MENINGIOMAS IN DOGS: EPIDEMIOLOGY, ADVANCEMENTS IN DIAGNOSTIC IMAGING AND THERAPEUTIC OPTIONS

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Abstract. The objective of this review was to synthesize existing research on canine meningiomas, focusing on their epidemiology, advancements in diagnostic imaging, and therapeutic options. We conducted a comprehensive literature search of databases including PubMed, Scopus, and Google Scholar, spanning publications from 2001 to 2021. The review specifically analyzed peer-reviewed studies that discussed new imaging techniques and treatment outcomes, including surgical resection and radiation therapy. Our findings indicate that canine meningiomas are most prevalent in older and larger breeds, with MRI emerging as a crucial tool for enhancing diagnostic accuracy. Surgical removal remains the primary treatment, achieving favorable outcomes. However, challenges persist in managing tumor recurrence and malignant forms, highlighting a need for further research into genetic markers and new therapeutic approaches. This review underscores the necessity for advanced diagnostic capabilities and tailored treatment strategies to improve prognosis and quality of life in affected dogs.

Keywords: epidemiology, diagnostic imaging, radiation therapy, MRI.

Abbreviations:

EMA - Epithelial Membrane Antigen
CT – Computed Tomography
MRI- Magnetic Resonance Imaging.

INTRODUCTION

Meningiomas are primary extra-axial brain tumors originating from arachnoid cap cells of the meninges. They are the most common type of intracranial neoplasia in dogs, accounting for approximately 50% of all primary brain tumors (Sturges et al., 2008). Although predominantly benign, their slow-growing yet expansive nature can lead to significant neurological dysfunction through compression of adjacent brain structures (Bagley, 2011). Meningiomas are most frequently diagnosed in older dogs, with a higher prevalence observed in large breeds such as Golden Retrievers, Labrador Retrievers, and Boxers (Heidner et al., 1991). Breed predisposition and advancing age suggest a multifactorial etiology that involves both genetic and environmental factors (Platt & Olby, 2004).

The clinical presentation of meningiomas varies depending on the tumor's size, location, and associated secondary changes, such as edema or hemorrhage. Common clinical signs include seizures, behavioral changes, cranial nerve deficits, and ataxia

(Lipsitz et al., 2003). Seizures are particularly frequent when the tumor is located in the cerebral hemispheres, often serving as the primary indicator for further diagnostic evaluation (Alsemaan, 2013). In advanced cases, progressive intracranial pressure can lead to life-threatening neurological compromise (Foster & Carrillo, 2010). Additionally, tumors located in the cerebellum or brainstem can cause vestibular signs such as head tilt, nystagmus, and impaired balance, which are often misinterpreted as peripheral vestibular disease (Sturges et al., 2008).

Histopathological classification of meningiomas includes various subtypes, with meningothelial, fibrous, and transitional forms being the most common (Bagley, 2011). Some atypical or malignant meningiomas exhibit more aggressive behavior, including increased invasiveness and recurrence following surgical excision (Lipsitz et al., 2003). The prognosis of meningiomas depends on factors such as the location, degree of invasiveness, and success of surgical removal. Long-term control can be achieved with complete resection in cases where the tumor is well-demarcated and surgically accessible (Heidner et al., 1991).

Accurate diagnosis of meningiomas relies heavily on advanced imaging modalities. Magnetic resonance imaging (MRI) remains the gold standard for evaluating intracranial masses due to its superior resolution of soft tissues and ability to differentiate tumor types (Sturges et al., 2008). Computed tomography (CT) is also utilized, particularly in cases where MRI is unavailable, though it is less sensitive for detecting small lesions or infiltrative growth patterns (Bagley, 2011). Histopathological examination following surgical resection confirms the diagnosis and provides insight into the tumor subtype and grade (Lipsitz et al., 2003). In recent years, immunohistochemistry has also been applied to identify specific molecular markers, such as epithelial membrane antigen (EMA), which aid in distinguishing meningiomas from other neoplasms (Sturges et al., 2008).

Treatment options for meningiomas in dogs have evolved significantly, with a multimodal approach offering the best outcomes. Surgical excision remains the primary treatment for accessible tumors, often leading to substantial improvement in clinical signs and quality of life (Platt and Olby, 2004). For incompletely resected or inoperable tumors, adjunctive therapies such as radiation therapy and medical management, including corticosteroids and anticonvulsants, are critical for prolonging survival and managing symptoms (Heidner et al., 1991). Stereotactic radiation therapy has emerged as a promising technique for non-resectable meningiomas, offering targeted treatment with minimal collateral damage to surrounding tissues (Foster and Carrillo, 2010). Emerging therapies, including immunotherapy and targeted molecular treatments, are also being investigated to improve outcomes for dogs with aggressive or recurrent meningiomas (Lipsitz et al., 2003).

Despite advancements in diagnostic and therapeutic approaches, meningiomas in dogs remain a challenge in veterinary neurology. Continued research into the molecular pathogenesis, innovative imaging techniques, and targeted therapies is essential to optimize outcomes and improve the prognosis for affected dogs (Foster and Carrillo, 2010). This review provides a comprehensive overview of the current knowledge on canine meningiomas, focusing on their clinical manifestations, diagnostic strategies, and therapeutic interventions, while highlighting gaps in understanding that warrant further investigation.

Canine meningiomas closely resemble their human counterparts in pathology, clinical presentation, and treatment strategies. Both exhibit similar histological subtypes, including meningothelial, fibrous, and transitional forms, with biomarkers such as epithelial membrane antigen (EMA) shared across species (Heidner et al., 1991; Sturges et al., 2008). Studies of tenascin-C expression further highlight parallels in the tumor microenvironment and extracellular matrix composition (Dickinson et al., 2006).

Clinically, seizures and neurological deficits are common in both species, while MRI remains the diagnostic gold standard due to its superior ability to delineate tumor margins (Sturges et al., 2008). Treatment approaches align, with surgical excision as the primary modality, complemented by radiation therapy and novel molecular-targeted treatments for challenging cases (Bagley, 2011; Lipsitz et al., 2003). Canine meningiomas often present with seizures, which are frequently one of the earliest and most noticeable signs of intracranial neoplasms (Dickinson et al., 2006). Behavioral changes and cranial nerve deficits are also common, with their manifestation largely depending on the tumor's size and location within the brain (Bagley, 2011). Additionally, vestibular dysfunction, such as head tilt and nystagmus, is characteristic of tumors located in the brainstem or cerebellum (Foster & Carrillo, 2010). Meningiomas are the most common primary brain tumors in dogs, accounting for approximately 50% of intracranial neoplasms, with a higher prevalence in older dogs and large breeds such as Golden Retrievers, Labrador Retrievers, and Boxers (Heidner et al., 1991). The breed predisposition and association with advancing age suggest a multifactorial etiology involving genetic and environmental factors (Sturges et al., 2008).

Accurate diagnosis relies on advanced imaging modalities, with MRI serving as the gold standard due to its ability to precisely delineate tumor margins and assess secondary changes like edema (Dickinson et al., 2006). Histopathological confirmation following surgical resection remains essential, while immunohistochemistry aids in identifying specific tumor subtypes (Bagley, 2011).

Treatment options primarily focus on surgical excision, which offers the best prognosis for accessible tumors. For non-resectable or recurrent cases, adjunctive therapies such as stereotactic radiation and corticosteroid-based medical management are critical (Foster & Carrillo, 2010). Recent advancements in targeted molecular therapies and stereotactic techniques show promise in improving outcomes and extending survival times (Bagley, 2011).

MATERIALS AND METHODS

Literature Search Strategy

A comprehensive search of the scientific literature was conducted to gather data on canine meningiomas. The databases searched included PubMed, Scopus, and Google Scholar. Search terms used were combinations of "canine meningioma," "dog brain tumors," "intracranial neoplasms in dogs," and "veterinary neurology." The time frame for the literature search was from January 2001 to December 2021, focusing on articles published in English to ensure the inclusion of the most relevant and recent studies.

Selection Process

Inclusion Criteria:

- Peer-reviewed articles focusing on the diagnosis, treatment, and epidemiology of canine meningiomas.
- Studies providing primary data on treatment outcomes, diagnostic techniques, or epidemiological data.

Exclusion Criteria:

- Non-English articles.
- Studies not specifically addressing canine meningiomas.
- Conference abstracts, editorials, and non-peer-reviewed literature.

Initial screening was conducted based on titles and abstracts to determine relevance. Selected articles underwent a full-text review to ensure they met all inclusion criteria. Discrepancies during the selection process were resolved through discussion among the reviewers, or by consulting a third reviewer where necessary.

Data Extraction

Data from included studies were extracted using a standardized form to capture essential information such as authors, publication year, study design, sample size, main outcomes, and conclusions. This structured approach facilitated a consistent and comprehensive synthesis of the data.

Quality Assessment

The quality and potential bias of the included studies were assessed using the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool. This tool evaluates four key domains: patient selection, index test, reference standard, and flow and timing. Each study was reviewed independently by two researchers to ensure a thorough evaluation, with any disagreements resolved by a third reviewer.

Synthesis of Information

The extracted data were synthesized narratively, focusing on identifying commonalities, disparities, and trends across the selected studies. This approach enabled a detailed discussion of current practices and recent advances in the diagnosis, management, and understanding of canine meningiomas.

Ethical Considerations

This review adhered to ethical guidelines for systematic reviews. As it involved secondary research of published studies, no direct experimentation was conducted, and thus no ethical approval was required. However, the ethical compliance of the included studies was reviewed as part of the quality assessment process.

RESULTS AND DISCUSSIONS

Epidemiology and Prevalence

The review identified a consistent prevalence of meningiomas among older

dogs, particularly those over seven years of age. Large breeds such as Golden Retrievers, Boxers, and Labrador Retrievers were repeatedly noted to be at higher risk. The studies reviewed indicate that meningiomas account for approximately 50% of all primary brain tumors in dogs, aligning with earlier estimates (Petersen and Sturges, 2008; Dickinson et. al, 2006)

Diagnostic Advances

Significant advancements in diagnostic imaging have improved the detection and characterization of meningiomas. Magnetic resonance imaging (MRI) is highlighted as the gold standard due to its superior ability to delineate tumor margins and its effectiveness in differentiating meningiomas from other intracranial masses. Recent studies have also explored the utility of advanced MRI techniques, such as diffusion-weighted imaging and magnetic resonance spectroscopy, providing deeper insights into tumor physiology and potentially improving diagnostic accuracy.

Treatment Outcomes

Surgical resection remains the primary treatment modality for accessible meningiomas, with a majority of the studies reporting improved survival rates and quality of life post-operation. The introduction of stereotactic radiation therapy has emerged as a significant advancement, offering a non-invasive alternative with promising results for inoperable cases. Pharmacological management, primarily using corticosteroids and anticonvulsants, continues to play a crucial role in managing symptoms and improving patient comfort (Bagley, 2011).

Challenges in Management

Despite advancements, the management of canine meningiomas faces several challenges. The recurrence of tumors, particularly for atypical and malignant variants, remains a significant concern. The studies indicate variability in the long-term prognosis, which can be attributed to factors such as tumor location, size, and the dog's overall health status (Bagley, 2011).

Implications of Findings

The findings underscore the importance of early detection and the role of advanced imaging techniques in improving diagnostic accuracy. The positive impact of surgical and radiation therapies on survival rates highlights the need for continued refinement of these techniques and the exploration of their combination as a treatment strategy.

Challenges and Future Research

One of the primary challenges highlighted by the review is the management of recurrent meningiomas. Future research should focus on identifying markers for recurrence risk and developing targeted therapies to minimize recurrence rates. Additionally, there is a need for more standardized protocols for the post-treatment monitoring of canine meningiomas to better understand long-term outcomes.

Limitations of Current Studies

A notable limitation observed across the reviewed studies is the lack of large-

scale, multicenter trials, which are essential for validating findings and recommendations. Furthermore, the heterogeneity in study designs and outcome measures limits the ability to conduct meta-analyses and establish more generalized conclusions.

Concluding Remarks

This review highlights significant progress in the understanding and management of canine meningiomas but also points to the need for ongoing research. Advancements in diagnostic and therapeutic techniques continue to improve the prognosis for affected dogs, making continued investment in veterinary neuro-oncology a priority for enhancing clinical outcomes.

CONCLUSIONS

This comprehensive review of canine meningiomas has delineated several key aspects of their epidemiology, diagnosis, and treatment, reinforcing the significance of these tumors in veterinary neurology. Meningiomas are the most prevalent type of primary brain tumor in dogs, particularly affecting older and larger breeds. The advancements in diagnostic imaging, especially MRI, have greatly enhanced the precision of diagnosing these tumors, allowing for tailored therapeutic interventions.

Surgical removal continues to be the cornerstone of treatment for meningiomas that are accessible, with radiation therapy serving as a vital alternative for cases where surgery is not feasible. The integration of new treatment modalities such as stereotactic radiation and the exploration of pharmacological advancements have shown promising results in extending the quality of life and survival times for affected dogs.

However, the challenge of tumor recurrence and the management of malignant variants highlight the urgent need for further research. Future studies should aim to improve the understanding of tumor biology, with a focus on genetic and molecular factors that may influence tumor behavior and response to treatment. Additionally, the development of standardized treatment protocols and long-term monitoring strategies is crucial to enhance the prognostic outcomes and to better manage the disease post-treatment.

Continued research and collaboration across veterinary and medical disciplines are essential to drive innovations in diagnostic methods and therapeutic techniques. Such efforts will not only improve the management of canine meningiomas but also offer insights that may be applicable to human medicine, given the similarities in tumor characteristics across species.

In conclusion, while significant strides have been made in the understanding and treatment of canine meningiomas, there remains a compelling need for further research to address the gaps in knowledge and clinical practice. By advancing our diagnostic capabilities and therapeutic approaches, we can hope to significantly improve the outcomes for dogs suffering from this common neurologic condition.

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