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Clinical Commentary

Computed tomography in the evaluation of the equine head

J. Kinns* and A. Pease

Michigan State University, D208 Vet Med Center, East Lansing, Michigan 48824, USA.

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Introduction

Diagnostic imaging of the equine head is challenging. Conventional radiography, available in most clinical practice settings, often provides limited information due to superimposition of complex anatomic structures. While multiple views can, and should, be obtained, accurate diagnoses and the exact regions involved are hard to determine. The degree of bone involvement can be particularly difficult to ascertain as a large amount of bone lysis must occur before it can be seen radiographically. With the advent of advanced cross sectional imaging modalities, such as computed tomography (CT) and magnetic resonance imaging (MRI) many of these limitations can be overcome.

Basics of computed tomography

Computed tomography uses x-ray beam technology to produce a tomographic slice of the patient's anatomy. As the region of interest on the patient moves through the CT gantry, an x-ray tube rotates about the region allowing x-ray beams to penetrate the tissue from multiple angles. Detectors contained within the gantry measure the attenuation of the x-ray beam, and these attenuation values are used to construct a transverse image or slice of that area. The information obtained from all the slices can then be used to create a volume of data that can be reconstructed in sagittal, dorsal and oblique imaging planes as required (**Fig 1**). Three-dimensional imaging reconstructs the volume of tissue into a structure that is more familiar to the clinician and therefore excellent for surgical planning. Three-dimensional image manipulation can also provide excellent images for teaching purposes, or display findings to the client in a way that is easier for them to understand. Specialised software (Barco Voxar 3D Visualization and Analysis Software)[1] allows reconstructions of multiple tissue layers allowing the anatomy of the patient, from cutaneous tissue down to bone, to be evaluated separately (**Fig 2**). CT is excellent for evaluating bone lesions, has superior contrast resolution to radiographs in evaluating soft tissues, and is typically the modality of choice for assessing acute haemorrhage in trauma cases (Go and Zee 1998).

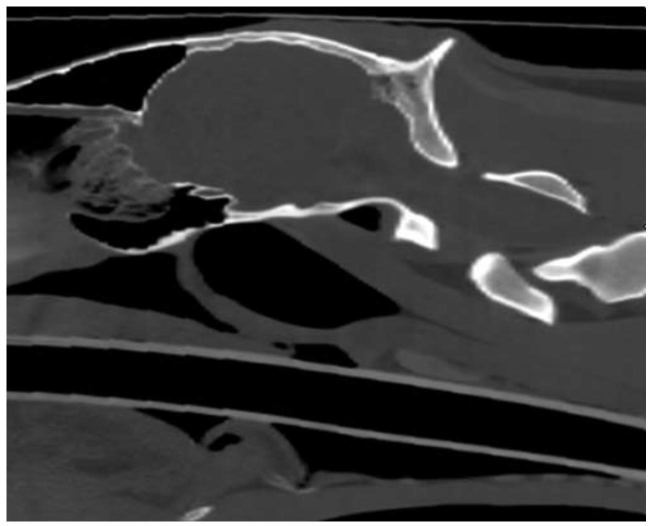

Fig 1: Sagittal reconstruction of the caudal skull and cranial cervical spine of a horse displayed using a bone window.

Viewing CT images

Computed tomographic images are adjusted when viewing to evaluate specific tissue types. This is done by either maximising spatial resolution or contrast resolution. Spatial resolution is the ability to determine 2 structures of the same attenuation as distinct from one another, while contrast resolution is the ability to differentiate structures of similar attenuation. Since CT produces approximately 4096 shades of grey, the computer needs to determine what the most important shades are and display the images accordingly. This is done through the use of 'window level' and 'window width'. In evaluating bone, for example, the

*Author to whom correspondence should be addressed.

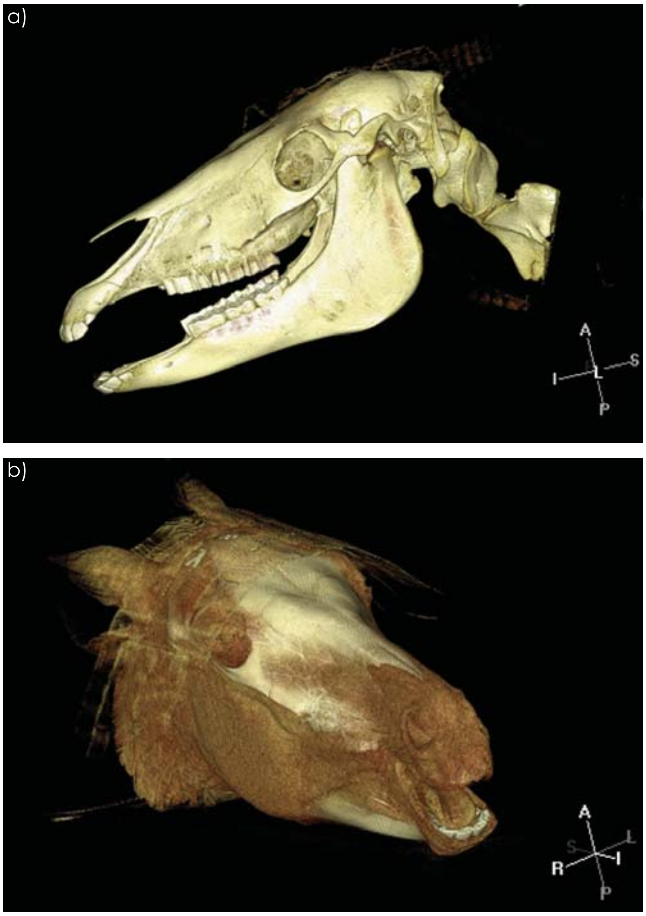

Fig 2: a) Three-dimensional reconstruction of a CT study of a normal equine head, demonstrating the normal anatomy of the skull. b) Three-dimensional reconstruction of a CT study of a normal equine head with a muscle layer included.

window ‘level’ is set to a typical CT attenuation value for bone and the window ‘width’ (the numbers of shades of grey included in that image) is wide (**Fig 3**). This gives an image with better spatial resolution but reduced contrast resolution (soft tissue and fluid cannot be differentiated). In evaluating soft tissues a narrow window width is used to maximise contrast (at the expense of spatial resolution) and the window level is set to optimise soft tissue. With the appropriate settings the white and grey matter within the brain can be differentiated (**Fig 4**). Furthermore, at the time of scanning, adjustments to the acquisition parameters can optimise the study for a particular tissue type. A bone algorithm study, for example, will have edge enhancement that further improves the spatial resolution of the images, although at some expense to the contrast resolution. Appropriate planning and subsequent thorough evaluation at different window and level settings are therefore important in interpretation. Diagnostically, the CT attenuation value of a structure (also referred to as the Hounsfield unit or CT number) can be used to determine the likely composition of that tissue. Thus acute haemorrhage and mineralisation, while both hyperattenuating (bright), can be differentiated.

Use of contrast media during CT of the head

Contrast enhanced CT improves our ability to evaluate soft tissue lesions. Peripherally injected i.v. iodinated contrast agents will localise to areas of increased perfusion. Image acquisition minutes after injection will demonstrate areas of hyperattenuation where contrast has accumulated. This can be very important in delineating the margin between normal and abnormal tissue that may not be evident on precontrast images alone. CT angiography takes this concept a step further. Following a bolus injection, image acquisition can be timed to coincide with the arrival of contrast in the arteries or veins and allow specific evaluation of these structures. This can be very useful in assessing the involvement of

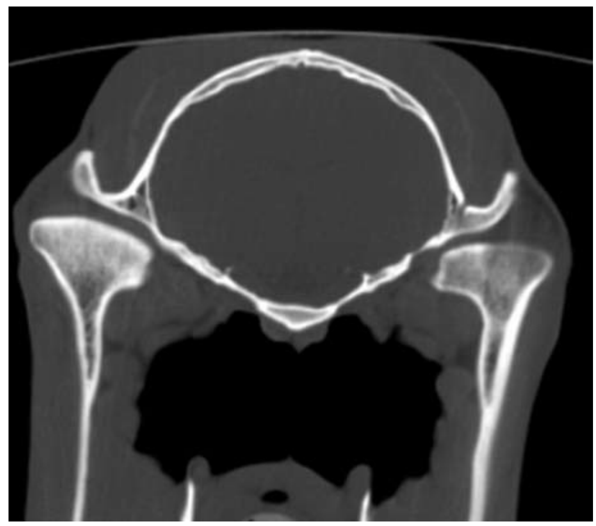

Fig 3: A transverse image of a normal equine head at the level of the temporomandibular joint, viewed with a bone window.

Fig 4: A transverse image of a normal equine head at the level of the mid-brain, viewed with a soft tissue window. Grey and white matter can be subtly differentiated, and the mesencephalic aqueduct is clearly visible, although the spatial resolution of the cranium is poor.

Fig 5: A horse undergoing positioning in the CT gantry for imaging of the head.

vessels in neoplastic structures and in the evaluation of vascular malformations. Other specific contrast CT procedures are used on a case by case basis. CT fistulography is useful in evaluating the origin of draining wounds, and CT dacryocystography can be used to evaluate occlusion of the nasolacrimal duct (Nykamp *et al.* 2004).

Artefacts associated with imaging the equine head

Certain CT associated artefacts can cause particular problems in imaging the equine head. The caudal fossa region of the head is particularly prone to artefact, due to the presence of the thick petrous parts of the temporal bones. The bone causes an effect called 'beam hardening' whereby the least energetic photons within the x-ray beam are absorbed and the effective kVp (the average energy) of the continuing beam increases. The more energetic beam is less attenuated, and the detectors erroneously calculate that the beam must have passed through less attenuating tissue, resulting in black bars and streaks across the image. One way to minimise this artefact in the equine head is to acquire the study as thin slices and then add these together to produce thicker transverse slices for interpretation. This thick-section reformatting has been shown to significantly improve the image quality of CT scans of the equine caudal fossa region (Porat-Mosenco *et al.* 2004).

Clinical use of CT in evaluation of the equine head

Computed tomography has been used in the evaluation of the equine head for the last 2 decades, although use is limited by its restricted availability, the necessity for a specially adapted equine table and the need for general anaesthesia (**Fig 5**). Recently a standing equine CT system has been developed, which has the potential to increase the utility of the modality in evaluation of the equine head (Jose-Cunilleras and Piercy 2007). Normal CT anatomy of the head has been well described (Morrow *et al.* 2000; Smallwood *et al.* 2002; Probst *et al.* 2005) and these studies can be used as a reference for clinical cases.

Indications for CT evaluation of the equine head are varied, and clinical use of this modality has been described in multiple disease processes. Sinonasal disease is a common clinical presentation for which conventional imaging often provides only limited information and makes it difficult to provide a specific diagnosis. CT can be used to determine the cause of such clinical signs (Henninger *et al.* 2003; Annear *et al.* 2008; Cehak *et al.* 2008). Dental causes of sinusitis can be well evaluated with CT, and the acquired images can be particularly useful for surgical planning. The CT features of alveolitis have been described; gas bubbles with a bulging root area or fragmentation of the root with thickening of the sinus mucosa were considered characteristic features of dental decay (Henninger *et al.* 2003). Age-related changes in the CT appearance of the mandibular cheek teeth are also documented (Kirkland *et al.* 1996) and CT has been used to define the presence of dental congenital anomalies prior to surgical removal (Tudor *et al.* 1999; de Mira *et al.* 2007).

Computed tomography is well suited to the evaluation of osseous lesions. The temporomandibular joint can be particularly difficult to evaluate radiographically. CT has been used to better define traumatic and infected lesions of that region (Warmerdam *et al.* 1997; Devine *et al.* 2005; Nagy and Simhofer 2006) and also of the stylohyoid bone (Pease *et al.* 2004; Chalmers *et al.* 2006).

Evaluation of intracranial structures is not possible radiographically. Although MRI is much better for the evaluation of soft tissues due to superior contrast resolution, CT can provide important diagnostic information and is more rapidly acquired. The normal CT appearance of the equine pituitary gland has been described (McKlveen *et al.* 2003) and may be used as a basis for evaluating pathological changes in the region. Intracranial abscesses can be visualised with CT (Allen *et al.* 1987; Janicek *et al.* 2006); the modality is particularly useful in determining the degree of associated calvarial lysis but can demonstrate brain compression and associated oedema. Intracranial neoplasia is not common in the horse, but contrast-enhanced CT can be used to localise certain lesions. The CT appearance of cholesterinic granulomas has been described, and although the attenuation and enhancement patterns are variable the lesion location is characteristic (Vink-Nooteboom *et al.* 1998). These growths of the choroid plexus occur in the lateral and fourth ventricles; they can cause neurological signs due to associated hydrocephalus and direct brain compression (Jackson *et al.* 1994). CT guided biopsy can be used to differentiate these from other less common tumour types (Vanschandevijl *et al.* 2008).

Computed tomographic evaluation of extracranial neoplasia is commonplace in smaller domestic species, and has been described previously in the equine head. It allows a more thorough evaluation of bone and soft tissue involvement than radiographs provide. Studies in other species show that CT is more accurate than radiography in determining the extent of disease (Thrall *et al.* 1989) and this is probably also true in the horse. While the features of certain tumours are well described in other species, the CT characteristics of equine cranial malignant neoplasia have not been determined, although the CT appearance of nasal adenocarcinoma has been described (Davis *et al.* 2002). The case series in this issue 'Computed tomography in the diagnosis of malignant sinonasal tumours in three horses' (Veraa *et al.* 2009) demonstrates the utility of CT in determining the extent of lesions associated with malignant neoplasia of the equine head. Further studies may allow us to better characterise the CT features typically associated with certain tumour types.

Conclusion

Computed tomography provides many advantages over radiography in evaluating the equine head. With appropriate planning and interpretation these studies can provide valuable information in the diagnosis, prognosis and surgical planning associated with multiple clinical conditions.

Manufacturer's address

[1]Barco, Kortrijk, Belgium.

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