Diagnostic Imaging

Diagnostic imaging refers to the use of those techniques for looking inside the body in a noninvasive manner to aid a diagnosis. It is integral in reaching a diagnosis of an extremely large number of conditions in equine veterinary medicine.

The aim of article is to give an introduction into these various modalities, how they work, their main advantages and disadvantages and some examples of cases in which they have been useful.

RADIOGRAPHY

X-rays were discovered by a German physicist Wilhelm Röntgen in 1895 and were quickly adapted for use in human medicine. A radiograph is obtained by placing an area of a patient in front of an x-ray detector (an x-ray plate) and then firing a short pulse of x-rays through the patient and onto the plate.

Bones contain a high amount of calcium, which due to its atomic properties, is good at absorbing, or attenuating, x-rays. The soft tissues contain atoms that are not as good as absorbing x-rays, so more x-rays pass through without being absorbed.

Traditionally x-ray sensitive film was used as the detector. When a beam of x-rays is shone through a patient onto a detector, areas where there is no structures that stop the x-rays, e.g. not the patient, the film turned black. If no x-rays hit the detector, e.g. behind very dense bone, the film turned white.

Any density in between these two extremes turned a grey, tone contrast depends on the relative density of tissues in between the x-ray generator and the detector

Applications

Radiographs are especially good at looking at bones and so of particular use for orthopaedic cases and for looking at structures of the head, including the teeth and sinuses. We can occasionally use radiographs for soft tissue pathology, e.g. confirming the presence of lung masses.

Disadvantages

Safety: X-rays are a form of ionizing radiation meaning they can alter the atoms in the body leading to unnatural chemical reaction inside cells, which may cause the cell to die or to become cancerous. Lead is very good at absorbing x-rays so lead gowns, gloves and thyroid protectors are worn by operators to shield the most sensitive areas of the body.

Sensitivity: It is not possible to detect small changes in bone density therefore changes may be undetectable early in a disease process. This is of particular relevance with stress fractures in racehorses. These small, hair-line fractures are often initially impossible to see radiographically but have the potential to propagate into complete catastrophic fractures. If there is suspicion but radiographs are negative, the horse is often put on strict box rest, or cross-tied, for 10-14 days before re-radiographing. During this period the bone will re-model in response to the fracture (the fracture line actually gets wider over this period as part of the bones natural healing process) and there may be enough change in bone density for it to be visible on the radiograph. The other option in these cases is for a nuclear scintigraphy.

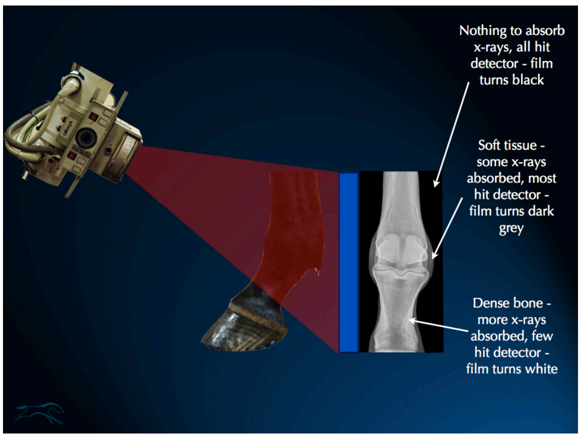
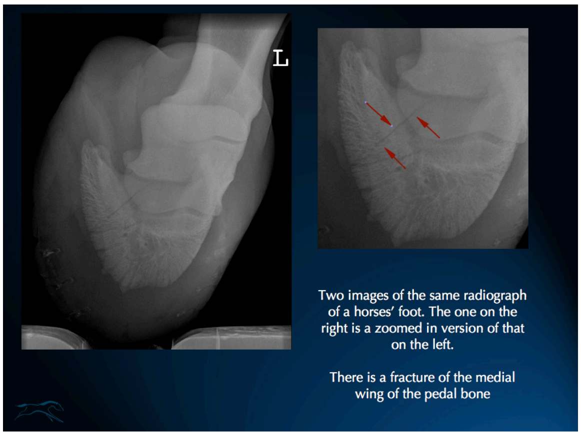
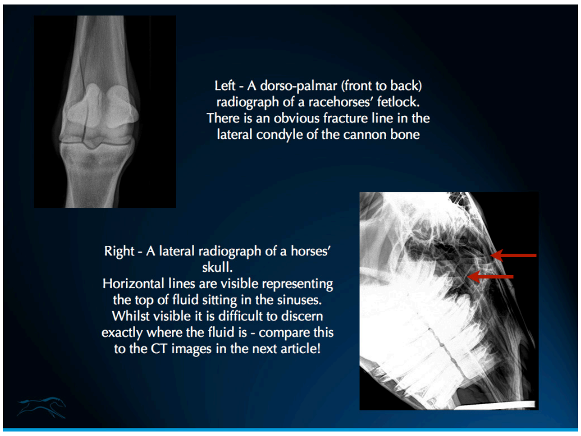


Fig. 1: Diagram showing how a radiograph is formed





Case slides 1 & 2

ULTRASONOGRAPHY

Ultrasonography relies on the use of high frequency sound waves. Images are produced by using an ultrasound transducer (probe) to send out pulses of ultrasounds. The waves are then reflected back from tissues under examination dependent or their density, and an image is produced by a computer.

Uses

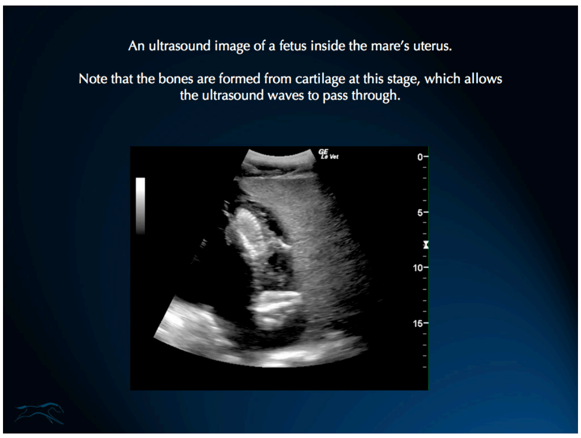
- **Orthopaedics** - for examining soft tissue structures such as tendons, ligaments, and muscles.
- Also extremely useful for looking at the surface of bones and joints.
- **Stud medicine** - to examine the ovaries and uterus in a non-invasive manner to provide information of ovarian follicular development, ovulation and ovarian pathology. It also allows for early and accurate pregnancy diagnosis, monitoring the development of the early embryo, sexing of the fetus as well as detection of pathology.

Advantages

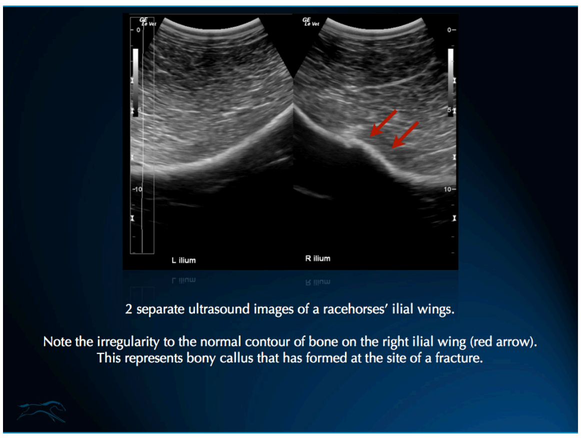
- **Portable**
- **Safe** - no ionizing radiation.
- **Quick** - there is no processing delay with images being acquired in real time meaning. Therefore can be used during certain procedures, e.g. for guiding in needle placement for blocking or medication of structures.

Disadvantages

- **Penetration** - all the waves are reflected back from air, bone and other dense materials, so no image is formed the other side of these structures. Ultrasound cannot therefore be used for looking into bone or into normal lung tissue.
- **Requires skill** - its accuracy is very dependent on the expertise, experience and knowledge of the individual operator.



Case slide 3



Case slide 4: Ilial Wings

GAMMA SCINTIGRAPHY ("BONE SCAN")

Gamma scintigraphy uses gamma rays emitted from radioactive substances to detect and evaluate bone disease that involves an increased rate of bone turnover. Gamma waves are identical to x-rays except for their source. In equine scintigraphy the vast majority of scintigraphic imaging is done using the pharmaceutical methylene diphosphonate (MDP), "labeled" with Technetium 99m (99mTc), a radioactive compound which emits gamma rays. When this radiopharmaceutical (99mTc-MDP) is injected into a horses' vein it will be distributed around the body. MDP binds to specific molecules that are highly prevalent at areas of bone with a high turnover and thus these areas emit gamma rays which can be detected using a gamma camera. The camera sends information regarding amount of radiation detected back to a computer that formulates a 2D image of relative radioactivity for interpretation. Abnormal areas of bone, those which are actively remodeling, will show up as "hot spots" on the 2D images, the greatest activity being associated with fractures, infection and tumor.

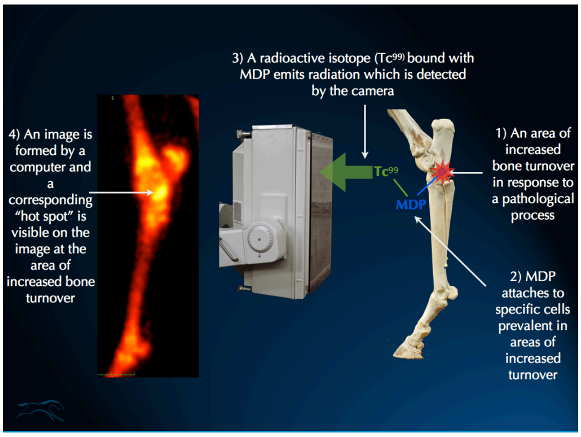
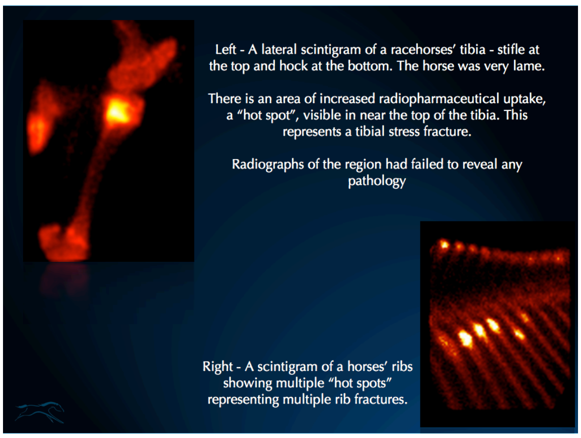


Fig 2: A Schematic Representation of Nuclear Scintigraphy



Case slide 5

Applications

- Cases where it is difficult to locate the origin of a lameness - particularly when it is non-specific or involves multiple limbs.
- **Back and pelvis injuries** - the large amount of overlying soft tissue structures restricts or limits the use of other modalities, as in the pelvis.
- **Stress fractures** - can be detected with scintigraphy within hours but may not be visible radiographically for 14 days.
- Confirming the significance of pathology detected using radiography; radiographs cannot tell us how recent or active an area of bony pathology is.

Advantages

- Highly sensitivity for areas of bone with increased turnover.
- Entire skeleton can be imaged relatively easily and quickly.

Disadvantages

- Poor for morphological changes
- Non-specific (fracture vs. infection vs. tumor); pattern recognition is important in interpretation as hot spots look similar for many conditions.
- Some significant lesions may not produce a change visible on the images
- **Safety** - Unlike radiography, it is the horse that is the source of radiation and thus some exposure to radiation is unavoidable in order to acquire the images. Horses emit radiation for some time following injection and are consequently put into "isolation" until the radiation they are emitting is below a certain level, usually about 24hours from injection. The radiopharmaceutical is excreted in the urine and special care has taken with the contaminated bedding.

CROSS SECTIONAL IMAGING MODALITIES

Cross sectional imaging refers to imaging based on cross-sections ("slices") of the body and includes both MRI and CT. These modalities are relatively recent additions to equine veterinary work but their availability and use for aiding diagnosis and surgical planning is becoming more wide-spread due to their vast benefits.

One of the main advantages of cross-sectional imaging is that it avoids superimposition of structures. It also enables the construction of slices in any desired image plane; in the case of CT this is often done retrospectively. Another gain is the improved spatial resolution.

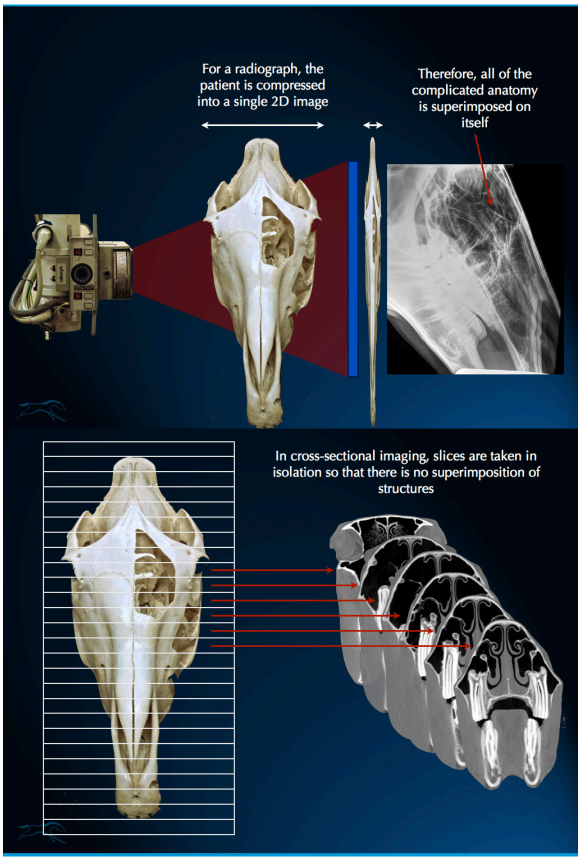


Fig 3a & 3b: Why Cross-Sectional Imaging Works

COMPUTED TOMOGRAPHY

Computed tomography (CT) is an x-ray imaging technique that uses computer-processed x-rays to produce slices of a patient. An English engineer Sir Godfrey Hounsfield first developed the technology in the 1970s providing a novel way for the indirect visualisation of organs.

Relatively recently systems have been adapted to allow to the scanning of horses under standing sedation, permitting CT scans of the head and cranial neck whilst negating the risks and costs involved with a general anaesthetic (GA). This development has led to CT becoming more accessible for equine veterinary use, although the scanner at Rossdales is one of only 7 systems in the UK capable of scanning horses under standing sedation. Standing CT in adult horses is limited to the head, neck and limbs; the amount of each depending on the individual system.

Basic Physics: An x-ray tube is spun around the patient firing multiple exposures to be measured by a detector opposite. The x-rays are attenuated (absorbed) to varying amounts by different tissues. The varying attenuation values of tissues, measured in Hounsfield units, enables the construction of a slice. Slices are then reconstructed into a volume by a computer that can then be used to construct planar images in any direction, called mulitplanar reconstruction.

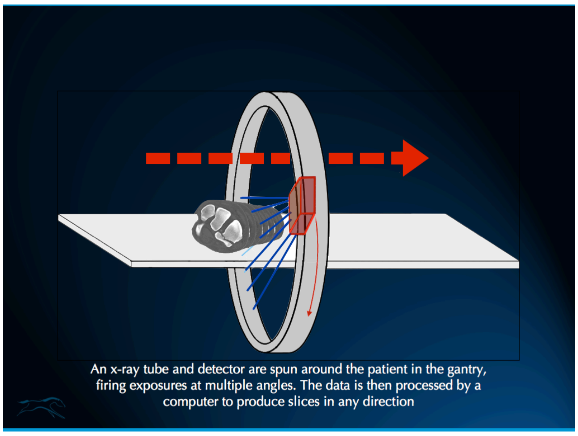


Fig 4

As with plain radiography, CT is best suited for evaluation of osseous structures where it affords excellent spacial resolution but it also has superior contrast resolution to radiographs in evaluating soft tissues.

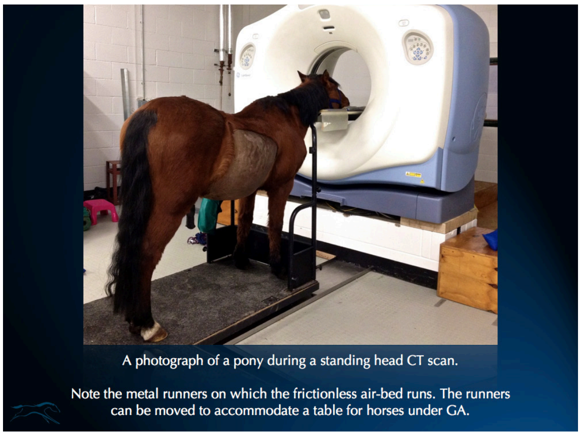


Fig 5

Applications and Advantages of Standing CT

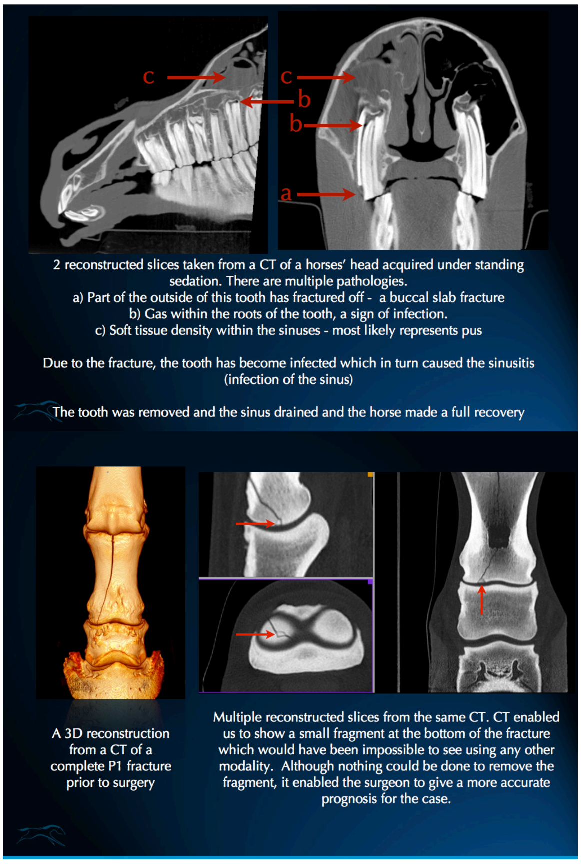
- Cases with **sinus and/or dental disease**. Radiography is limited in assessing for disease of the head due to superimposition of the complicated anatomy, poor spacial resolution and lack of contrast for soft tissues. CT has been crucial in the advancement of our knowledge and understanding of sinus and dental diseases, which are common in horses.
- Cases of **head trauma** where the morphology and extent of complicated fractures can be difficult to discern.
- **Neurological** cases and headshakers.
- Excellent **surgical planning**

Standing CT: Disadvantages

- **Movement** - much greater compared to an anesthetised patient, decreasing image quality
- **Risk of injury** to the horse or personnel or damage to the machine. Having an experienced and relatively constant team will reduce some of this risk.
- **Limited** to head and top of the neck, the further the horses' head is in the gantry, the greater the risk of damage or injury.
- It can take a long **time** to get the horse in the correct plane of sedation to persuade them to put their entire head through the gantry, and in some it is not possible at all.
- **Expensive**

Applications and Advantages of GA CT

- **Fractures** - the information that CT affords in comparison to radiography is vast enabling accurate assessment of morphology of complicated fractures and location of bone fragments.
- **Keratomas** and other space occupying lesions - CT enables accurate surgical planning for removal.
- **Foals** - especially for certain cases of septic arthritis, lung disease and rib fractures.



Case slides 6a & 6b

MAGNETIC RESONANCE IMAGING

Magnetic resonance imaging (MRI) uses radio waves and magnetic fields to produce images. The patient is placed in magnet and hydrogen atoms in water molecules in the tissues line up with the magnetic field and "resonate". The magnetic field is then altered using a radiofrequency (RF) coil fitted around the patient, changing the resonance of the atoms. This is detected using the RF coil and the data is fed back into the computer to formulate an image. The physics behind how and why this is achieved is vastly complex and requires a degree in quantum physics to fully understand!

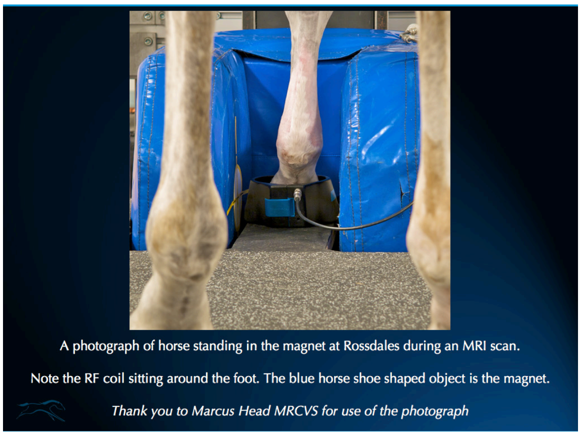


Fig 6

The first human MR scanner was produced in 1977 by Damadian, Goldsmith and Minkoff. MRI was first used in veterinary medicine in the 1990s with the use of human machines scanning heavily sedated or anesthetised patients. However the potential value of the technique for equine use wasn't recognised until the development of a scanner capable of scanning standing equine patients.

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The standing MR system is what is known as a "low field" scanner, meaning the strength of the magnet is less than 1 tesla (T). Most MR scanners in human hospitals are between 1.5-3 T. The images from the equine scanner do not have the clarity as those acquired using high field scanners but still are able to give us exquisite anatomical and physiological information of both soft tissues and bone.

Applications

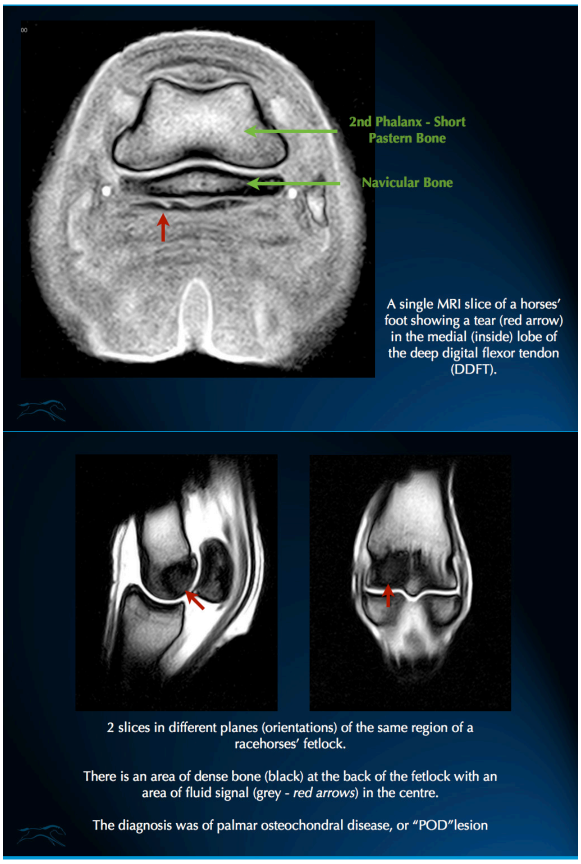
The equine MR scanner is capable of scanning up to the knee and hock in horses. However, the two main areas we routinely scan on a daily basis at Rossdales are feet and fetlocks. MRI has revolutionised our understanding of foot pathology and demonstrated the presence of numerous previously unrecognised or poorly understood conditions of the limbs.

Advantages

- Contrast for soft tissue - MRI has extremely good contrast for soft tissues but it also can give us an enormous amount of information regarding about bone compared with other modalities.
- Safe –there is no ionizing radiation

Disadvantages

- Expense
- Expertise - both to read the images but also to acquire them.
- Time and patience - the horse needs to stand completely still until the scan is complete. To complete a scan of one foot takes around an hour to acquire. Consequently some horses are not suitable candidates for MRI - e.g. young horses



Case slides 7 & 8