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Utility of magnetic resonance imaging in veterinary sciences with special reference to dogs and cats: A review

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Abstract

Magnetic resonance imaging (MRI) has become a cornerstone diagnostic modality in veterinary medicine, particularly for dogs and cats, due to its superior soft tissue contrast and multi-planar capabilities without the use of ionizing radiation. It is most widely utilized in neurology, accounting for the majority of clinical cases, where it excels in diagnosing conditions such as brain tumors, encephalitis, and intervertebral disc disease, outperforming techniques like CT and radiography. Beyond neurological applications, MRI is increasingly valuable in oncology, orthopedics, and internal medicine. Advances such as functional MRI, diffusion tensor imaging, and AI-assisted analysis are further enhancing diagnostic precision and prognostic capabilities. Despite challenges related to cost and accessibility, innovations like low-field portable systems and telemedicine are expected to expand its use, solidifying MRI as the gold standard for soft tissue and neurological imaging in small animal practice.

Keywords: Brain tumor, Magnetic resonance imaging, veterinary imaging, veterinary oncology

1. Introduction

The field of veterinary diagnostic imaging has undergone considerable advancements with the advent of cross-sectional imaging modalities. Traditional radiography, while offering fundamental structural insights, is constrained by inadequate soft tissue contrast and its inherently two-dimensional perspective. Ultrasonography, although capable of delivering real-time imaging, is significantly influenced by operator skill and demonstrates diminished efficacy in assessing osseous structures or gas-containing regions^[1]. Computed tomography (CT) has enhanced the visualization of intricate anatomical areas, such as the skull and thorax; however, it remains associated with ionizing radiation and presents inferior soft tissue contrast relative to more sophisticated modalities like magnetic resonance imaging (MRI)^[2, 3]. MRI, which is predicated on the principles of nuclear magnetic resonance (NMR), affords remarkable soft tissue delineation without the risks associated with ionizing radiation and was integrated into veterinary practice in the early 1990s, albeit initially hampered by financial constraints and the necessity for anesthesia^[4, 5]. In the last decade and a half, innovations including low-field MRI systems, tailored protocols for specific species, and functional imaging methodologies have significantly enhanced its accessibility and clinical applicability^[6, 7]. Canine and feline patients, as the predominant companions in veterinary practice, derive substantial benefits from MRI's enhanced diagnostic capabilities in the evaluation of neurological, musculoskeletal, and abdominal conditions when compared to alternative imaging techniques^[1]. The increasing availability of MRI technology in veterinary clinics and mobile imaging services has contributed to a global rise in its utilization^[8]. This review aims to elucidate the principles of MRI, its clinical applications, comparative advantages, inherent limitations, and prospective developments, thereby offering a comprehensive, evidence-based resource for veterinary practitioners.

2. Principles, Equipment and Protocols of Magnetic Resonance Imaging in Veterinary Practice

The contrast observed in MRI imaging is primarily influenced by tissue-specific T_1 and T_2 relaxation times, proton density, and various imaging parameters. T_1 relaxation denotes the rate at which protons realign following excitation, resulting in fat and protein-rich substances exhibiting heightened brightness on T_1 -weighted images. Conversely, T_2 relaxation indicates the loss of proton phase coherence, leading to hyperintense appearances of water, cerebrospinal fluid, and edema on T_2 -weighted images [9, 10]. Gadolinium-based contrast agents serve to enhance the visibility of tissues characterized by increased vascularity or compromised blood–brain barriers, thereby facilitating the identification of neoplastic, inflammatory, and vascular lesions [11]. Standard MRI sequences encompass T_1 -weighted imaging, which is utilized for anatomical detail and contrast enhancement evaluation [12]; T_2 -weighted imaging, which is effective in detecting edema and pathological conditions [13]; FLAIR imaging, which emphasizes periventricular and cortical lesions [12, 14]; STIR imaging, which is adept at identifying musculoskeletal edema [15, 16]; diffusion-weighted imaging, which is employed for the detection of ischemia and cellular tumors [17]; and GRE/SWI sequences, which are utilized for the identification of hemorrhage and mineralization [18, 19].

Veterinary MRI systems are classified based on their magnetic field strength, which significantly impacts both image quality and clinical applications. Low-field systems, operating at 0.2 to 0.5T, are economically viable and frequently utilized in general veterinary practice, providing sufficient imaging capabilities for significant brain and spinal lesions, albeit with lower resolution [20, 18]. In contrast, high-field systems, ranging from 1.0 to 3.0T and prevalent in referral centers, deliver enhanced signal-to-noise ratios, greater detail, expedited scanning times, and advanced imaging functionalities, with 1.5 Tesla recognized as the clinical standard and 3.0T primarily employed in research contexts [21, 22]. Additionally, emerging ultra-low-field portable systems, operating below 0.1T, seek to enhance accessibility, although they currently exhibit limitations in image detail [23]. The application of MRI in veterinary medicine necessitates the use of general anesthesia or deep sedation to mitigate motion artifacts, with species-specific protocols established for canines and felines, alongside rigorous monitoring facilitated by MRI-compatible equipment [24, 25]. Optimal image quality is contingent upon appropriate positioning and coil selection, while size limitations may pose challenges for larger patients [7]. Standardized imaging protocols generally encompass T_1 - and T_2 -weighted sequences, Fluid-Attenuated Inversion Recovery (FLAIR), contrast-enhanced imaging, and diffusion-weighted imaging for neurological evaluations, whereas musculoskeletal and abdominal examinations employ specialized sequences tailored to the specific anatomical region of interest [13, 26].

3. Comparative Advantages of MRI Over Other Imaging Modalities

3.1 MRI vs. Radiography

Conventional radiography remains the most accessible and cost-effective imaging modality in veterinary practice, but its utility for soft tissue evaluation is limited due to poor contrast resolution and superimposition of structures. It cannot adequately visualize muscles, nerves, spinal cord, or intracranial tissues, and in conditions like IVDD, it only suggests indirect changes without confirming cord

compression or hemorrhage—findings that MRI can reliably detect [27, 28]. While radiography is effective for identifying bone abnormalities, it fails to assess soft tissue components such as ligaments, tendons, and cartilage. MRI, in contrast, enables detailed evaluation of both soft tissue and joint structures in a single scan without ionizing radiation, making it especially valuable for repeated imaging in young or pregnant animals [15].

3.2 MRI vs. Computed Tomography

Computed tomography (CT) provides excellent bone detail, rapid image acquisition, and wider availability, making it the preferred modality for evaluating fractures, nasal tumors, lung disease, and planning osseous surgeries. However, its soft tissue contrast is significantly inferior to MRI, limiting its effectiveness for brain parenchyma, spinal cord disorders, and joint cartilage assessment [2, 29]. Comparative studies show MRI is more sensitive in detecting intracranial tumors, encephalitis, and epileptic-related hippocampal changes, identifying lesions missed by CT in up to 40–60% of neurological cases [12, 22]. Despite this, CT remains valuable in emergency trauma settings due to faster scan times and reduced anesthesia duration, though its use involves ionizing radiation, which is a concern for repeated imaging, especially in young animals [2].

3.3 MRI vs. Ultrasonography

Ultrasonography is a widely used, portable, and radiation-free imaging modality that provides real-time evaluation, particularly valuable for abdominal, cardiac, and ocular assessments. However, its effectiveness is limited by poor penetration through bone and air, preventing evaluation of the brain, spinal canal, and certain musculoskeletal structures, making it complementary rather than competitive to MRI [7]. While ultrasound is useful for guided procedures like biopsies, MRI offers superior characterization of complex conditions such as hepatic lesions, adrenal masses, renal disease, and vascular invasion by tumors [30, 18].

3.4 Sensitivity, Specificity, and Safety Aspects

MRI demonstrates high diagnostic accuracy in veterinary medicine, with sensitivity for intracranial lesions in dogs ranging from 85–97%, far exceeding CT (67–78%) and radiography (<30%) [12, 31]. For intervertebral disc disease, MRI achieves near-perfect sensitivity and specificity (95–100%) when correlated with surgical findings [27]. It is generally very safe when proper protocols are followed, with contraindications such as ferromagnetic implants or certain devices being rare in animals [7]. Gadolinium-based contrast agents are well tolerated, and complications like nephrogenic systemic fibrosis have not been clearly reported in veterinary patients, though caution is advised in those with renal impairment [11].

4. Clinical Applications of MRI in Dogs and Cats

4.1 Neurological Disorders

4.1.1 Brain Tumors

Intracranial neoplasia is a major indication for MRI in veterinary medicine, particularly in dogs and cats, where meningioma is the most common brain tumor, especially in cats (50–70%), followed by tumors such as glioma, choroid plexus tumors, pituitary macroadenoma in dogs, and lymphoma in cats [32, 33]. MRI provides precise tumor localization and detailed assessment of mass effect, edema, and tumor spread. Contrast enhancement patterns aid

differentiation, with meningiomas showing strong homogeneous enhancement and a dural tail, while high-grade gliomas exhibit ring enhancement with necrosis [7]. These imaging features are critical for surgical planning, radiation therapy, and prognosis [22].

4.1.2 Epilepsy

Epilepsy is a common neurological disorder in dogs, affecting about 0.5–5.7% of the population, and MRI plays a key role in distinguishing idiopathic from structural causes and guiding prognosis and treatment [34]. In dogs, structural epilepsy may be associated with conditions such as cortical dysplasia, hippocampal atrophy, tumors, cysts, or ischemic lesions [12]. In cats, structural causes like meningioma and inflammatory brain disease are more common than idiopathic epilepsy [35]. FLAIR sequences are especially useful for detecting subtle hippocampal and cortical abnormalities, while advanced techniques like MR spectroscopy and voxel-based morphometry are emerging tools for studying epileptic networks in veterinary neurology [22].

4.1.3 Encephalitis and Meningoencephalitis

Inflammatory brain diseases in veterinary patients include infectious causes (e.g., canine distemper virus, Toxoplasma, Neospora, Cryptococcus) and immune-mediated conditions such as granulomatous meningoencephalomyelitis (GME), necrotizing meningoencephalitis (NME), and necrotizing leukoencephalitis (NLE) [36]. MRI is the most sensitive non-invasive method for detecting and characterizing these disorders and guiding further diagnostics like CSF analysis or biopsy. GME typically presents as multifocal, poorly defined T₂-hyperintense lesions with variable enhancement, while NME shows severe unilateral or bilateral cortical and subcortical T₂ hyperintensity, sometimes with restricted diffusion in active stages [37]. Infectious encephalitis may appear as focal ring-enhancing masses or diffuse white matter changes depending on the pathogen involved [36].

4.1.4 Intervertebral Disc Disease (IVDD)

Intervertebral disc disease (IVDD) is the most common spinal cord disorder in dogs and a major indication for MRI, particularly Hansen Type I in chondrodystrophoid breeds and Type II in larger dogs [27, 28]. MRI enables accurate localization of disc material, evaluation of spinal cord compression, and detection of intramedullary T₂ changes indicating edema or myelomalacia, as well as hemorrhage and vertebral involvement. These findings are key prognostic markers and help predict surgical outcomes, while also allowing detection of ascending myelomalacia, a rare but fatal progressive condition [27, 13]. In cats, IVDD is less common, usually Hansen Type II, and most often affects the thoracolumbar and cervical regions [38].

4.1.5 Spinal Cord Injuries and Other Myelopathies

In addition to intervertebral disc disease (IVDD), magnetic resonance imaging (MRI) plays a crucial role in the diagnosis of various spinal pathologies, including neoplasia, degenerative myelopathy, fibrocartilaginous embolism (FCE), spinal infarction, syringomyelia, and atlantoaxial instability [39]. FCE is characterized by a focal intramedullary hyperintensity on T₂-weighted images, which occurs in the absence of compression, thereby differentiating it from disc-related disorders. Furthermore, MRI is indispensable for the identification and management of syringomyelia, particularly

in cases associated with Chiari-like malformations [40, 39].

4.2 Musculoskeletal Disorders

4.2.1 Ligament Injuries

Cranial cruciate ligament (CCL) rupture is the most common orthopedic disease in dogs, and MRI provides highly accurate assessment of ligament disruption as well as associated meniscal, cartilage, and subchondral bone lesions not fully seen on radiography or arthroscopy [41]. MRI is also useful for evaluating patellar luxation, shoulder instability, and tendon disorders with superior soft tissue detail [42].

4.2.2 Soft Tissue Trauma and Joint Abnormalities

MRI demonstrates significant efficacy in the evaluation of muscle tears, tendinopathies, and periarticular injuries in canine subjects. This imaging modality facilitates precise localization, grading of injury severity, and differentiation between edema and hemorrhage, thereby informing therapeutic interventions [15, 42]. Furthermore, MRI offers a more comprehensive assessment of articular cartilage compared to CT arthrography, allowing for the identification of defects and contributing to the diagnosis and staging of osteochondrosis dissecans (OCD), which is critical for surgical planning [43].

4.3 Oncology

4.3.1 Tumor Detection and Staging

MRI provides excellent soft tissue contrast for oncologic imaging, enabling accurate assessment of tumor margins, local invasion, vascular involvement, and lymph nodes for staging and surgical planning [2]. Contrast-enhanced and dynamic MRI help characterize tumor vascularity, distinguish viable tissue from necrosis or hemorrhage, and detect satellite lesions [7].

4.3.2 Soft Tissue Sarcomas

Soft tissue sarcomas (STS) in dogs including fibrosarcoma, peripheral nerve sheath tumor (PNST), and hemangiosarcoma are notoriously infiltrative, with histological margins extending significantly beyond gross tumor boundaries. MRI precisely defines the three-dimensional extent of STS, identifies neurovascular involvement, and guides margin planning for limb-sparing surgery or radiation field delineation [44].

4.3.3 Brain and Spinal Neoplasms

Intracranial and intraspinal neoplasms are among the most important MRI indications in companion animals. Spinal cord tumors including meningioma, PNST, astrocytoma, neuroblastoma, and metastatic disease—are classified by MRI as intradural-intramedullary, intradural-extramedullary, or extradural, with each category carrying distinct prognostic and therapeutic implications [28, 7].

4.4 Reproductive and Endocrine Disorders

In dogs with pituitary-dependent hyperadrenocorticism (PDH), MRI is essential for evaluating pituitary tumor size, which guides prognosis and treatment; macroadenomas (>10 mm) are associated with more severe neurological signs and reduced survival. Dynamic contrast-enhanced MRI aids tissue differentiation and tumor lateralization for surgical planning. In cats, MRI is key for diagnosing pituitary adenomas causing hypersomatotropism and for guiding radiation therapy [45].

5. MRI in Feline vs. Canine Patients: Species-Specific Considerations

5.1 Anatomical and Physiological Differences

Dogs and cats show important anatomical differences that require species-specific MRI protocols. Cats have a more rounded brain, different gyral patterns, and a relatively larger cerebellum, requiring adjustments in slice thickness, field of view, and imaging parameters for optimal resolution. Their intervertebral discs retain higher water content into adulthood, unlike dogs where early disc degeneration predisposes to IVDD, explaining its lower incidence in cats [38, 7]. Coil selection also varies with body size: cats typically fit human head or extremity coils with higher signal quality, while large dogs often require body or phased-array coils, which may reduce signal-to-noise ratio [7].

5.2 Disease Prevalence Variation, Handling and Anesthesia Challenges

Veterinary MRI elucidates distinct interspecies variations in disease manifestations between canines and cats. In cats, meningioma is identified as the predominant cerebral neoplasm, frequently observed incidentally in geriatric individuals, while canines exhibit a broader spectrum of neoplasms, encompassing gliomas and choroid plexus tumors [46]. Idiopathic epilepsy and inflammatory cerebral diseases are more commonly observed in canines, whereas cats often present with encephalitis are associated with feline infectious peritonitis (FIP). Furthermore, pituitary disorders demonstrate variability; pituitary-dependent hyperadrenocorticism (PDH) is prevalent in canines, while acromegaly is more characteristic of cats. Cats require more careful MRI handling and anesthesia than dogs due to higher stress sensitivity and a narrower safety margin [46, 47].

6. Limitations and Challenges of MRI in Veterinary Practice

6.1 High Cost and Limited Accessibility: High equipment, maintenance, and staffing costs make veterinary MRI expensive. A single scan is costly for clients, and insurance often does not fully cover expenses [8, 20].

6.2 Requirement for General Anesthesia

MRI requires anesthesia, introducing risks (0.1–0.3% mortality) not present in human imaging. Neurological patients may have added complications and specialized MRI-compatible monitoring increases procedural complexity [48].

6.3 Time-Consuming Procedures

Preparation to recovery takes 90–180 minutes, while advanced systems reduce scan time, overall workflow remains lengthy, though AI and protocol optimization aim to improve efficiency [7, 22].

6.4 Interpretation Expertise and Subspecialty Availability

MRI interpretation requires specialized expertise, but limited trained professionals create bottlenecks. Radiology and neurology improves access, though variability exists, and recognizing artifacts is essential to avoid diagnostic errors [9].

7. Recent Advances in Veterinary MRI

7.1 Functional MRI (fMRI)

In veterinary medicine, it is mainly research-based, especially in awake, trained dogs studying cognition, emotion, and sensory processing. fMRI uses BOLD contrast to map brain activity by detecting changes in regional blood flow. It

provides insights into canine neurobiology and human–animal interaction [22, 49].

7.2 Diffusion Tensor Imaging (DTI)

DTI evaluates directional water diffusion to visualize white matter tracts via tractography. In veterinary applications, it helps assess brain connectivity and spinal cord damage in IVDD, with diffusion changes reflecting tissue injury [50].

7.3 Contrast-Enhanced and Advanced Perfusion MRI

Advanced techniques such as DCE-MRI, DSC-MRI, and ASL quantify perfusion, blood volume, and vascular permeability for tumor characterization and treatment monitoring. Magnetic resonance spectroscopy (MRS) provides metabolic profiling to differentiate neoplastic, inflammatory, and epileptic conditions [51].

7.4 Artificial Intelligence and Machine Learning Integration

AI is increasingly used for automated lesion detection, segmentation, and tumor classification in veterinary MRI. AI-based reconstruction reduces scan time and anesthesia duration by improving image quality from faster acquisitions, with future systems expected to support clinical decision-making [52].

8. Role of MRI in Research and Translational Veterinary Medicine

8.1 Translational Pathology and Comparative Oncology

Advanced neuro-imaging and standardized diagnostic criteria may help to evaluate malignancies like glioblastoma in immunocompetent models, bridging the gap between veterinary medicine and human clinical applications [52].

8.2 Neuroanatomical Insights and Cognitive Modeling

Comparative neuroscience leverages MRI to investigate structural and functional brain adaptations across various species, particularly focusing on the intersection of aging and neurodegeneration [7, 22].

8.3 Advanced Therapeutics and Longitudinal Clinical Trials

The integration of quantitative MRI metrics, such as perfusion imaging and volumetric analysis, offers a rigorous framework for monitoring treatment efficacy in veterinary clinical trials [22].

9. Conclusion and Future perspectives

Magnetic Resonance Imaging (MRI) continues to be regarded as the gold standard in the realm of soft-tissue diagnostics, providing unmatched accuracy in the fields of veterinary neurology and oncology. Historically, its application has been constrained by high costs and the necessity for anesthesia; however, the advent of portable low-field systems and AI-enhanced reconstruction techniques is progressively broadening its accessibility. This accessibility is further augmented by the development of sustainable infrastructure, which includes cryogen-free magnets and refurbished systems that alleviate traditional financial barriers. The discipline is increasingly shifting towards precision medicine, wherein the amalgamation of radiomics and machine learning with molecular profiling facilitates highly personalized prognostic assessments and targeted therapeutic interventions. Importantly, veterinary MRI serves as a conduit between species; by employing spontaneous diseases in animals as

translational models, it bolsters the One Health initiative. Future innovations in hardware and specialized educational programs are imperative for enhancing the global influence of imaging on both veterinary and human health.

Conflict of Interest

Not available

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