Magnetic resonance imaging (MRI)

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- MRI is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body in both health and disease.
- MRI scanners use strong magnetic fields, magnetic field gradients, and radio waves to generate images of the organs in the body.
- MRI does not involve X-rays or the use of ionizing radiation, which distinguishes it from CT or CAT scans and PET scans.
- Magnetic resonance imaging is a medical application of nuclear magnetic resonance (NMR).
- NMR can also be used for *imaging* in other NMR applications such as NMR spectroscopy.

Conti…

- MRI was originally called NMRI (nuclear magnetic resonance imaging) and is a form of NMR, though the use of 'nuclear' in the acronym was dropped to avoid negative associations with the word.
- Certain atomic nuclei are able to absorb and emit radio frequency energy when placed in an external magnetic field.
- In clinical and research MRI, hydrogen atoms are most often used to generate a detectable radio-frequency signal that is received by antennas in close proximity to the anatomy being examined.
- Hydrogen atoms are naturally abundant in people and other biological organisms, particularly in water and fat.
- For this reason, most MRI scans essentially map the location of water and fat in the body.
- Pulses of radio waves excite the nuclear spin energy transition, and magnetic field gradients localize the signal in space.
- By varying the parameters of the pulse sequence, different contrasts may be generated between tissues based on the relaxation properties of the hydrogen atoms therein.

- In recent years, there has been a rapid increase in the availability of magnetic resonance imaging (MRI). Previously, these modalities were only available in universities or large referral institutions.
- Nowadays, first opinion practices is acquiring low field MRIs and mobile imaging units make these advanced imaging modalities readily accessible to the veterinary profession.
- Since their development, MRI has undergone continuous technological improvement and a large number of scientific papers describing features of diseases in animals have been published, contributing greatly to the advancements in clinical veterinary medicine.

- MRI is a diagnostic imaging procedure that has become commonplace in first-opinion practices.
- This is continually undergoing technological improvement and each has its advantages for different applications.
- MRI scanning will remain complex and expensive procedures. Fundamental differences exist between both technologies.
- Veterinarians are often faced with a choice between CT or MRI for the optimal diagnostic workup of their patients.
- A clear understanding of the strengths and weaknesses of both modalities will allow them to select the optimal imaging modality.

How does MRI works?

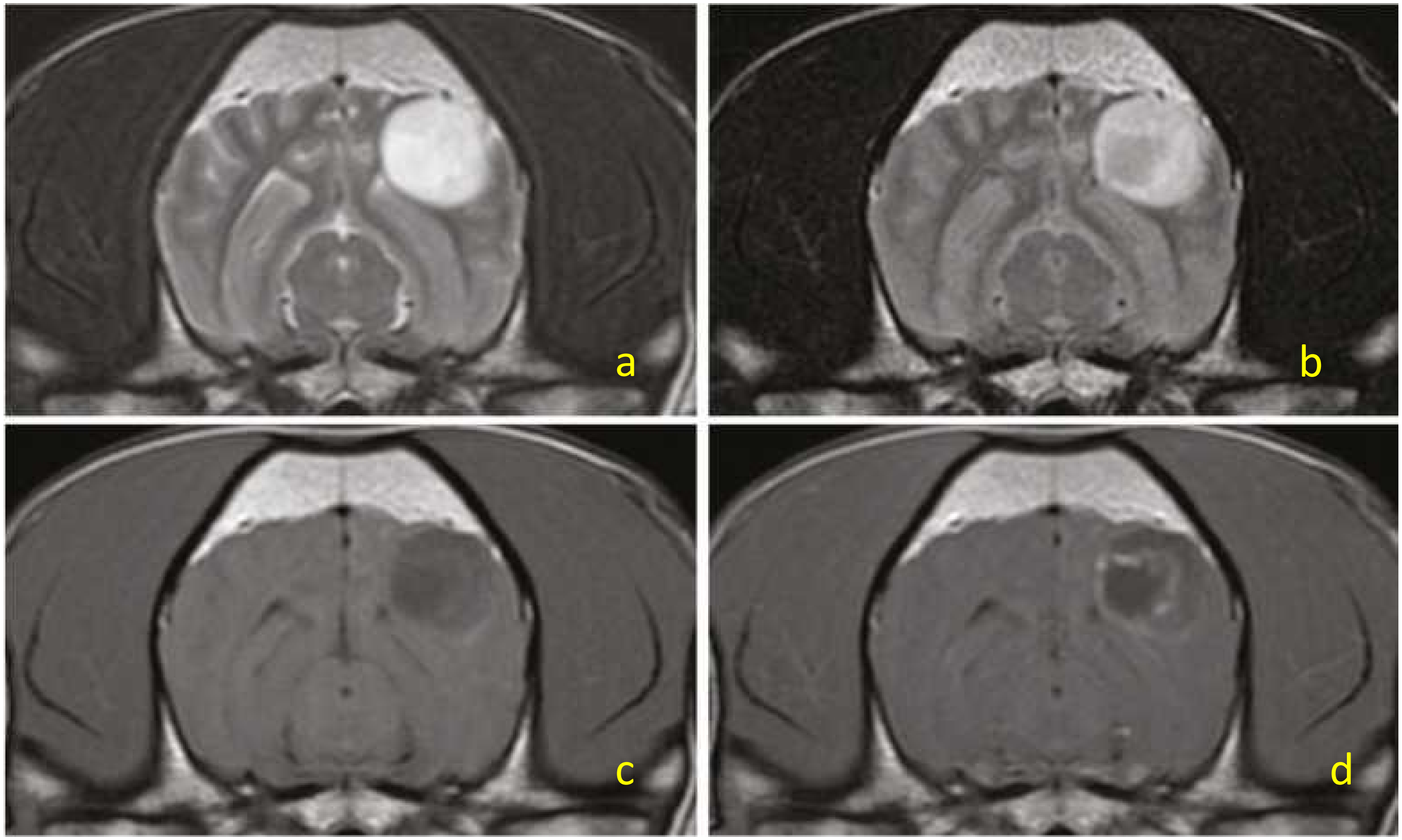
- Based on the magnetic properties of protons, MRI can be seen as a map of hydrogen protons of the body.
- The patient needs to be in a strong magnetic field. The magnetic moments of the hydrogen protons of the patient then align with the direction of the external magnetic field.
- With the help of radiofrequency (RF) transmitter coils, an additional magnetic field is then temporarily created.
- The RF pulse causes some protons to alter their alignment relative to the field. Once the RF pulse is turned off again, the altered protons return to their original equilibrium, a process called relaxation, accompanied by a release of energy in the form of an RF signal.
- The RF signal is captured by the RF receiver coil, which is usually placed close to the body part of interest.

- The speed of return to equilibrium is defined by two physical factors, the T1 and T2 relaxation times, which are tissue specific.
- This allows differentiation of different tissues on an MR image.
- Different combinations of RF pulses and magnetic fields can be used to create sequences of images with different tissue contrast.
- The spin-echo T1 and T2 sequences are most commonly.

Tissue characteristics on MRI images

Tissue/material	T1 weighted MRI	T2 weighted MRI
Air	Black	Black
Cortical bone	Black	Black
Fluid	Dark	Bright
Fat	Very bright	Very bright
Cerebrum	White matter brighter than grey matter	Grey matter brighter than white matter

- Additional MRI sequences can be applied to suppress selected tissues/material, such as fluid (FLAIR sequence) or fat (STIR sequence), in order to increase the visibility of adjacent structures.
- Intravenous injection of gadoliniumbased contrast medium is used in most patients to increase the vascular and soft tissue contrast.



Transverse MRI images of the brain of a dog with a histologically confirmed brain tumour (oligodendroglioma). The brightness of the tumour and the contrast to the neighbouring brain tissue varies between the T2-weighted image (a), FLAIR (b), T1-weighted image (c) and T1-weighted image post-contrast (d). The use of multiple MRI sequences helps to localise the lesion in the left frontal lobe and characterises its fluid-filled nature.

- In contrast to CT, MR images can be acquired in any desired body plane (transverse, dorsal, sagittal, oblique) with maximal image resolution. This leads to an increase in total examination time.
- For example, a typical brain protocol will take between 30 and 45 minutes. Post processing reconstruction in other planes is also possible, but due to the bigger slice thickness of MR images (usually 2 mm or more), the image resolution is then markedly decreased.
- An MRI scanner is composed of a main magnet, an RF transmitter coil and a receiver coil. Two main types of MRI scanners exist, which will be discussed now.

Low-field-strength MRI

- These systems use a permanent magnet with a field strength of approximately 0.25 Tesla. The magnetic field is created between two horizontal discs allowing a relatively open access for the patient. This can be advantageous for the scanning of equine patients or large body parts of other animals.
- Low field systems are relatively low in purchase price and maintenance as they have no specific requirements for electric supply and cooling and only require inexpensive magnetic shielding. They also have a small footprint and the low magnetic field is a bonus from a safety perspective.
- The image quality of current systems is good for most body parts, but it is not excellent. Because of the relatively small usable magnetic field, long body parts, such as the spine, need to be imaged in many small segments for which the animal needs to be repositioned.
- This increases the total examination time.

High-field-strength MRI

◦ These systems use superconducting magnets with a diffusion-weighted imaging (DWI) used in the characterization of ischemic strokes.

a. High-field-strength MRI and b. Low-field-strength MRI

Key differences between CT and MRI

CT	MRI
Ionising radiation	No ionising radiations
Based on x-ray technology	Relies on magnetic fields and radiofrequency pulses
X-ray beam attenuation as it passes through the body	Creates a map of hydrogen atoms in the body
Two main types of scanners: single-slice and multi-slice	Two main types of scanners: low- and high-field-strength
Image acquisition in transverse plane and reconstruction with near equivalent resolution in multi-slice scanners	Image acquisition in any plane
Thin slices (up to 0.5 mm)	Thicker slices (usually minimal 2 mm)
Quick acquisition, usually seconds to few minutes	Slow acquisition, usually about 30 to 60 minutes
Great imaging detail for bones	Great imaging detail for soft tissues
Equipment, setup and maintenance usually less expensive than MRI	Equipment, setup and maintenance usually more expansive than CT
Iodinated contrast media	Gadolinium-based paramagnetic contrast media

Indications for MRI according to the anatomical region

	MRI
Central nervous system	Imaging modality of choice Excellent tissue contrast Special sequences to identify particular pathology (eg, gradient echo, FLAIR, DWI)
Skull and splanchnocranium	Excellent Show additional meningeal enhancement in case of cribriform plate invasion Superior assessment of cranial nerves, inner ear, adjacent brainstem Special sequences to identify nerve pathology ...(eg, STIR)
Thorax	MRI should be performed only if CT is not available Respiratory and cardiac gating required
Abdomen and pelvis	Superior soft tissues contrast but requires additional expertise and experience
Musculoskeletal	Superior assessment of articular cartilage, synovial fluid, periarticular soft tissues, tendinous and ligamentous structures Superior assessment of bone marrow neoplastic infiltration
Angiography	Excellent Best results obtained with high-field-strength MRI scanners and special sequences