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Artificial Intelligence in Veterinary Radiology: A Narrative Review of Technical, Diagnostic, and Clinical Integration Challenges

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ABSTRACT

The integration of artificial intelligence (AI) into veterinary radiology holds significant promise for enhancing diagnostic accuracy, reducing interpretation time, and addressing workforce shortages in specialized imaging. This article reviews current literature to identify and characterize the major challenges hindering seamless clinical translation. A comprehensive literature search was conducted to identify relevant studies addressing the challenges of artificial intelligence in veterinary radiology. The electronic databases PubMed, Scopus, Web of Science, and Google Scholar were systematically searched from January 2020 to June 2026, using combinations of the keywords. Technically, the lack of large-scale, standardized, annotated veterinary image datasets, compared with those in human medicine, severely limits the development and validation of robust deep learning models. Heterogeneity in patient positioning, breed-specific anatomical variations, and differences in imaging equipment across veterinary practices further compound this issue. Diagnostically, AI models trained predominantly on human radiographs often fail to generalize to veterinary patients due to fundamental differences in physiology, common pathologies (e.g., gastric dilatation-volvulus, feline bronchial disease), and species-specific artifacts. Moreover, the challenge of detecting subtle or early-stage lesions in multiple species without species-optimized algorithms raises concerns about false negatives and clinical safety. Clinically, integration into real-world workflow poses substantial hurdles: most commercial AI tools are not embedded within existing practice management software or PACS (Picture Archiving and Communication Systems), requiring manual toggling between platforms. Cost-effectiveness remains unproven for many small to medium-sized clinics, and there is a notable lack of prospective validation studies demonstrating improved patient outcomes or client satisfaction. Additionally, medicolegal and ethical uncertainties persist regarding accountability when AI-generated recommendations conflict with a clinician's judgment, particularly in emergency settings. Resistance to adoption among general practitioners, stemming from inadequate AI literacy and fear of over-reliance, further slows progress. Finally, this review highlights that, unlike human medicine, veterinary radiology lacks standardized benchmarks, regulatory frameworks, and continuing education programs tailored to AI applications.

Keywords: *Veterinary radiology, Artificial intelligence, Diagnostic challenges, Clinical integration, Deep learning*

1. INTRODUCTION

Veterinary radiology has become a major player in diagnosing diseases in animals in recent decades [1]. As pet owners' expectations have risen and diseases in farm and zoo animals have become more complex, the volume of radiological images and the need for their accurate and rapid interpretation have increased dramatically. However, the number of specialist veterinary radiologists is limited in many countries, leading to delays in diagnosis, interpreter fatigue, and sometimes diagnostic errors. In such circumstances, the use of assistive technologies, such as artificial intelligence, has been considered a potential solution [2].

Artificial intelligence, particularly deep learning and convolutional neural networks, has revolutionized human radiology and is now taking its first steps in veterinary medicine [3]. Capabilities such as automatic detection of bone fractures, detection of lung metastases, organ measurement, and even detection of abnormal soft-tissue patterns are among the potential applications of this technology. Early studies have shown that algorithms can identify certain normal and pathological findings with reasonable accuracy across species such as dogs, cats, and horses [4]. However, the path to reliable clinical application in veterinary medicine is not smooth, and several challenges lie ahead [5].

The first and most important challenge in this area is the lack of standardized, large, and labeled datasets of veterinary radiology images [6]. Unlike human medicine, where there are large databases of homogeneous images, veterinary medicine faces an extraordinary diversity of species (from parrots to elephants), breeds (with extreme anatomical variations, such as bulldogs compared to greyhounds), body sizes, and imaging techniques [7]. Also, animal movement during imaging (due to lack of cooperation) and numerous artifacts reduce data quality. Training AI algorithms on poor or low-volume data directly reduces accuracy and generalizability [8] (Figure 1).

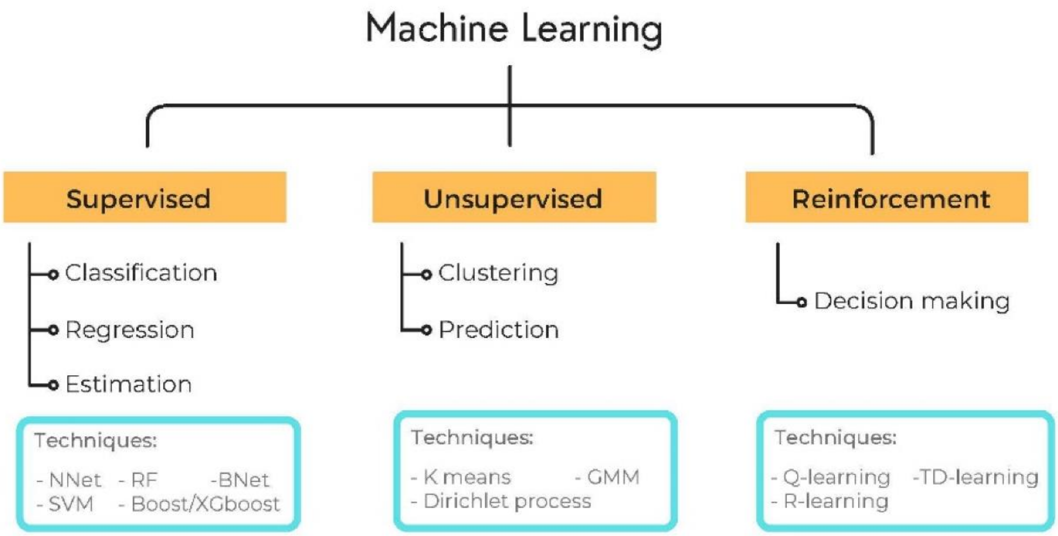

Figure 1. Supervised, unsupervised, and reinforced machine learning (MDPI Copyright, 2022) [9].

In addition to the technical challenges, there are also specific diagnostic limitations that are less common in human medicine. Many existing AI algorithms are primarily trained on human images and cannot be easily applied to animals, because physiology, disease spectrum, and normal findings vary across species [10]. For example, diagnosing a mild gastric motility disorder in a German Shepherd is significantly different from diagnosing a Great Dane. Furthermore, in emergencies such as gastric volvulus or pyometra, AI may fail to understand clinical nuances, and misreporting may endanger the animal [2, 11].

Even if accurate, species-specific models are built, the ultimate challenge is integrating them into the daily workflow of veterinary clinics and hospitals. Currently, many AI tools operate separately from conventional picture archiving and communication systems (PACS), requiring manual data entry, which is time-consuming. The cost of implementing these technologies is also prohibitive for many small and medium-sized clinics. On the other hand, the level of digital literacy and trust in AI among general veterinarians varies, and some are resistant to its adoption. This review aims to identify and categorize the three challenges (technical, diagnostic, and integration) to provide a clear picture of the barriers facing AI in veterinary radiology and to emphasize the need for interdisciplinary collaboration to overcome them.

2. SEARCH STRATEGY

A comprehensive literature search was conducted to identify relevant studies addressing the challenges of artificial intelligence in veterinary radiology. The electronic databases PubMed, Scopus, Web of Science, and Google Scholar were systematically searched from January 2020 to June 2026, using combinations of the following keywords: "artificial intelligence," "deep learning," "machine learning," "veterinary radiology," "veterinary radiography," "diagnostic imaging," "challenges," "limitations," "data scarcity," "clinical integration," and "implementation." The search strategy was adapted for each database using Boolean operators (AND, OR). Additionally, the reference lists of included articles and relevant review papers were manually screened to identify further eligible studies. Only peer-reviewed articles published in English, including original research, case series, and conference proceedings, were considered. Exclusion criteria comprised studies focused exclusively on human radiology without veterinary application, non-English articles without available translation, and opinion pieces lacking empirical or experiential data. The search yielded an initial total of 1,247 records. After removing duplicates and screening titles, abstracts, and full texts based on relevance to the predefined challenges (technical, diagnostic, and clinical integration), 27 articles were ultimately included in this narrative review.

3. APPLICATIONS OF AI: TECHNICAL AND DATA-RELATED CHALLENGES

The first and most fundamental technical challenge in applying AI to veterinary radiology is the severe lack of standardized, large, and high-quality datasets [12, 13]. In human medicine, there are huge databases such as NIH ChestX-ray or MURA that contain tens of thousands of labeled images. In contrast, the largest veterinary radiology databases typically contain a few thousand images for only one or two species (mostly dogs and cats). Deep learning algorithms typically require tens of thousands of training images to achieve acceptable accuracy. A lack of data leads to overfitting, i.e., the model retains patterns from the training images but fails to generalize to new images. This is especially acute in the diagnosis of rare diseases or in less studied species such as reptiles, ornamental birds, or marine mammals [14, 15].

The second major technical challenge is the tremendous anatomical variation among species and even different breeds of a species. While human anatomy is relatively uniform in adulthood, a veterinary radiologist must compare images of a bulldog (with a flat face, short spine, and deformed vertebrae) with images of a greyhound (with a deep chest and elongated spine) [16]. This diversity makes it virtually impossible to train a single AI model for all dog breeds. Furthermore, in large-animal veterinary medicine, it is equally challenging to distinguish between a Thoroughbred Arabian horse and a heavy-bodied Druid, or between a Holstein cow and a Charolais cow. Each AI model must either be trained separately for different breeds (requiring even more data) or suffer from lower accuracy for less commonly seen breeds [4, 17] (Figure 2).

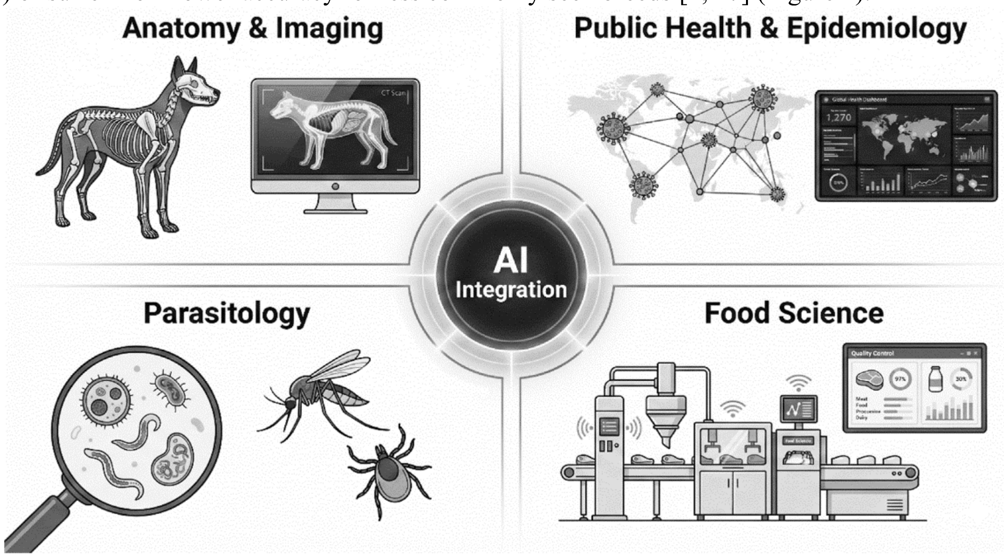

Figure 2. Schematic overview of AI integration across core veterinary disciplines, including anatomy and imaging, parasitology, food science and public health (MDPI Copyright, 2026) [18].

Another technical challenge is the inherent low quality of many veterinary radiology images. Unlike in human medicine, where patients can be instructed to remain still and hold their breath, animals often require physical restraint or sedation, and yet motion during imaging is common. This motion creates blurring that can severely confuse AI algorithms [19, 20]. Also, differences in imaging equipment (voltage, current, source-to-film distance), nonstandard positioning techniques, and the presence of foreign objects (such as collars, dressings, or anesthesia tubes) can create numerous artifacts. An algorithm trained on high-quality human images will perform very poorly on these artifact-rich images and may even misidentify normal anatomical areas as lesions [21].

The fourth technical challenge concerns the image annotation process and the lack of uniform assessment standards. Annotating veterinary radiology images requires the presence of highly specialized veterinary radiologists, a group whose numbers are very limited worldwide [22]. Even when such specialists are available, inter-rater agreement in interpreting many radiological findings in animals is low. For example, the diagnosis of the mildest degree of hip dysplasia in a dog or mild pleural effusion in a cat can differ between two experienced radiologists. Furthermore, there is no unified standard or protocol for annotating images (e.g., using bounding boxes or pixel-by-pixel segmentation) in veterinary medicine [23]. The lack of these standards makes it difficult to compare the performance of different AI models and calls into question the validity of the results of multiple studies. Taken together, these four technical challenges demonstrate that before any widespread clinical application of AI in veterinary radiology can occur, a huge investment in data collection, protocol standardization, and training of labeling specialists must be made [24].

4. DIAGNOSTIC, CLINICAL, AND INTEGRATION CHALLENGES

The first set of diagnostic challenges concerns the fundamental differences in physiology, anatomy, and disease spectrum among species [12, 13]. Unlike human medicine, where AI algorithms are trained to diagnose hundreds of the same diseases in millions of humans with similar anatomy, in veterinary medicine, each species has a unique radiological pattern. For example, the normal appearance of the lung in a horse is fundamentally different from that of a dog, or the pattern of laryngeal cartilage calcification in an elderly cat can be mistaken for a foreign body [4, 17]. Also, many diseases are seen in only one or two species (such as metastatic bladder tumors in Scottish terriers). An algorithm trained primarily on dog images is virtually ineffective at diagnosing diseases in cats or horses. This means that a separate AI model is needed for each species (and even for each major breed) – something that seems unachievable with the current available data [9].

Another diagnostic challenge is the significant risk of false-positive and false-negative diagnoses, which can have irreparable consequences in a veterinary emergency. Imagine an AI algorithm in a 24-hour veterinary hospital interpreting a radiology image of a dog with severe abdominal distension. If the algorithm mistakenly misses gastric volvulus (GDV) (a false negative), the veterinarian may not perform emergency surgery, and the animal may die within hours [3, 14]. Conversely, if the algorithm mistakenly reports gastric volvulus (a false positive), the animal will undergo unnecessary surgery, which carries the risk of anesthesia and death. Studies have shown that AI algorithms are far less accurate than experienced radiologists in detecting subtle findings or the borderline between normal and pathological (such as mild liver enlargement or mild splenomegaly). In human medicine, these errors are corrected by the attending physician. Still, in veterinary medicine, where the number of cases per general veterinarian is higher, there is a risk of over-reliance on real AI [25].

The third major challenge is integrating AI tools into existing systems in veterinary clinics and hospitals. Currently, most AI solutions for veterinary radiology are offered as standalone or cloud-based tools that require users to upload images manually, wait for processing, and then view the results in a separate window. This process is time-consuming and disruptive to workflow, especially in busy clinics where a general veterinarian may perform dozens of radiographs per day [6, 19]. Many small and medium-sized veterinary clinics still use legacy PACS systems or even paper archives that lack an application programming interface (API) for connecting to AI. Also, the lack of communication standards, such as DICOM (well-established in human medicine), in many low-cost veterinary equipment makes data exchange difficult. As a result, even if an accurate and valid AI model exists, it is practically impossible to deploy it in a real clinical environment without a fundamental redesign of the IT infrastructure [26, 27].

The fourth set of challenges is economic, legal, and behavioral. From an economic perspective, the cost of acquiring, installing, and maintaining AI software, along with the required hardware (powerful servers or cloud subscriptions), is not justifiable for many private veterinary clinics, especially in rural areas or developing countries [28]. Unlike in human medicine, where insurance may cover the cost of new technologies, in veterinary medicine, most costs are borne directly by the animal owner. From a legal perspective, the issue of accountability remains completely unresolved: if AI makes an incorrect diagnosis and the veterinarian trusts it, and the animal suffers, is the liability with the veterinarian, the software developer, or both? No legal system in the world has yet clearly answered this question in the veterinary field. On the other hand, the professional resistance of veterinarians is also real. Many general veterinarians are not sufficiently digitally literate to understand the strengths and weaknesses of AI and either over-trust it or reject it altogether. The lack of formal training programs in veterinary schools on the principles of working with AI further exacerbates this gap.

The final challenge in this section is the complete lack of legal and ethical frameworks, as well as clinical evaluation standards, specific to AI in veterinary radiology. In human medicine, organizations such as the FDA (USA) or the CE (Europe) have specific guidelines for the clinical validation of AI algorithms. In veterinary medicine, such regulatory bodies are almost non-existent. There is also no agreement on what performance criteria (e.g., sensitivity, specificity, AUC) an AI model should have for application in a particular species. From an ethical perspective, the transparency or "explainability" of algorithms in veterinary medicine has received less attention. If an algorithm says, "This image is suspicious for a lung tumor," the veterinarian does not know which features (e.g., nodule size, margins, or density) the algorithm is based on to reach that conclusion (Table 1).

Table 1. Summary of diagnostic, clinical, and integration challenges of AI in veterinary radiology

Category	Specific Challenge	Key Consequence
Diagnostic	Inter-species and breed variations in anatomy & physiology	Poor generalization of human-trained or single-species models
	High risk of false positives/negatives, especially in emergencies (e.g., GDV)	Life-threatening delays or unnecessary surgeries
	Difficulty detecting subtle or borderline findings (e.g., mild hepatomegaly)	Reduced diagnostic reliability
Clinical Integration	Lack of compatibility with existing PACS and practice management software	Disruption of clinical workflow; time loss
	High implementation and maintenance costs	Not cost-effective for small/mid-size clinics
	Professional resistance and low AI literacy among general practitioners	Underutilization or over-reliance without critical evaluation
Legal & Ethical	Unclear accountability for AI errors (veterinarian vs. software developer)	Legal liability gaps
	Absence of veterinary-specific regulatory frameworks (like FDA/CE for humans)	No safety or performance benchmarks
	"Black box" nature of AI (lack of explainability)	Reduced trust and clinical adoption

5. CONCLUSION

This narrative review article demonstrated that although AI has significant potential to transform veterinary radiology by increasing diagnostic accuracy, reducing interpretation time, and compensating for the shortage of expert radiologists, the path to widespread and safe clinical application is fraught with numerous and serious challenges in the three areas of technical, diagnostic, and integration. From a technical perspective, the lack of standardized, large, and labeled datasets, coupled with the unique diversity of species, breeds, and anatomy, as well as poor image quality due to motion and artifacts, are the most important obstacles. From a diagnostic and clinical perspective, interspecies differences in physiology and disease spectrum, the risk of false diagnoses, especially in emergency settings, and the lack of legal, ethical, and evaluation standards make the direct application of algorithms developed for humans unreliable in veterinary medicine. Integration challenges, including incompatibility with existing systems, high costs, resistance from veterinarians, and a lack of formal training, pose practical barriers to the widespread adoption of this technology. Ultimately, close interdisciplinary collaboration between veterinary radiologists, computer scientists, industry, and regulatory and educational institutions is essential to overcome these challenges. The future vision requires targeted investment in creating open, standardized veterinary databases; developing explainable, species-specific algorithms; establishing clear legal and ethical guidelines; designing integrated educational programs in veterinary schools; and providing cost-effective solutions compatible with clinics' daily workflows. Until then, AI should be considered an adjunct to, not a replacement for, the expertise and clinical judgment of the veterinarian.

Declarations and statements

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Conflict of interest

The authors declare no conflicts of interest.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethical approval

All applicable international, national, and/or institutional guidelines for writing a review paper were followed.

Author contribution

Conceptualization: [Maryam Kermanshahian, Tara Marzban], …; Methodology: [Maryam Kermanshahian, Tara Marzban], …; Formal analysis and investigation: [Maryam Kermanshahian], …; Writing - original draft preparation: [Maryam Kermanshahian, Tara Marzban]; Writing - review and editing: [Maryam Kermanshahian, Tara Marzban], …; Funding acquisition: [Self-funding], …; Supervision: [Maryam Kermanshahian].

Consent to participate

Not applicable

Consent for publication

Not applicable

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After the content was fully written, an AI-powered tool was exclusively used to review and refine the article's grammar, punctuation, and overall linguistic flow. The AI tool was used strictly as a proofreading and language-refinement assistant and was not employed at any stage to generate content, ideas, or article sections.

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