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Recent advancements in imaging techniques and their application in veterinary practice: A review

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ABSTRACT

Diagnostic imaging has evolved considerably from the conventional anatomical methods that traditionally depended on dissection and detailed anatomical illustrations. Modern imaging technologies now provide rapid, non-invasive and highly informative visualization of anatomical structures and physiological processes in living animals, making them valuable tools in both veterinary clinical practice and biomedical research. The progressive improvement in veterinary diagnostic imaging has resulted in the increasing use of advanced modalities such as computed tomography (CT), magnetic resonance imaging (MRI), nuclear medicine techniques including positron emission tomography (PET) and single-photon emission computed tomography (SPECT), as well as hybrid imaging systems such as PET/CT, SPECT/CT and PET/MRI. Conventional radiography and ultrasonography continue to serve as the primary imaging modalities in veterinary medicine because of their relatively low cost, widespread availability and ease of operation. However, these techniques may have limitations in evaluating anatomically complex regions and in differentiating tissues with similar radiographic characteristics. Advanced cross-sectional and molecular imaging techniques overcome several of these limitations by providing detailed three-dimensional anatomical, functional and metabolic information. Despite their increasing clinical importance, advanced imaging facilities remain less accessible in many developing regions because of high installation and maintenance costs, limited availability of trained personnel, shortage of specialists for image interpretation and the need for equipment capable of accommodating animals of different sizes. Nevertheless, continuing technological developments are expected to expand the role of advanced diagnostic imaging in veterinary medicine, particularly in oncology, neurology, orthopaedics, cardiopulmonary disease and research.

Keywords: Imaging techniques, Application, Veterinary practice

Introduction

Radiography became an important component of veterinary profession soon after its discovery and clinical applications (Latif *et al.*, 2024; Mariano *et al.*, 2017) [1, 2]. For many years, conventional radiography represented the principal imaging method available for evaluating internal anatomical structures in animals (Latif *et al.*, 2024) [1]. Although radiographs remain extremely useful, they provide a two-dimensional projection of three-dimensional anatomical structures, resulting in superimposition of tissues and organs. Consequently, interpretation of complex anatomical regions or subtle pathological changes may sometimes be difficult (Bealey, 2016) [3]. The development of ultrasonography and endoscopic techniques significantly expanded the diagnostic capabilities of veterinary clinicians (Mariano *et al.*, 2017) [2]. Endoscopy permits direct visualization of internal surfaces, whereas ultrasonography provides real-time imaging of soft tissues and internal organs without the use of ionizing radiation (Latif *et al.*, 2024; Sigrist *et al.*, 2017) [1, 4]. Nevertheless, these techniques also have specific limitations, creating a need for additional diagnostic modalities capable of providing more comprehensive anatomical and functional information.

The introduction of cross-sectional imaging, particularly computed tomography (CT) and magnetic resonance imaging (MRI), has substantially improved the evaluation of anatomical structures in living animals (Latif *et al.*, 2024; Mayerhoefer *et al.*, 2020) [1, 5]. These techniques enable organs and tissues to be examined in multiple planes while minimizing or eliminating the problem of anatomical superimposition (Yitbarek *et al.*, 2022; Pinilla, 2025) [6, 7]. In addition, advanced computer-based reconstruction permits the generation of three-dimensional anatomical models that can be used for diagnosis, surgical planning, teaching and research (Yitbarek *et al.*, 2022; Kanaga *et al.*, 2021) [6, 8]. Modern imaging technologies can provide not only static anatomical images but also dynamic representations of physiological processes (Kanaga *et al.*, 2021) [8]. Computer-assisted image processing allows individual anatomical components such as bones, blood vessels and internal organs to be digitally isolated and reconstructed (Yitbarek *et al.*, 2022; Latif *et al.*,

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2024) [6, 1]. Such three-dimensional models can assist in understanding normal anatomy, pathological alterations and complex spatial relationships between structures (Latif *et al.*, 2024) [1]. Although conventional radiography and ultrasonography remain the most commonly used imaging modalities because of their accessibility, affordability and practical advantages, advanced imaging techniques are increasingly being incorporated into veterinary practice (Yitbarek *et al.*, 2022; Sigrist *et al.*, 2017) [6, 4]. CT and MRI provide high-quality cross-sectional anatomical information, while nuclear medicine techniques such as PET and SPECT provide functional and metabolic information (Mayerhoefer *et al.*, 2020) [5]. Hybrid systems combine these complementary advantages and allow anatomical abnormalities to be correlated with physiological or metabolic changes (Yitbarek *et al.*, 2022; Kanaga *et al.*, 2021) [6, 8].

Imaging techniques

X-rays

X-rays are produced when high-speed electrons strike a metal target (usually tungsten) inside an X-ray tube (Bealey, 2016) [3]. Based on the differential absorption of X-ray radiation by different materials in the body, different tissues absorb X-rays to different extents like bones absorb more X-rays because they are dense and contain calcium, so they appear white on the X-ray image. Soft tissues absorb fewer X-rays, so they appear gray. Air-filled structures (such as the lungs) absorb the least X-rays, so they appear black (Latif *et al.*, 2024) [1]. Finally, the X-rays that pass through the body reach a detector or film, creating an image based on the varying amounts of X-rays transmitted (Bealey, 2016) [3].

Computed tomography

Computed tomography (CT) is a cross-sectional diagnostic imaging technique that uses X-rays and computer-based image reconstruction to produce detailed sectional images of the body (Abdulkareem *et al.*, 2003; Latif *et al.*, 2024) [9, 1]. Unlike conventional radiography, CT minimizes the effects of anatomical superimposition and permits individual tissues and structures to be evaluated in transverse sections (Yitbarek *et al.*, 2022; Pinilla, 2025) [6, 7]. In a CT scanner, an X-ray tube rotates around the patient while emitting a narrow or fan-shaped beam of X-rays through the body. Detectors positioned opposite the X-ray tube measure the amount of radiation that passes through the patient (Jeffery *et al.*, 1992) [10]. As the X-ray beam travels through tissues of different densities, varying amounts of radiation are attenuated. The detectors record these differences from multiple projections obtained during rotation of the X-ray tube. The acquired data are transferred to a computer, which uses mathematical reconstruction algorithms to generate cross-sectional images (Latif *et al.*, 2024) [1]. These images can subsequently be reformatted into sagittal, dorsal and oblique planes (Yitbarek *et al.*, 2022) [6]. Three-dimensional volume-rendered and surface-rendered images can also be generated from the acquired data (Yitbarek *et al.*, 2022; Kanaga *et al.*, 2021) [6, 8]. The degree of X-ray attenuation is represented numerically using Hounsfield units (HU), allowing differentiation between tissues based on their relative radio density (Latif *et al.*, 2024) [1]. Administration of an intravenous iodinated contrast medium can further improve visualization of blood vessels, soft tissues, lesions and areas of altered perfusion (Latif *et al.*, 2024) [1].

Applications of computed tomography

CT has extensive applications in veterinary practice because of its ability to provide high-resolution cross-sectional images of both skeletal and soft-tissue structures (Latif *et al.*, 2024; Pinilla, 2025) [1, 7]. It is particularly valuable in regions where conventional radiographs are limited by extensive anatomical superimposition (Yitbarek *et al.*, 2022) [6]. Common veterinary applications include evaluation of nasal cavity and paranasal sinuses, skull and brain (Yitbarek *et al.*, 2022; Pinilla, 2025) [6, 7], dental arcade and maxillofacial structures (Yitbarek *et al.*, 2022; Kanaga *et al.*, 2021) [6, 8], temporo-mandibular

joints, tympanic bullae, middle ear and retrobulbar structures (Yitbarek *et al.*, 2022) [6], thorax, pulmonary structures and abdominal organs (Gerhard *et al.*, 2024) [11], appendicular skeleton (Yitbarek *et al.*, 2022) [6], vertebral column and musculoskeletal abnormalities (Gerhard *et al.*, 2024; Pinilla, 2025) [11, 7], neoplastic lesions (Latif *et al.*, 2024; Pinilla, 2025) [1, 7] and vascular abnormalities (Latif *et al.*, 2024; Pinilla, 2025) [1, 7], orthopaedic imaging (Yitbarek *et al.*, 2022; Pinilla, 2025) [6, 7] etc. It can demonstrate fractures, cortical defects, subtle or incomplete fractures, bone thickness, trabecular architecture, angular deformities and three-dimensional relationships between skeletal structures (Yitbarek *et al.*, 2022; Latif *et al.*, 2024) [6, 1]. These capabilities make CT valuable for assessing developmental and degenerative orthopaedic disorders, skeletal deformities, neoplasia and traumatic injuries (Yitbarek *et al.*, 2022; Latif *et al.*, 2024) [6, 1]. In addition, CT can be used to evaluate the morphology and spatial orientation of bones and joints (Yitbarek *et al.*, 2022) [6]. Measurements of bone angles, rotation, thickness and anatomical dimensions can assist in the diagnosis and management of conditions such as dysplasia, angular limb deformities, osteopathy and degenerative joint disease (Yitbarek *et al.*, 2022) [6].

Contrast-enhanced CT (CECT) further increases the diagnostic capability of the modality. Intravenous iodinated contrast allows assessment of vascularity, tissue perfusion, enhancement characteristics and lesion margins (Latif *et al.*, 2024) [1]. Dynamic contrast-enhanced CT can provide information regarding blood flow and tissue perfusion and may therefore be useful in the investigation of tumours and vascular abnormalities (Yitbarek *et al.*, 2022; Latif *et al.*, 2024) [6, 1]. CT has also been used to evaluate the heart, lungs, liver, spleen, kidneys and various neoplastic conditions (Latif *et al.*, 2024; Gerhard *et al.*, 2024) [1, 11]. Because CT provides sectional rather than projectional images, the effects of superimposition are substantially reduced. Consequently, lesions can often be localized more accurately, their extent can be determined more precisely and their relationship with adjacent structures can be assessed more effectively (Yitbarek *et al.*, 2022) [6].

Magnetic resonance imaging

Magnetic resonance imaging (MRI) is an advanced imaging technique that uses a strong magnetic field, radiofrequency pulses and magnetic field gradients to produce detailed images of body tissues (Latif *et al.*, 2024; Mariano *et al.*, 2017) [1, 2]. When an animal is placed within the magnetic field, hydrogen nuclei, which are abundant in biological tissues because of their high water and fat content, become partially aligned with the magnetic field (Mariano *et al.*, 2017) [2]. Radiofrequency energy is then applied to disturb this alignment. When the radiofrequency pulse is discontinued, the hydrogen nuclei return toward their original state and release energy in the form of radiofrequency signals. These signals are detected by receiver coils and processed by a computer to generate images. Differences in tissue composition and relaxation characteristics result in differences in signal intensity. By altering the sequence parameters and timing of radiofrequency excitation and signal acquisition, different MRI sequences can be obtained, including T1-weighted, T2-weighted and fluid-sensitive sequences (Mariano *et al.*, 2017) [2]. MRI does not use ionizing radiation and provides exceptional soft-tissue contrast. It is therefore particularly valuable for evaluating the central nervous system, musculoskeletal system, soft tissues and many neoplastic conditions (Pinilla, 2025) [7].

Applications of magnetic resonance imaging

MRI has become an important diagnostic modality in veterinary practice because of its excellent soft-tissue contrast and multiplanar imaging capability. It permits detailed evaluation of anatomical structures and pathological alterations in vivo (Pinilla, 2025) [7]. Important clinical applications include intervertebral disc disease, intracranial and spinal neoplasia, brain and spinal cord disorders, peripheral nerve disorders, musculoskeletal diseases, joint and tendon abnormalities, osteochondrosis, soft-tissue injuries, inflammatory disorders, os

teomyelitis, abscesses, neoplastic diseases, orbital and ocular disorders (Gerhard *et al.*, 2024; Pinilla, 2025) [11, 7]. MRI is particularly useful in veterinary neurology because of its ability to distinguish between different types of brain and spinal cord pathology. It can also provide valuable information about the extent and characteristics of soft-tissue lesions. In orthopaedic patients, MRI can detect abnormalities involving cartilage, ligaments, tendons, muscles, bone marrow and other soft tissues that may not be adequately characterized by conventional radiography. MRI has also contributed to the investigation of several musculoskeletal disorders in animals, including navicular disease, traumatic arthritis and osteochondrosis in horses and cervical spinal disorders such as wobblers syndrome in dogs (Pinilla, 2025) [7]. An additional advantage of MRI is its ability to characterize lesions based on their signal intensity and enhancement pattern. This can assist in differentiating inflammatory lesions from neoplastic masses and in distinguishing tumour tissue from surrounding oedema (Mariano *et al.*, 2017) [2]. MRI is also useful in detecting conditions such as osteomyelitis, cellulitis and abscessation because of its high sensitivity for alterations in soft tissues and bone marrow (Pinilla, 2025) [7].

Magnetic resonance angiography

Magnetic resonance angiography (MRA) is a specialized MRI technique used to visualize blood vessels without conventional invasive angiographic procedures. Depending on the technique, vascular structures may be demonstrated with or without contrast administration. MRA can be used for the assessment of vascular malformations, aneurysms, thrombi, abnormal vascular anatomy and portosystemic shunts (Mariano *et al.*, 2017) [2].

Magnetic resonance spectroscopy

Magnetic resonance spectroscopy (MRS) is an advanced MRI-based technique that provides biochemical information about tissues rather than merely anatomical images (Kanaga *et al.*, 2021; Mariano *et al.*, 2017) [8, 2]. It can be used to evaluate tissue metabolites and may have applications in the characterization of neurological and neoplastic disorders (Kanaga *et al.*, 2021; Mariano *et al.*, 2017) [8, 2]. MRI has also been applied to veterinary ophthalmology, including the evaluation of orbital and optic nerve lesions (Pinilla, 2025) [7]. Its ability to demonstrate neural structures and soft tissues makes it particularly useful in complex orbital and intracranial diseases (Pinilla, 2025) [7].

Veterinary nuclear medicine

Nuclear medicine differs fundamentally from conventional radiography, CT and MRI because it primarily evaluates physiological and metabolic activity rather than anatomy alone. In nuclear medicine, a radioactive substance known as a radionuclide or radiopharmaceutical is administered to the patient, either intravenously, orally or by another appropriate route. The radiopharmaceutical accumulates in specific tissues according to its biological properties. The radiation emitted from the radionuclide is detected externally using specialized gamma cameras or other radiation detectors. The resulting information can be used to determine the distribution and activity of specific tissues or physiological processes. Therefore, nuclear medicine can provide both functional and, depending on the modality, anatomical information. The two major nuclear medicine imaging techniques are Positron emission tomography (PET) and Single-photon emission computed tomography (SPECT) (Yitbarek *et al.*, 2022; Mayerhoefer *et al.*, 2020) [6, 5].

Positron emission tomography

Positron emission tomography (PET) is a functional imaging technique that uses radiopharmaceuticals labelled with positron-emitting radionuclides (Yitbarek *et al.*, 2022; Mayerhoefer *et al.*, 2020) [6, 5]. Following administration, the radiotracer accumulates in tissues according to a particular physiological or biochemical process (Mayerhoefer *et al.*, 2020) [5]. When a positron emitted by the radionuclide encounters an electron, the two particles undergo annihilation.

This interaction produces two gamma photons travelling in approximately opposite directions. PET detectors identify these photons simultaneously, and computer algorithms use the detected events to reconstruct a three-dimensional distribution of radiotracer activity (Yitbarek *et al.*, 2022) [6]. Consequently, PET provides information about tissue metabolism and physiological activity, rather than simply anatomical structure (Yitbarek *et al.*, 2022; Mayerhoefer *et al.*, 2020) [6, 5].

Applications of PET in veterinary medicine

PET has become increasingly important in veterinary research and selected clinical applications, particularly in oncology and metabolic research. Its applications include detection and staging of malignant tumours, identification of primary and metastatic neoplasms, assessment of tumour margins, treatment planning, monitoring therapeutic response, evaluation of inflammatory processes, investigation of pain, assessment of brain metabolism, investigation of cognitive dysfunction, evaluation of glucose metabolism, study of muscle metabolism during and after exercise, investigation of musculoskeletal inflammation and injury (Yitbarek *et al.*, 2022; Kanaga *et al.*, 2021) [6, 8]. PET can be particularly useful in oncology because malignant tissues frequently demonstrate altered metabolic activity compared with normal tissues. Functional abnormalities may therefore become detectable even before substantial anatomical changes develop (Yitbarek *et al.*, 2022) [6]. PET can also be combined with anatomical imaging modalities to improve lesion localization and interpretation (Yitbarek *et al.*, 2022; Kanaga *et al.*, 2021) [6, 8].

Single-photon emission computed tomography

Single-photon emission computed tomography (SPECT) is another nuclear medicine imaging technique that provides three-dimensional information regarding the distribution of a radiopharmaceutical (Yitbarek *et al.*, 2022; Mayerhoefer *et al.*, 2020) [6, 5]. In SPECT, the administered radiopharmaceutical contains a radionuclide that emits gamma photons. A gamma camera rotates around the patient and acquires multiple two-dimensional projection images from different angles. The collected projections are processed computationally to reconstruct a three-dimensional representation of radiopharmaceutical distribution within the body. Thus, SPECT primarily provides information about regional physiological function and radiotracer distribution (Yitbarek *et al.*, 2022) [6].

Applications of SPECT

SPECT has several potential applications in veterinary medicine and biomedical research. Examples include evaluation of renal function, assessment of renal perfusion and filtration, investigation of cerebral blood flow, evaluation of neurological disorders, assessment of neurotransmitter systems, investigation of neuro-inflammation, evaluation of blood-brain barrier alterations, research into epilepsy and seizure disorders and assessment of dopamine transporter activity (Yitbarek *et al.*, 2022) [6].

Combined-modality and hybrid imaging

Each imaging modality provides a different type of information. CT and MRI primarily provide anatomical information, whereas PET and SPECT provide functional or metabolic information (Yitbarek *et al.*, 2022) [6]. Combining these techniques allows anatomical abnormalities to be correlated with physiological or molecular changes (Yitbarek *et al.*, 2022; Mayerhoefer *et al.*, 2020) [6, 5]. Hybrid imaging refers to the integration of two imaging technologies within a single imaging system or coordinated imaging procedure (Yitbarek *et al.*, 2022) [6].

The major hybrid imaging modalities include PET/CT (Yitbarek *et al.*, 2022; Kanaga *et al.*, 2021) [6, 8], SPECT/CT (Yitbarek *et al.*, 2022) [6] and PET/MRI (Yitbarek *et al.*, 2022) [6]. These systems combine the complementary strengths of their individual components (Yitbarek *et al.*, 2022) [6].

Pet/ct

PET/CT combines metabolic information from PET with the detailed anatomical information provided by CT. PET identifies regions of altered metabolic activity, while CT accurately localizes those abnormalities anatomically. This combination is particularly valuable in oncology, tumour staging and detection of metastasis, treatment planning and monitoring therapeutic response (Yitbarek *et al.*, 2022; Kanaga *et al.*, 2021) [6, 8].

Spect/ct

SPECT/CT combines functional information from SPECT with high-resolution anatomical information from CT. This improves localization and characterization of areas showing abnormal radiopharmaceutical uptake. It can be useful in the evaluation of skeletal, neurological, renal and other functional disorders (Yitbarek *et al.*, 2022) [6].

Pet/mri

PET/MRI combines the metabolic information of PET with the superior soft-tissue contrast of MRI. This combination is particularly attractive for neurological, oncological and soft-tissue applications where detailed anatomical information is required alongside metabolic assessment (Yitbarek *et al.*, 2022) [6].

Advantages of advanced imaging modalities

Advanced diagnostic imaging has several advantages over conventional imaging techniques (Yitbarek *et al.*, 2022; Latif *et al.*, 2024) [6, 1]. Major advantages include non-invasive assessment of internal anatomy, reduction of anatomical superimposition, multiplanar image reconstruction, three-dimensional visualization (Yitbarek *et al.*, 2022; Jeffery *et al.*, 1992) [6, 10], improved soft-tissue characterization (Yitbarek *et al.*, 2022; Mariano *et al.*, 2017) [6, 2], better detection and localization of lesions (Yitbarek *et al.*, 2022; Latif *et al.*, 2024) [6, 1], assessment of lesion extent and tissue involvement (Yitbarek *et al.*, 2022; Latif *et al.*, 2024) [6, 1], functional and metabolic assessment (Yitbarek *et al.*, 2022; Mayerhoefer *et al.*, 2020) [6, 5], improved surgical planning (Yitbarek *et al.*, 2022; Kanaga *et al.*, 2021) [6, 8], treatment monitoring (Yitbarek *et al.*, 2022; Mayerhoefer *et al.*, 2020) [6, 5], improved understanding of disease pathophysiology (Yitbarek *et al.*, 2022; Mayerhoefer *et al.*, 2020) [6, 5], applications in clinical diagnosis, teaching and research (Yitbarek *et al.*, 2022; Jeffery *et al.*, 1992) [6, 10].

Three-dimensional reconstruction is particularly useful for understanding complex anatomical relationships (Yitbarek *et al.*, 2022) [6]. It can assist surgeons in planning procedures and can also be used for educational purposes and the development of patient-specific anatomical models (Yitbarek *et al.*, 2022; Kanaga *et al.*, 2021) [6, 8].

Limitations and challenges

Despite the considerable diagnostic benefits of advanced imaging, several limitations restrict their widespread use in veterinary medicine. The major challenges include high initial investment, maintenance expenses, specialized personnel, expert interpretation, animal size variation (Yitbarek *et al.*, 2022; Latif *et al.*, 2024) [6, 1], anaesthesia or sedation (Gerhard *et al.*, 2024) [11], radiation safety (Latif *et al.*, 2024) [1], limited availability (Yitbarek *et al.*, 2022; Latif *et al.*, 2024) [6, 1] and high operational costs (Yitbarek *et al.*, 2022; Latif *et al.*, 2024) [6, 1]. These limitations are particularly relevant in developing countries, where the availability of advanced veterinary imaging remains relatively limited (Yitbarek *et al.*, 2022; Jeffery *et al.*, 1992) [6, 10].

Future prospects

The continued development of imaging technology is expected to further increase the role of advanced diagnostic imaging in veterinary medicine (Latif *et al.*, 2024; Mayerhoefer *et al.*, 2020) [1, 5]. Improvements in detector technology, image reconstruction algorithms, artificial intelligence, three-dimensional modelling and molec-

ular imaging are likely to enhance both diagnostic accuracy and efficiency (Mayerhoefer *et al.*, 2020) [5]. Artificial intelligence and computer-assisted image analysis may assist in automated detection and characterization of lesions (Kanaga *et al.*, 2021; Mayerhoefer *et al.*, 2020) [8, 5]. Three-dimensional reconstruction and virtual modelling may further contribute to surgical planning, anatomical education and patient-specific treatment (Yitbarek *et al.*, 2022; Kanaga *et al.*, 2021) [6, 8]. Development of new molecularly targeted radio-pharmaceuticals may improve the ability of PET and SPECT to detect specific biological processes (Mayerhoefer *et al.*, 2020) [5]. Similarly, improvements in hybrid imaging systems may allow more precise correlation between anatomical abnormalities and functional or molecular changes (Mayerhoefer *et al.*, 2020) [5]. As technology becomes more accessible and costs decrease, advanced imaging is expected to become increasingly integrated into veterinary diagnostic and research facilities (Gerhard *et al.*, 2024; Mayerhoefer *et al.*, 2020) [11, 5].

Conclusion

Veterinary diagnostic imaging has progressed from conventional radiography toward sophisticated techniques capable of providing detailed anatomical, functional and molecular information (Yitbarek *et al.*, 2022; Latif *et al.*, 2024) [6, 1]. Radiography and ultrasonography continue to be fundamental imaging tools because of their affordability, accessibility and ease of application (Yitbarek *et al.*, 2022; Sigrist *et al.*, 2017) [6, 4]. However, CT and MRI provide superior cross-sectional anatomical information, while PET and SPECT enable assessment of physiological and metabolic processes (Yitbarek *et al.*, 2022; Mayerhoefer *et al.*, 2020) [6, 5]. The integration of anatomical and functional imaging through hybrid techniques such as PET/CT, SPECT/CT and PET/MRI provides a more comprehensive assessment of disease (Yitbarek *et al.*, 2022) [6]. These technologies have expanded diagnostic capabilities in veterinary oncology, neurology, orthopaedics, internal medicine and biomedical research (Latif *et al.*, 2024; Mayerhoefer *et al.*, 2020) [1, 5]. Although high equipment costs, maintenance requirements, limited availability of trained personnel and radiation safety considerations remain important challenges, technological advancements are expected to make advanced imaging increasingly accessible (Yitbarek *et al.*, 2022; Latif *et al.*, 2024) [6, 1]. The continued integration of three-dimensional reconstruction, artificial intelligence, molecular imaging and hybrid technologies is likely to further improve the diagnosis, treatment planning and monitoring of diseases in veterinary patients (Kanaga *et al.*, 2021; Mayerhoefer *et al.*, 2020) [8, 5].

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