Advanced equine diagnostics – developments in computed tomography

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Advanced Equine Diagnostics – Developments In Equine Computed Tomography

Short title: Equine CT Developments

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Introduction

Moving away from the use of general anaesthesia (GA) for diagnostic imaging in equine practice is an ongoing challenge, the risk of GA related injury, myopathy and neuropathy can not be an overlooked consideration when evaluating the use of new technology. Although marginal advancement of pre-operative and procedural care has been made, anaesthesia risk in horses is still disproportionally high in comparison to other companion animals (Dugdale, 2016). There are also staff safety concerns to consider in relation to CT, the large volume of radiation emitted during scanning increases occupational exposure and risk to staff, preventing staff manually restraining patient during the procedure. Many methods have been adapted recently with these key factors considered, while ensuring the continuation of image quality and diagnostic accuracy. Within this article, we will review some of the different systems that have been created to overcome the complexities faced by those working in the equine veterinary industry.

CT Hardware

CT imaging is built up of three main components; the patient couch, x-ray tube and the detectors which rotate inside the gantry, around the patient acquiring and collecting attenuation data. The computer, which processes attenuation data, uses pre-defined reconstruction algorithms to create images. The user also has access to the operating console which enables software access, gantry control, exposure factor control and post processing viewing; enabling manipulation of data to ensure attainment of imaging is suitable for purpose, this also allows the construction of 3D imaging. Typically, veterinary practices will also utilise a Picture Archiving and Communication System (PACS), enabling the storage of all imaging gained from separate modalities in a central location. The common format of image archiving is Digital Imaging and Communication (DICOM), this ensures images are readily available, transferrable and may be viewed and manipulated via a DICOM viewer installed on any computer, although its worth noting the screen resolution may limit image quality (Seeram, 2018).

Conventional CT makes use of a fan shaped beam of x-rays collecting a series of axial slices in a continuous spiral (helical) motion about the subject. This is achieved by the patient either moving through the aperture of the gantry or the gantry of the system moving along the axis of the patient (Garvey, 2002). Cone Beam CT (CBCT) uses a cone-shaped beam of x-rays and a flat panel detector mounted opposite, using as minimal as one rotation about the subject (Venkatesh, 2017). Multi Slice Helical CT (MSCT) and fan beam geometry is typically used in CT scanners available to the veterinary market, due to their fast image acquisition and lower doses. MSCT uses slip ring technology where electrical energy is passed to a rotating ring using brushes so no static wires exist between the two enabling a continuous rotation, this coupled with moving the patient through the gantry aperture enables the helical data set to be acquired. The slice geometry of MSCT does not create a single planar section of data, therefore a step during algorithm reconstruction called interpolation must be used. Interpolation is a mathematical technique for estimating the value of a function from the known values on either side of it (Seeram, 2018).

Advantages of CT

Radiographic examinations are typically the first imaging modality of choice for suspected bone related pathology in the horse, superimposition of complex structures restricts evaluation of all potentially affected areas such as skull fractures. The use of a cross sectional imaging modality such as CT enables further information and could be considered for surgical planning and prognosticating a case (Crijns *et al*., 2019).

CT scanning uses x-ray beam attenuation as the fundamental for the image formation, the image created uses a grey scale that is assigned to the varied tissue density's dependent on the CT number (Hounsfield Unit) of the tissue. CT produces user friendly images as interpretation is similar to that of radiography where tissues of low density ie, the lung will appear dark and are described as hypoattenuating, whereas tissues such as dentine or bone will appear bright, and are described as hyperattenuating (Labruyère & Schwarz, 2013). With the use of MSCT small (<1mm) and overlapping slices can be obtained, this contributes to the high spatial resolution and ability of CT to be used in MPR and 3D surface reconstructions (figure 1) (Puchalski, 2012).

Limitations of CT

Although CT has many benefits in practice including the fast acquisition time, this does not mean it is a flawless imaging modality, a CT image is a digital image so is affected by at least five physical properties; spatial resolution, contrast resolution, temporal resolution, noise and artifacts. The exposure factors are directly linked to the quality of the images, increasing mA (beam quantity) and increasing kV (beam quality) reduces noise and helps to improve image quality but will increase effective dose (mSv) to the patient. Operators are committed to working within the remit of the 'As Low As Reasonably Achievable' (ALARA) principle, whereby patient dose is kept to a minimum but image quality is not compromised (Seeram, 2018).

CT has limited efficacy in the identification of soft tissue lesions due to the way images are created despite algorithms, window level and width settings for soft tissues. When two tissues that are of similar density are in apposition it can be hard to differentiate between them. Practitioners can utilise contrast enhancement to help alleviate this problem (Puchalski, 2012).

Contrast Media

Positive contrast enhancement typically utilises an iodine-based contrast media, this is due to the high atomic number of iodine leading to its ability to attenuate x-rays. Vascular administration of iodine contrast results in highlighting of areas with altered blood flow which can occur with injured of inflamed soft tissues, enhancing the capabilities of CT in the use of soft tissue related lesions (Nelson *et al.,* 2017). Intrasynovial use of contrast or arthrography/ tenography can be used to outline the surface of structures that comprise the region. One study reported that CT arthrography was better than high field MRI for the identification of cartilage lesions in the equine fetlock joint (Figure 1.) (Hontoir *et al.,* 2014).

Figure 1. Arthrography of the standing equine Fetlock Joint courtesy of Vet-Dicon, Germany

Adverse events associated with contrast media have been noted in equine studies, one study noted hyperthermia in 11% of cases while another noted urticaria or skin oedema in 4% of horses in both studies all of the signs resolved without veterinary intervention. A study that looked into associated reactions of GA myelographic procedures found that 34% (n=95) of the 278 patients included had an adverse reaction, and of those 95 patients, 3% of were euthanised at the owner's discretion and 5% were euthanised as a result of the adverse reaction. The adverse reactions were significantly associated with larger volumes of contrast material and longer GA time when compared to patients that did not show any signs of an adverse reaction (Mullen et al, 2015; Pollard & Pulchalski, 2011). Gough *et al.* (2020), found a similar incidence of post myelographic contrast reactions with 36% (n=18) of the 51 cases reviewed displaying an adverse reaction.No horses were found to display any clinical signs of seizure like activity or resulted in euthanasia; although one horse did suffer a catastrophic fracture during the anaesthetic recovery period. Authors concluded the nature of the procedure to be in line with previously described risks of any kind of GA procedure and that the superior diagnostic and prognostic information that CT provides outweighed the risks.

Clinical Applications Standing & GA

CT systems for equine patients are becoming more widely available throughout the UK at specialist centres, for both standing sedated and/or GA patients. Depending on the practices requirements there are different systems commercially available within the UK, many of which utilise one gantry with the ability to change from patient bed to, for standing head scanning to patient table for more complex structures, such a limbs and lower neck. Most systems are developed with the practical application of the set up in mind, and individual to the centre, therefore variations may be seen throughout different venues.

Standing sedated CT for equine patients can be used for imaging the head, most commonly looking for pathology within the paranasal sinuses and nasal cavities, larynx, pharynx and the guttural pouches, dental arcades, orbit, temporomandibular joint and cranial nerves it is also an invaluable tool for the further evaluation of head trauma and skull fractures (Dakin *et al.,* 2014). Accurate identification of all cranial nerves from their surrounding tissues is not possible with current CT protocols (Dixon *et al.,* 2017). Imaging the cranial cervical vertebrae is possible standing, although using this method there are limited quality; and the potential for reduced patient cooperation, movement artifacts and patient size issues.

Two main techniques have been described; these include a sliding gantry system that passes over a stationary head or a stationary gantry where the patient's head is passed through the aperture of the gantry. The latter requires the patient's body to be suspended on an air platform hovercraft system designed to make the patient “weightless”, it can then be driven by the couch mechanics. Typical scan times are about 30 seconds, this enables acquisition of attenuation data from C1 to the incisive region of the skull. (See Figures 2 & 3) (Dakin *et al*., 2014).

Figure 2. Horse positioned for a standing

Figure 3. Horse positioned on a hovercraft air platform

Standing limb CT, although in early development, has the potential to revolutionize orthopedics and lameness diagnosis in the equine patient. Many authors, from different centers, have reported on different means of acquiring standing CT images of the distal limbs. One such system available uses CBCT technology and operates robotic arms mounted with an X Ray tube and flat panel detectors that are controlled to move around the area of interest systematically to acquire the images (Riggs, 2019).

A system available through Asto CT™, enables patients to walked over the gantry before it raises up around the limb. The attenuation data is gathered from fully weight baring limbs and generally is capable of attaining images from the hoof to the proximal carpus/tarsus. Commonly this is completed within 30 seconds. Another added benefit can be observed during standing surgical procedures, patient may stand on the platform allowing for CT imaging to occur during at intervals of the procedure; checking placement and progress. Very low tube currents are used so minimal dose is produced enabling operators to stay safely with the patient. The gantry has been designed so that it is sealed and can withstand a 1000kg strikeforce should an incident occur; the operator control panel has also been created with veterinary practice in mind with a simple to use software (See Figure 4).

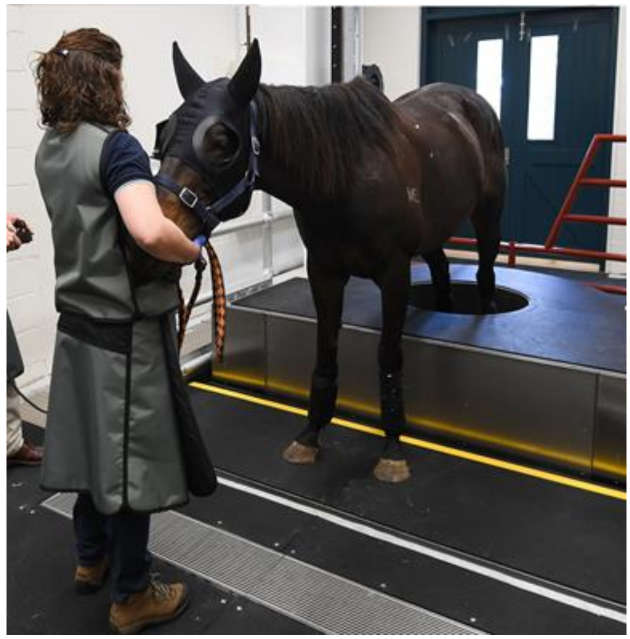

Figure 4. Horse positioned for standing limb-pair CT scan Courtesy of Asto CT/OSL & University of Melbourne, USA.Figurefindd

Another system commercially available through Vet-Dicon in Germany is the Qalibra™. Joint partnership between Canon Medical using their Aquillion LB gantry system with an opening of 90cm and imageable field of view of 70cm has been linked to a patented sliding and height adjustable platform controlled via the CT control panel. The gantry is lowered to floor level and the patient places a fore or hindlimb through the aperture of the gantry; completing the scan by the gantry moving away from the patient during attenuation data collection (Figure 5).

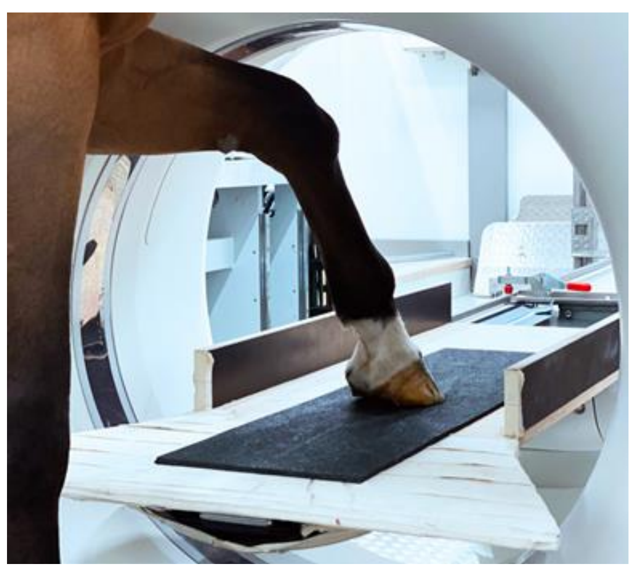

Figure 5. Horse limb positioned for a standing forelimb CT. Courtesy of Vet-DICon, Germany.

At the end of 2020, Hallmarq launched a new CBCT standing system capable of imaging the distal limb. The system is installed at sub floor level or within a low platform frame, prioritising horse safety by creating a walk in/walk out set up. Detector plate and generator revolve around the limb on a novel dual concentric ring design. The plate remains close to the imaged limb improving image quality, with acquisition time taking 60 seconds. Additionally, Hallmarq is one of the few companies to incorporate motion correction technology into their software to better ensure clear high-quality images of the standing patient.

GA CT is less widely available in the UK than standing CT however it is invaluable for imaging of the entire cervical vertebrae and cranial thoracic vertebrae. Cervical vertebral column pathology has been identified as the leading non-infectious cause of ataxia in equine patients (Lindgren *et al.,* 2020). CT scanning of the cervical vertebrae has become an additional next-step diagnostic tool after traditional latero-lateral and Laterodorsal-Lateroventral radiographic projections have failed to give an accurate diagnosis and a lack of detail (Withers, 2010). The tomographic nature of CT has the advantage of removing superimposition and allowing for the use of multiplanar reconstructions facilitating a more accurate diagnosis; leading to higher sensitivity and specificity (Gough *et al.,* 2020). CT is commonly utilised in combination with myelography as a diagnostic tool, with the potential to become a gold standard diagnostic modality of the future with further refinement (See Figure 6&7) (Dixon, 2018).

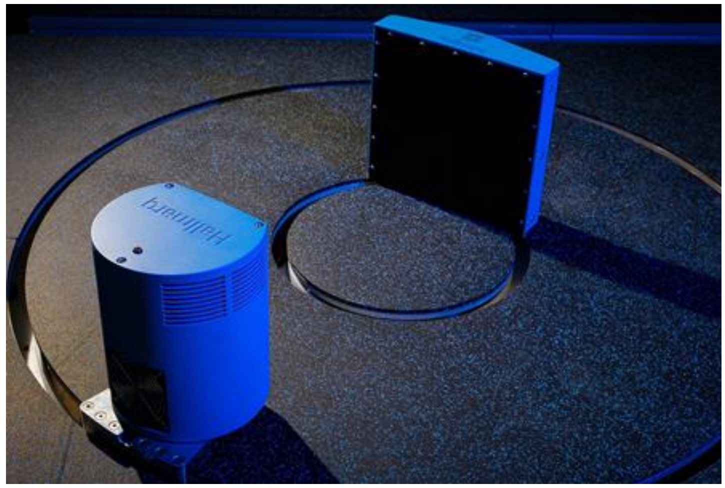

Figure 6. Hallmarq Standing limb CT Scanner.
Courtesy of ©Hallmarq Veterinary Imaging 2021

Figure 7. Horse positioned for standing forelimb CT Scan with operator positioned behind lead screen. Courtesy of ©Hallmarq Veterinary Imaging 2021

GA CT imaging of the limbs is typically done by positioning the horse on a modified patient bed which is attached to the human couch or the system available from Vet-Dicon has modified the human couch to withstand the weight of the horse; enabling fast positioning. The gantry then moved over the patient and imaging is completed within 10 minutes. Imaging from the hoof structures all the way up to the carpus and tarsus can be easily imaged and centres reporting methods of imaging of the equine stifle as well as pelvis (See Figures 8&9) (Bergman *et al*., 2007).

Figure 8. Horse positioned in dorsal recumbency for CT of the cervical spine. Courtesy of Vet-DICon, Germany.

Figure 9. C6 - T3 3D surface reconstruction. Courtesy of B&W

CT limb imaging can be a useful diagnostic tool when ultrasound and radiographic examinations reveal no clear cause for lameness. A case report of two endurance horses found that CT was able to diagnose palmar metacarpal stress fractures where repeat radiographs and scans failed to give a diagnosis (Beccati *et al.,* 2019). CT imaging has also been compared to the widely available standing low field MRI system, 22 lame horses (31 limbs) that had hoof scans using both modalities were compared for lesion identification. It was found MRI was better at DDFT lesion identification within the distal to the proximal portion of the navicular bone, but CT was able to identify lesions more proximally that were not visualised on MRI. This was attributed to the smaller scan field of view and signal drop out at the proximal portion of the MRI protocol. Due to the fundamentals of MRI it has an advantage over CT due to its ability to identify physiological properties of the patient, fluid accumulation within bone or "bone oedema" can be identified that is not seen in CT imaging (Vallance *et al.,* 2011). However, new techniques from human medicine using non-calcium bone reconstructions have been adapted by Vet-Dicon, which have an adequate sensitivity and specificity for the diagnosis of bone marrow oedema, highlighting scope for future improvements (Diekhoff *et al*., 2019).

Conclusion

Many companies strive to develop a one size fits all CT Scanner for the equine patient, many of the current systems show great promise being able to image from the hoof to carpus and tarsus as well as the head and cranial neck standing but with few installations it is hard to gage their success (Riggs, 2019) (See figures 10 & 11).

Figure 10.. Horse positioned in lateral recumbency for a stifle CT. Courtesy of Vet-DICon, Germany.

Figure 11. Horse positioned in lateral recumbency for hindlimb CT using a modified scissor-lift patient bed. Courtesy of B&W Equine Vets, UK.

No conflict of interest none.

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