burden of protozoan and helminthic infections in clinically healthy camels. The consistent detection of sexual coccidian stages in asymptomatic animals advocates for routine post-mortem screening in abattoirs. Furthermore, the first-time report of *Ogmocotyle*-like trematodes in camels opens new avenues for research into their life cycle, host specificity, and potential pathogenic mechanisms.

This study demonstrates a high occurrence of *E. cameli*, *E. dromedarii*, and *Ogmocotyle*-like trematodes in the small intestines of clinically healthy dromedary camels. The detection of all sexual stages of *Eimeria* spp., along with segment-specific histopathological damage especially in the ileum indicates a substantial subclinical parasitic burden. The identification of an *Ogmocotyle*-like trematode in camels represents a novel finding and contributes valuable data to camelid parasitology. Although molecular and immunological analyses were not performed, the combined use of histopathology, histochemistry, and morphometry provided robust diagnostic evidence. In routine abattoir investigations, the combined use of H&E, PAS histochemistry, and morphometric assessment may serve as a practical first-line diagnostic approach, while molecular tools should be used for definitive species-level confirmation whenever feasible. These results highlight the need for routine intestinal surveillance and species-level identification to improve health monitoring and management in camel populations from endemic regions.

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The authors declare that there are no acknowledgements.

Ethical Declaration
The methodology protocols of the present study followed the ethical concepts in animal experimentation, recommended by FELASA and approved by the Algerian Ministry of Higher Education and Scientific Research (Executive Decree 10-90 supplementing the Algerian government decree 04-82) and the AASEA (45/DGLPAG/DVA.SDA.14).

Conflict of Interest
The authors declare that there is no conflict of interest regarding the publication of this article.

Authorship contributions
Concept: T.A., R.B., M.E.A., Design: T.A., R.B., M.E.A., Data Collection or Processing: R.B., B.B., M.C., N.S., Analysis or Interpretation: S.G., O.K., Literature Search: M.B.T., G.Y., S.B.K., T.S.Y., Writing: T.A., M.E.A.

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This study does not cover any thesis. This study has not been previously presented at any congress/symposium or published in another journal.

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RESEARCH ARTICLE

Antimicrobial Efficacy of Sevoflurane in Infected Wounds

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ABSTRACT

The aim of this study was to investigate the antimicrobial efficacy of sevoflurane in wounds infected with *Staphylococcus aureus*, a species known for rapid antibiotic resistance. The study material was formed of 80 healthy, male Sprague-Dawley rats. A wound was created in each animal, and then infected with methicillin-sensitive *Staphyloccocus aureus* and with methicillin-resistant *Staphyloccocus aureus*. Isotonic sodium chloride, hypochlorous acid and liquid sevoflurane were applied to the wounds. Our results show that sevoflurane exhibited greater antimicrobial efficacy than both hypochlorous acid and isotonic sodium chloride in wounds infected with *Staphyloccocus aureus*. Therefore, topical use of sevoflurane could be considered a viable alternative, particularly for methicillin-resistant *Staphyloccocus aureus* infections. The wound healing with topical liquid sevoflurane was also seen to be more rapid than those with hypochlorous acid and isotonic sodium chloride.

INTRODUCTION

Staphylococcus aureus (*S. aureus*) is an important pathogen causing infections in the skin and soft tissue (Cheng et al., 2011). In a previous study, the microorganism most often causing wound infections was reported to be *S. aureus* at the rate of 41.4% (Turhanoglu et al., 2018). Antibiotic-resistant *Staphylococcus* species have been isolated from skin lesions such as pyoderma in dogs (Rosser, 2006).

The solutions to be used in irrigation should be isotonic solutions to avoid causing osmotic damage in healing tissues. Lactate Ringer solution at 45°C or isotonic sodium chloride can be used for this purpose. The addition of antiseptics not only physically removes the bacteria causing the contamination but also provides antisepsis. Antiseptics such as hypochlorous acid can be used (Sakarya et al., 2014). However, the use of antibiotics can cause side-effects or the development of antibiotic resistance (Gottlieb et al., 2018). *S. aureus* have the ability to rapidly develop resistance to antibiotics. Therefore, alternative techniques independent of antibiotics have been sought for treatment or prevention (Kobayashi et al., 2015).

Topical application of liquid sevoflurane has been observed to provide healing in wounds infected with antibiotic-resistant micro-organisms (Rueda-Martinez et al., 2014).

Although there is a limited number of case reports in literature related to the antimicrobial effect of sevoflurane, and there are no controlled experimental model studies.

MATERIALS AND METHODS

Ethics and animals

Ethical approval for this study was obtained from Experimental Animals Local Ethics Committee of Aydin Adnan Menderes University (Approval number: 64583101/2020/136).

The study material was formed of 80 healthy male Sprague-Dawley rats (mean body weight 360.11±49.4 g). Animals had ad libitum access to food and water and were housed under controlled environmental conditions (22±2 °C, 50–55% relative humidity, 12-h light/12-h dark cycle). All procedures were performed in the Experimental Animals Unit, Faculty of Veterinary Medicine, Aydın Adnan Menderes University.

Preparation of inoculum

The standard methicillin-sensitive *S. aureus* ATCC 29213 and methicillin-resistant *S. aureus* ATCC 43300 strains were seeded in blood agar containing 5% sheep blood in the Microbiology Department, Veterinary Faculty, Adnan Menderes University, and incubated aerobically at 37°C for 24 hours. At the end of the incubation period, colonies were

observed on the blood agar, and a bacterial suspension was prepared in nutrient broth to a 0.5 McFarland turbidity for the *S. aureus* colonies. The prepared suspensions were adjusted to a rate of 2 X 10^8 kob/ml and prepared for immediate use at a volume of 100 µl (Mölne and Tarkowski, 2000; Winn et al., 2006).

Wound model, experimental groups and treatments

After a 2 week adaptation period, anesthesia was induced by isoflurane (FORANE, Abbott, Illinois, USA) using a drop jar method. The dorsal inter-scapular region of each animal was shaved with an electric cliper. Then skin was cleaned by povidone-iodine (POVIIODEKS, Tıpkimsan, İstanbul, Türkiye) and 70% isopropyl alcohol (ISOPROPYL ALCOHOL, Lepus Kimya, Tekirdağ, Türkiye). The skin was stabilized by one hand and a circular full thickness skin wound of 6 mm diameter was formed with a sterile punch biopsy (BIOPSY PUNCH-6mm, Kai Medical, Seki City, Japan). Wounds of the same size were thus created in all animals.

Immediately after the wounds were formed, rats were assigned to eight groups by simple randomization. At the same time, methicillin-sensitive *S. aureus* (MSSA) was inoculated on the wounds of 4 groups (Group 1, 2, 3 and 4) and methicillin-resistant *S. aureus* (MRSA) on the wounds of the other 4 groups (Group 5, 6, 7 and 8).

Immediately before inoculation (day 0), photographs of each wound were taken with a paper ruler placed next to the wound. The same procedure was repeated on day 3 and day 7. In this manner, the wound areas for each animal were calculated with the Image J (IMAGE J, Version 1.x, Loci, University of Wisconsin, USA). Wound healing was assessed by comparing wound areas between days 0 and 3, and 7.

Wound care started 24 h after in vivo infection and was performed twice daily by gently wiping the wound with a sterile 5×5 cm gauze pad moistened with equal volumes (5 mL) of isotonic saline (Group 2 and 6), hypochlorous acid (Group 3 and 7), or liquid sevoflurane (Group 4 and 8). For standardization Group 1 and 5 were control groups and no treatment was applied.

At the beginning of the study (day 0), the body temperature (T) and the bodyweight (BW) were measured, and the same procedures were repeated on days 3 and 7.

Post-treatment bacterial isolation and identification

On day 7 of the experiment, samples were collected for bacterial isolation and identification using a sterile transport swab (CULTIPLAST®, LP Italiana SPA, Milano, Italy) from the wounds. The obtained samples were sent to the Microbiology Department laboratories of the Veterinary Faculty at Aydın Adnan Menderes University for biochemical and carbohydrate fermentation tests and microbiological analysis for the isolation and identification of *S. aureus*.

Sheep blood agar (5%) was used for incubation in an aerobic environment at 37°C for 24 hours. After incubation, the colonies isolated were tested with a gram stain. Under light microscopy, colonies identified as Gram-positive were subjected to catalase and coagulase tests. Colonies determined as positive in the catalase and coagulase tests were confirmed with the Phoenix Automated Identification System (BD PHOENIX™, BD Biosciences, USA). For this, suspected colonies were purified on trypticase soy agar and incubated at 37°C for 24 hours. At the end of the incubation, suspensions were prepared at 0.5 McFarland density with ID broth prepared in test tubes from fresh cultures. The Phoenix PMIC/ID87 (BD PHOENIX™ PMIC/ID87, BD Biosciences, USA) panel was used for the identification of Gram-positive bacterial isolates.

Statistical analysis

An a priori power analysis was conducted for a repeated-measures, between-factors design with 8 groups and 5 measurements to detect a medium-to-large effect size ($f = 0.35$) at $\alpha = 0.05$ with power = 0.80. The total sample size was determined to be 80 (10 per group). Analysis used F-tests for repeated measures with between-subject factors. The power analysis was performed with G*Power 3.1, and the actual power for the specified design was 0.816.

Standardization was applied to avoid bias originating from differences in wound areas between the groups, and the wound tissue healing was expressed as percentages. As there were 8 groups and the standardization method was used, the Kruskal-Wallis test was applied in the statistical analysis of the wound areas. To determine which groups differed, post hoc comparisons were conducted using the Dwass–Steel–Critchlow–Flignet (Dwass–Steel–Critchlow–Fligner) method. Statistical analyses of the data were performed using SPSS (SPSS® Statistics version14.1, Licence No. 9869264, International Business Machines®, New York, USA) and R software. A value of $p<0.05$ was considered statistically significant.

RESULTS

The mean bodyweight (BW) and temperature (T) values for the groups and the changes between days 0, 3, and 7, are shown in Tables 1 and 2, respectively.

On day 7 of wound treatment, the wounds had markedly reduced in size, and it was determined that wound cleaning would be ineffective on subsequent days due to thickening of the scab; as a result, sampling with a swab was not feasible without disturbing the scab, and wound care was terminated on day 7. Wound photographs from days 0, 3, and 7 are presented in Figure 1.

Healing percentages for the study groups are shown in Table 3 and Figure 2. On day 3, there was a statistically significant difference in wound healing between Group 1 and Group 3, and between Group 3 and Group 5. The healing percentage in Group 3 was higher than in Groups 1 and 5. When the day 7 wound data were evaluated, the healing percentage of Group 4 was statistically significantly higher than that of Groups 1, 2, 3, 5, 6, and 7, and the healing percentage of Group 8 was statistically significantly higher than that of Groups 1, 3, and 7.

Regarding bacterial isolation and identification on day 7, animals treated with sevoflurane showed greater improvement, with negative cultures. The proportions of positive and negative *S. aureus* cultures are presented in Table 4.

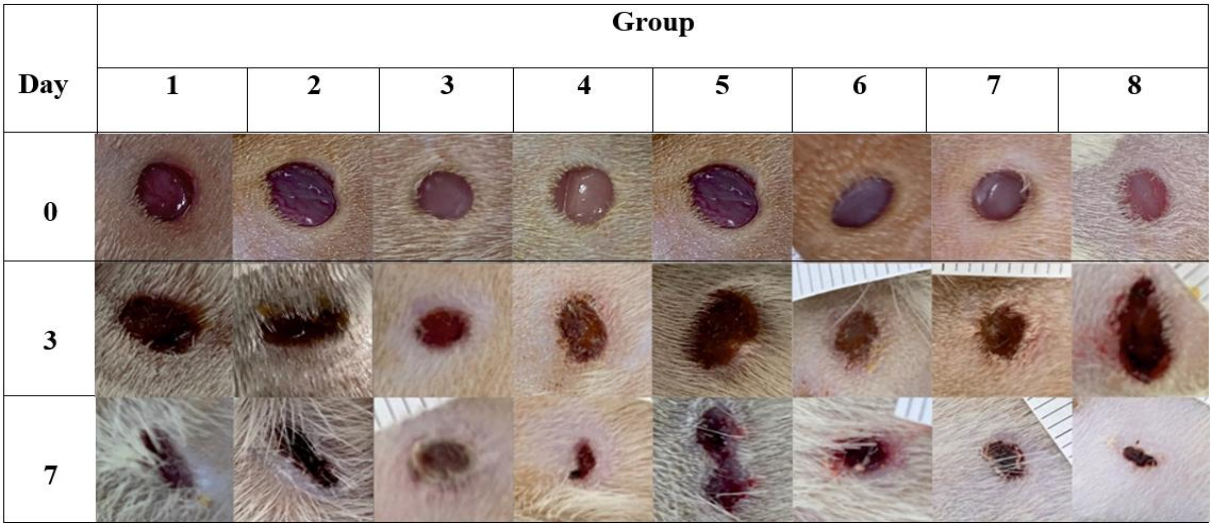

Figure 1. Photographs of the wounds at 0, 3 and days 7 of the study

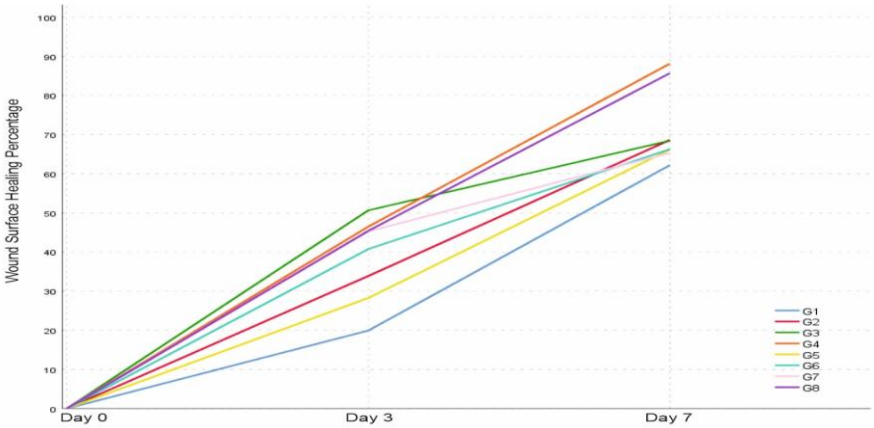

Figure 2. The healing percentages of the study groups according days

Table 1. The mean bodyweights of the groups by days

	Time (Day)			p	
Group	**0**	**3**	**7**	**Group**	**Day**
Group 1	332.5±28.54^{cd}	363.2±25.31^{b}	363.9±28.98^{b}		
Group 2	307.7±17.73^{d}	356±24.78^{b}	375.4±19.56^{b}		
Group 3	364.4±27.61^{b}	383±32^{ab}	388.6±32.28^{ab}		
Group 4	432±36.03^{a}	411.5±47.14^{a}	424.3±29.96^{a}		
Group 5	301.7±22.16^{d}	350.4±35.18^{b}	374.8±32.18^{b}	<0.001	<0.001
Group 6	371.5±20.02^{bc}	393.5±18.96^{ab}	396.5±20.24^{ab}		
Group 7	382±30.86^{b}	396±42.38^{ab}	389.8±26.48^{ab}		
Group 8	389.1±36.41^{b}	396.5±37.1^{ab}	399.5±36.16^{ab}		
All Groups	360.11±49.4^{C}	381.26±38.61^{B}	389.1±32.58^{A}		

a, b, c, d: Different letters in the same column indicate statistically significant difference in groups ($p<0.05$).
A, B, C: Different letters on the same line indicate statistically significant difference in time ($p<0.05$).

Table 2. The mean body temperature of the groups by days

	Time (Day)			p	
Group	**0**	**3**	**7**	**Group**	**Day**
Group 1	26.57±0.8^{a}	26.94±0.95^{b}	30.07±1.19^{a}		
Group 2	28.55±1.22^{a}	27.86±0.76^{ab}	29.77±1.24^{ab}		
Group 3	28.15±0.88^{a}	28.84±1.33^{a}	27.49±1.41^{c}		
Group 4	28.02±0.71^{a}	27.73±0.64^{ab}	27.74±1.14^{c}		
Group 5	27.9±0.68^{ab}	28.63±0.52^{a}	28.17±1.23^{bc}	<0.001	0,221
Group 6	27.59±0.65^{b}	28.31±1.05^{b}	27.94±0.67^{c}		
Group 7	28.36±0.71^{a}	28.05±0.94^{b}	28.12±1.58^{c}		
Group 8	29.03±1.81^{a}	28.32±0.8^{b}	27.52±0.68^{c}		
All Groups	28.02±1.18	28.09±1.15	28.35±1.47		

a, b, c: Different letters in the same column indicate statistically significant difference in groups ($p<0.05$)

Table 3. The healing percentages of the study groups

Group	N	3rd day healing %	7th day healing %
1	10	18 (15.4-23.9) [cd]	59.8(57.2-69.7) [c]
2	10	29.8 (28.1-40.7) [acd]	66.3(63.8-74.4) [bc]
3	10	50.9 (46.7-59.2) [ab]	69.1(64.8-73.4) [c]
4	10	48.6 (41.1-53.6) [abd]	89.6(86.4-91.4) [a]
5	10	30.2 (20.4-36.6) [cd]	64.2(57.9-76.8) [bc]
6	10	46.2 (23.8-55.5) [abcd]	64.8(60.1-66.5) [bc]
7	10	42.6 (39.8-55.5) [abd]	70.2(59.1-71.2) [c]
8	10	46 (36.2-55.3) [abd]	83.8(82.2-93.8) [ab]

a, b, c, d: Different lettering in the same column indicates statistically significant difference

Table 4. The rate of positive and negative *S. aureus* cultures after treatment

Group	Negative culture (%)	Positive culture (%)
1	-	100
2	-	100
3	20	80
4	79	21
5	30	70
6	10	90
7	60	40
8	90	10

DISCUSSION AND CONCLUSION

The healing effect of liquid sevoflurane arises from several properties: a direct antimicrobial effect, a local anesthetic effect, and, theoretically, a vasodilatory effect. The local anesthetic effect has been shown to facilitate irrigation and to permit higher-quality irrigation. (Rueda-Martinez et al., 2014).

Martinez-Monsalve et al. (2018) applied topical sevoflurane during surgical debridement and reported that the analgesic effect of sevoflurane began rapidly, was long-lasting, and was adequate. In the current study, in contrast to the information in literature, desensitization, licking/chewing movements, aggressive behavior or findings of pain such as writhing were not observed in any rat during wound care, which prevented evaluation of the local anaesthetic effect of sevoflurane, and it was thought that this was due to the animals not feeling pain as the acute wounds were only cleaned by wiping rather than performing abscess irigation or wound debridement. Moreover, when the mean body weight values of the groups were examined, the changes did not indicate loss of appetite.

Although there were statistically significant differences between the groups in respect of the mean body temperatures, the group mean values were not outside the limits of normal values, and thus it was concluded that the change in body temperatures did not indicate clinical significance.

In studies conducted on methicillin-resistant *S. aureus,* Imbernon-Moya et al. (2017) applied local sevoflurane without any systemic antibiotics in 3 patients with chronic venous ulcers in the extremities infected with antibiotic-resistant *Pseudomonas aeruginosa* and MRSA. It was reported that sevoflurane reduced bacteria colonization, foul smell, and exudation. At the end of the first month, the wound in the patient infected with MRSA was fully closed and no bacteria were isolated. In the present study, it was observed that wound healing up to day 3 was better in the hypochlorous acid–treated group than in the 0.9% NaCl–treated group. Wound cleaning with liquid sevoflurane in the groups infected with the MRSA was seen to provide greater healing than in group treated with hypochlorous acid. In the wounds treated with sevoflurane, there was seen to be healing of 83.8% (Group 8) of the wound area on day 7, and this rate was <70.2% in the other groups.

According to the swab samples on day 7, there was negative *S. aureus* culture of 90% of animals treated with sevoflurane. However positive culture was determined in 40% of the rats where hypochlorous acid was used. Similar to the study by Imbernon-Moya (2017), it was concluded in the current study that *S. aureus* infections were brought under control more quickly with sevoflurane, primarily more successfully in methicillin-resistant strains.

For methicillin-susceptible *S. aureus*, The effect on wound healing of the use of hypochlorous acid was seen to be better up to day 3 compared with the control group. The use of hypochlorous acid on wounds infected with MSSA provided healing of 50.9% of the wound area in the first 3 days. In a case report Gencay (2019), applied local sevoflurane to a pressure ulcer, and necrotic tissues were cleared and wound culture was negative after one month. In our study, on day 7, wound cleaning with liquid sevoflurane in the groups infected with the MSSA was seen to provide greater healing than in all the other groups. This rate was 89.6% in wound care group with sevoflurane and was lower than 69.1% in the other groups.

According to swab samples collected on day 7, 79% of the animals treated with sevoflurane had negative *S. aureus* cultures. However, positive cultures were detected in 80% of the rats treated with hypochlorous acid. (Group 3). A study conducted on mice by Kuwabara et al. (2018) compared hypochlorous acid and pure water application in wounds infected with *P. aeruginosa.* It has been reported that hypochlorous acid is superior in both wound healing and infection control. In our study, when we examined the effect of hypochlorous acid on MSSA, on day 7 the percentage of wound healing was not statistically different from the control and the isotonic sodium chloride group. However, relative to these two groups, the hypochlorous acid group had a lower rate of positive cultures. In other words, for infection control, hypochlorous acid was more effective than isotonic saline but less effective than sevoflurane.

Lee et al. (2010) anesthetized wounded rats with sevoflurane in an anesthesia chamber, and reported that sevoflurane might alter the inflammatory phase and reduce collagen formation. Similarly, Cha et al. (2009) exposured rats to inhalant sevoflurane and reported that sevoflurane decreased blood flow in the wound and enlarged the wound area. In contrast to this studies, in our research sevoflurane was not applied via inhalation; it was applied topically as a liquid and was more effective in wound healing than other solutions. Simillary, according to Çelik et al. (2025), topical sevoflurane promotes burn injury healing by modulating inflammatory reponses and enhancing tissue repair.

In conclusion, topical sevoflurane was found to be superior in antimicrobial efficacy and wound healing rate compared with hypochlorous acid and isotonic sodium chloride in wounds infected with MRSA and MSSA. Wound care with liquid sevoflurane may be expensive but could offer an alternative for antibiotic-resistant bacteria.

In our study, wound care was performed with small amounts of sevoflurane, so the researcher applying the treatment was not exposed to the odor. However, when larger wounds require application, it is recommended to use a well-ventilated room to protect the operator.

As there are few studies related to the antimicrobial property of sevoflurane and the wound healing effect, the

current study can be considered a resource for future studies.

LIMITATIONS

This study did not assess the histopathological effects of sevoflurane, which is a limitation. It is also known that treatment of chronic wounds is more challenging than that of acute wounds. Therefore, future studies should investigate the effects of sevoflurane on chronic wounds and elucidate its histopathological effects.

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The authors declare that there are no acknowledgements.

Ethical Declaration

Ethical approval for this study was obtained from Experimental Animals Local Ethics Committee of Aydin Adnan Menderes University (Approval number: 64583101/2020/136).

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Authorship contributions

Concept: Z.C., Design: B.K.K., Z.C., Data Collection: Z.C., Z.B.Ü., B.K.K., Analysis: Z.C., H.T.Y.D., Literature Search: Z.C., A.B., Z.B.Ü., Writing: Z.C., A.B., H.T.Y.D.

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Additional informations.

This study does not cover any thesis. This study has not been previously presented at any congress/symposium or published in another journal.

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CASE REPORT

Unilateral Perinephric Pseudocyst in a Young British Shorthair Cat: Diagnostic Imaging and Surgical Outcome

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ABSTRACT

This case report describes the clinical presentation, diagnostic imaging, histopathological findings, and surgical management of a 2-year-old spayed female British Shorthair cat with a unilateral left-sided perinephric pseudocyst. The cat presented with lethargy, anorexia, weight loss, and progressive abdominal distension. Clinical examination revealed a palpable abdominal mass, which was confirmed as a perinephric pseudocyst via ultrasonography and radiography. Surgical intervention involved capsulectomy and nephrectomy, with histopathological confirmation of the diagnosis. The cat initially recovered but developed similar symptoms 54 days postoperatively, with ultrasonographic evidence of cystic structures in the contralateral kidney, necessitating a capsulectomy. Despite initial stabilization, the cat progressed to stage II renal failure 73 days postoperatively and succumbed to the disease. This case highlights that perinephric pseudocyst, although rare, should be considered in the differential diagnosis of young cats presenting with abdominal distension and renomegaly. Notably, biochemical markers of renal pathology may remain within normal limits, underscoring the importance of ultrasonography and histopathology for accurate diagnosis. Although surgical intervention can alleviate symptoms, long-term prognosis remains guarded due to potential recurrence and progressive renal dysfunction. Further studies are needed to explore potential genetic predisposition in British Shorthair cats.

INTRODUCTION

Perinephric pseudocyst is an uncommon renal disorder in cats, characterized by the accumulation of fluid within a fibrous sac lacking an epithelial lining (Ochoa et al., 1999). These cysts are more frequently diagnosed in middle-aged to older cats, with a reported median age of 11–16 years (Beck et al., 2000; Mazzanti et al., 2013). While male cats appear to be more commonly affected, no definitive breed predisposition has been identified (Beck et al., 2000).

The exact etiology of perinephric pseudocysts remains unclear, though proposed mechanisms include increased hydrostatic pressure, lymphatic obstruction, or rupture of renal cysts (Adamama-Moraitou et al., 2018). Possible contributing factors include chronic kidney disease (CKD), trauma, congenital defects, or idiopathic origins (Mouat et al., 2009). Clinical presentation varies significantly, ranging from incidental findings to symptomatic cases with abdominal distension, palpable masses, anorexia, or urinary obstruction (Mazzanti et al., 2013; Salgüero et al., 2015). Additionally, histologically, perinephric pseudocysts lack an epithelial lining, which differentiates them from true renal cysts (Lemire and Read, 1998). Diagnosis is primarily based on ultrasonographic findings, where an anechoic fluid accumulation between the renal capsule and parenchyma is characteristic (Schaefer et al., 2018).

Management of perinephric pseudocysts depends on size, clinical impact, and concurrent renal disease. Small, asymptomatic pseudocysts may be managed conservatively, whereas larger or symptomatic cases require surgical intervention, including capsulectomy, nephrectomy, or percutaneous drainage (McCord et al., 2008; Placer and McManis, 2019). Postoperative monitoring is essential to detect complications such as hemorrhage, infection, and progressive renal dysfunction (Beck et al., 2000).

Perinephric pseudocysts should also be differentiated from several other cystic or fluid-accumulating conditions affecting the kidney and the perirenal region. Differential diagnoses include true renal cysts, hydronephrosis, perirenal hematoma, urinoma, and perirenal abscess, which may produce similar ultrasonographic findings characterized by fluid accumulation surrounding the kidney (Beck et al., 2000; Debruyn et al., 2012). In

addition, parasitic cystic diseases such as cystic echinococcosis should also be considered, as hydatid cysts may rarely involve the kidneys and can present as cystic renal lesions associated with abdominal distension (Erdem et al., 2022).

This case report describes the diagnosis, surgical treatment, and postoperative outcome of a young British Shorthair cat with a unilateral perinephric pseudocyst, emphasizing the role of ultrasonography and the challenges associated with long-term management.

MATERIALS AND METHODS

A 2-year-old spayed female British Shorthair cat was presented with lethargy, anorexia, weight loss, and progressive abdominal distension. On physical examination, significant abdominal distension was noted, with asymmetry favoring the left side. No other abnormalities were detected.

Diagnostic Evaluation

Blood samples were collected from the jugular vein using 21-gauge needles into serum and anticoagulant (EDTA) tubes for hematological and biochemical analysis. Complete blood count (CBC) was performed using an automated hematology analyzer (Mindray BC-5000Vet, China). Biochemical parameters, including blood urea nitrogen (BUN), creatinine (CRE), blood urea nitrogen-to-creatinine ratio (BUN/CRE), phosphorus (P), total protein (TP), albumin (ALB), albumin-to-globulin ratio (ALB/GLOB), alanine aminotransferase (ALT), alkaline phosphatase (ALP), gamma-glutamyl transferase (GGT), glucose (GLU), total bilirubin (TBIL), total cholesterol (TCHO), and calcium (Ca), were measured using a biochemistry autoanalyzer (Fuji DRI-CHEM NX700V, Japan) (Tables 1 and 2).

Table 1. Complete Blood Count Parameters and Reference Ranges.

Complete Blood Count			
Parameters	**Value**	**Results**	**Reference Range**
WBC (x 10^9/L)	5.99	N	5.5 - 19.5
BAS (x 10^9/L)	0.00	N	0.0 - 0.1
BAS (%)	0.1	N	0.0 - 1.2
NEU (x 10^9/L)	4.52	N	3.1 - 12.6
NEU (%)	75.5	N	38.0 - 80.0
EOS (x 10^9/L)	0.31	N	0.1 - 1.9
EOS (%)	5.0	N	1.0 - 11.0
LYM (x 10^9/L)	1.03	N	0.7 - 7.7
LYM (%)	17.2	N	12.0 - 45.0
MON (x 10^9/L)	0.13	N	0.1 - 1.4
MON (%)	2.2	N	1.0 - 8.0
RBC (x 10^{12}/L)	7.63	N	4.6 - 10.2
HGB (g/dL)	10.2	N	8.5 - 15.3
MCV (fL)	**37.9**	**L**	38.0 - 54.0
MCH (pg)	13.4	N	11.8 - 18.0
MCHC (g/dL)	35.3	N	29.0 - 36.0
RDW-CV (%)	22.8	N	16.0 - 23.0
RDW-SD (fL)	36.9	N	26.4 - 43.1
HCT (%)	28.9	N	26.0 - 47.0
PLT (x 10^9/L)	125	N	100.0 - 518.0
MPV (fL)	12.0	N	9.9 - 16.3
PDW (Adet)	14.7	N	12.0 - 17.5
PCT (ml/L)	1.50	N	0.9 - 7.0

WBC: White blood cell, BAS: Basophil, NEU: Neutrophil, EOS: Eosinophil, LYM: Lymphocyte, MON: Monocyte, RBC: Red blood cell, HGB: Hemoglobin, MCV: Mean corpuscular volume, MCH: Mean corpuscular hemoglobin, MCHC: Mean corpuscular hemoglobin concentration, RDW-CV: Red cell distribution width coefficient of variation, RDW-SD: Red cell distribution width standard deviation, HCT: Hematocrit, PLT: Platelet, MPV: Mean platelet volume, PDW: Platelet distribution width, PCT: Plateletcrit. N: Normal, L: Low, H: High.

Table 2 Serum Biochemistry Parameters and Reference Ranges in the Case Study Cat.

Serum Biochemistry Parameters			
Parameters	**Value**	**Results**	**Reference Range**
ALB (g/dL)	2.7	N	2.3 - 3.5
ALB/GLOB	**0.40**	**L**	0.6 - 1.5
ALP (U/L)	26	N	9.0 - 53.0
ALT (U/L)	64	N	22.0 - 84.0
BUN (mg/dL)	26.2	N	17.6 - 32.8
BUN/CRE	22.20	N	4.0 - 33.0
Ca (mg/dL)	10.3	N	8.8 - 11.9
CRE (mg/dL)	1.18	N	0.8 - 1.6
GGT (U/L)	10	N	1.0 - 10.0
GLU (mg/dL)	107	N	71.0 - 148.0
P (mg/dL)	**6.9**	**H**	2.6 - 6.0
TBIL (mg/dL)	0.2	N	0.1 - 0.4
TCHO (mg/dL)	129	N	89.0 - 176.0
TP (g/dL)	**9.5**	**H**	5.7 - 7.8

ALB: Albumin, ALB/GLOB: Albumin-to-globulin ratio, ALP: Alkaline phosphatase, ALT: Alanine aminotransferase, BUN: Blood urea nitrogen, BUN/CRE: Blood urea nitrogen-to-creatinine ratio, Ca: Calcium, CRE: Creatinine, GGT: Gamma-glutamyl transferase, GLU: Glucose, P: Phosphorus, TBIL: Total bilirubin, TCHO: Total cholesterol, TP: Total protein, N: Normal, L: Low, H: High.

Abdominal radiography (ventrodorsal and lateral views) revealed a large mass localized in the left renal region (Figure 1A, B). Ultrasonography (VETUS 7, MINDRAY, China) confirmed the presence of anechoic fluid surrounding the left kidney (Figure 2).

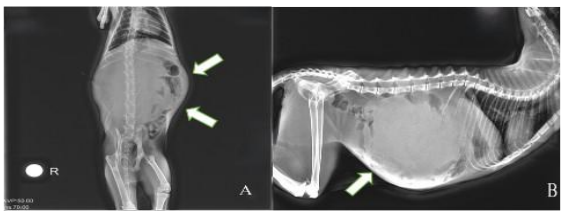

Figure 1. A) The radiograph of a 2-year-old female domestic British Shorthair cat reveals a swollen lesion in the ventrodorsal radiography and B) lateral radiography, indicated by arrows.

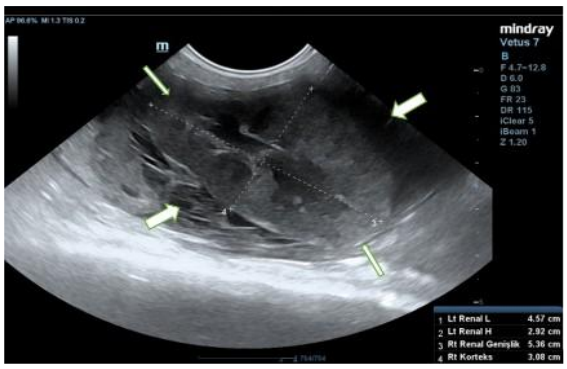

Figure 2. Abdominal ultrasonography of the 2-year-old female domestic British Shorthair cat. Left Kidney. The kidney (small arrows) was surrounded by a large amount of anechoic fluid (large arrows).

Surgical Intervention

The cat was referred for surgical management, and a left unilateral nephrectomy was performed (Fossum, 2019). Anesthesia was induced with Propofol (6 mg/kg IV, Fresenius Kabi, Germany) and maintained with isoflurane (MAC=1.5%, Piramal Critical Care, USA) (Clarke et al., 2014). A midline incision through the linea alba allowed

access to the abdominal cavity, and the peritoneum over the left kidney was incised. The pseudocyst fluid was aspirated, followed by a stab incision for complete drainage (Figure 3A, B). The kidney was carefully elevated, and the renal vein and arterial branches were ligated. The left ureter was also ligated near the bladder before the kidney and ureter were excised.

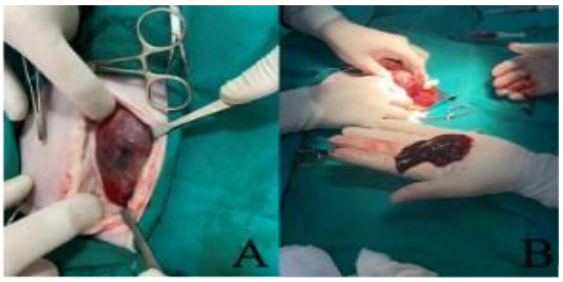

Figure 3. A) Appearance of the cyst in the left kidney; B) Left kidney surrounded by the pseudocyst.

Postoperatively, the cat received Cefazolin (22 mg/kg IM, Cezol, Türkiye) for one day and a single dose of Tramadol (2 mg/kg SC, Contramal, Türkiye) for pain management (Fossum, 2019; Clarke et al., 2014).

Histopathological Findings

Microscopic examination of the excised kidney, which included eight sections, revealed widespread tubular epithelial enlargement with granular and occasional vacuolar degeneration. Focal hemorrhagic areas were observed, along with mononuclear inflammatory infiltrates and glomerular hypertrophy. Additionally, fibrous connective tissue proliferation and lymphoid cell accumulations were noted. The kidney capsule exhibited significant thickening with necrotic foci and dense pseudomembrane formations. Based on these findings, the final diagnosis was chronic nephrosis, interstitial nephritis, and perinephric pseudocyst formation (Figure 4).

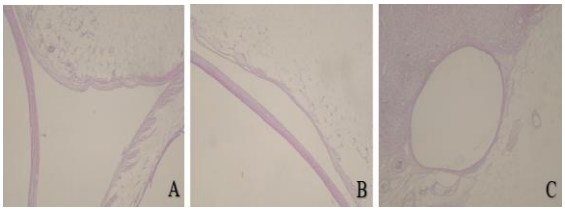

Figure 4. Histopathological appearance of the perinephric pseudocyst in the kidney of the cat. A) Multilocular cystic structures located within the perirenal adipose tissue (H&E, 4x). B) Cyst wall and lumen surrounded by adipose tissue (H&E, 4x). C) Cystic structure with a fibrous wall and a large cystic lumen (H&E, 4x).

Postoperative Course and Recurrence

The cat initially recovered well; however, 54 days post-surgery, it presented with abdominal asymmetry. A biochemical profile showed elevated BUN (36.7 mg/dL) with normal CRE and P levels. Ultrasonography confirmed fluid accumulation around the right kidney (Figure 5), prompting a capsulectomy (Figure 6A, B).

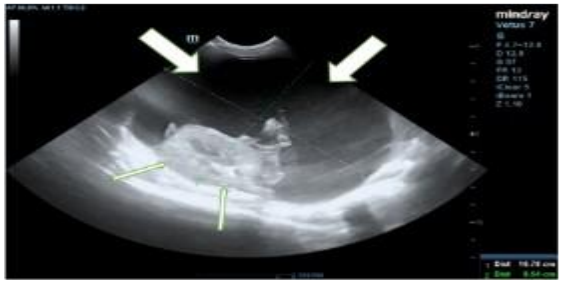

Figure 5. Abdominal ultrasonography of right kidney in the 2-years-old female domestic British Shorthair cat. The kidney (small arrows) was surrounded by a large amount of anechoic fluid (large arrows).

Figure 6. A) Appearance of the cyst in the right kidney; **B)** Right kidney surrounded by the pseudocyst.

Seventy-three days postoperatively, the cat exhibited signs of progressive renal dysfunction, including polydipsia, polyuria, anorexia, vomiting, and generalized weakness. Laboratory evaluation indicated a marked increase in BUN to 77.9 mg/dL, CRE to 1.85 mg/dL, and P to 13.2 mg/dL, consistent with declining renal function (Elliott and Barber, 1998; Polzin, 2011). Urinalysis revealed an isosthenuric urine specific gravity of 1.011, suggesting impaired renal concentrating ability (Debruyn et al., 2012). Based on these findings, the cat was classified as having stage II CKD according to the International Renal Interest Society (IRIS) guidelines (IRIS, 2023).

Supportive Therapy and Outcome

Supportive treatment was initiated to manage renal dysfunction and improve clinical stability. Fluid therapy was administered to enhance renal perfusion, and the cat's diet was adjusted to a therapeutic regimen, Prescription Diet® k/d® feline, provided in three daily portions (Salgüero et al., 2015). To control hyperphosphatemia, lanthanum carbonate (400 mg/cat, orally) was prescribed (Kim et al., 2006), while maropitant (1 mg/kg, subcutaneously) was administered to alleviate vomiting (Hickman et al., 2008).

Despite intensive supportive care, the cat's renal function continued to deteriorate, ultimately leading to death three days after the initiation of therapy. Postmortem examination confirmed progressive renal insufficiency as the primary cause of mortality.

DISCUSSION AND CONCLUSION

Previous studies indicate that perinephric pseudocysts predominantly affect older cats, typically over 8 years of age (Beck et al., 2000). A retrospective study of 26 cases reported a mean age of 11 years, with 73% of affected cats being male (Ochoa et al., 1999). Another study involving 13 cats documented a mean age of 16 years (Mazzanti et al., 2013).

Perinephric pseudocysts in younger cats are rare, and their etiology remains unclear. While some cases are associated with CKD, infectious diseases, or acute kidney injury, a significant proportion remain idiopathic (Polzin, 2011). In the present case, the cat was relatively young, female, and had no history of trauma or toxin exposure, suggesting an idiopathic origin. Renal dysfunction in perinephric pseudocysts is thought to result from parenchymal compression or interstitial fibrosis, leading to progressive renal impairment (Debruyn et al., 2012). Approximately 90% of affected cats exhibit some degree of renal disease at diagnosis (Salgüero et al., 2015). Although serum CRE levels were initially within the reference range, renal parameters worsened over time, particularly after nephrectomy. This aligns with previous reports indicating that biochemical markers alone may not reliably reflect renal function in unilateral perinephric pseudocysts (Schaefer et al., 2018). Ultrasonography remains the most valuable diagnostic tool, allowing early detection of cystic structures and monitoring of disease progression (Beck et al., 2000; Schaefer et al., 2018). Similarly, in our case, the use of ultrasonography allowed the diagnosis of a perinephric pseudocyst despite normal hematological and serum biochemical findings.

Management strategies for perinephric pseudocysts include percutaneous drainage, capsulectomy, and nephrectomy, depending on the severity and progression of the disease (McCord et al., 2008). While percutaneous drainage may provide temporary relief, recurrence is common (Beck et al., 2000). In this case, nephrectomy was performed due to left kidney dysfunction, resulting in an initial resolution of clinical signs. However, perinephric pseudocysts subsequently developed in the remaining kidney, ultimately leading to progressive renal failure and death. Survival time following diagnosis varies widely, with a reported mean postoperative survival of 9 months in previous studies (Beck et al., 2000). In our case, the survival period was only 4.5 months following surgery, likely due to bilateral disease progression and the limited compensatory capacity of the remaining kidney. This highlights the importance of long-term postoperative monitoring and early intervention in cases of contralateral renal involvement.

Although rare, perinephric pseudocysts should be considered in the differential diagnosis of young cats presenting with abdominal distension and renomegaly. Given that biochemical markers may not reliably indicate underlying renal pathology, abdominal ultrasonography and histopathological evaluation remain the gold standard for accurate diagnosis and disease monitoring. While surgical intervention is the most effective treatment, recurrence remains a significant challenge, necessitating close postoperative follow-up.

Furthermore, the potential genetic predisposition of British Shorthair cats to perinephric pseudocysts warrants further investigation. Future studies evaluating breed-specific risk factors, as well as alternative treatment approaches, could provide valuable insights for improving prognosis and disease management in affected cats.

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The authors declare that there are no acknowledgements.

Ethical Declaration
This study is a single-case report. All diagnostic and therapeutic procedures were performed as part of routine clinical practice. Therefore, institutional ethics committee approval was not required. Informed consent was obtained from the animal owner for the use of the clinical data and images in a scientific publication.

Conflict of Interest
The authors declare that there is no conflict of interest regarding the publication of this article.

Authorship contributions
Concept: E.E., M.S.A., Design: E.E., M.S.A., Data Collection or Processing: M.İ., S.O., Analysis or Interpretation: M.İ., M.S.A., Literature Search: E.E., S.O., Writing: E.E., S.O.

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