The Role of Head Computed Tomography in Equine Patients

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Introduction

Diseases of the head of horses occur frequently and are often categorized by their location into dental, sinonasal or neurological origin. Additionally, lesions of the soft tissues including the tongue, alivary glands, the temporomandibular joints as well as the hyoid apparatus may be present. The most common reasons why equine radiography of the head is performed is due to dental or sinonasal disease or for evaluation of injuries due to a traumatic event. Head radiographs provide a good spatial resolution; however, due to the superimposition of anatomic structures, localization of lesions can be quite challenging. In cases were radiography and endoscopy do not provide sufficient information or when there is incomplete or no response to treatment, additional diagnostic imaging modalities are often considered. The equine head is an anatomically very complex structure, making it therefore most suitable for exploration using cross sectional imaging techniques such as computed tomography (CT) or magnetic resonance tomography (MRI), where the superimposition of anatomic structures is eliminated. CT is commonly the method of choice for evaluation of osseous or air-filled structures and MRI is usually the preferred method for evaluation of the brain, spinal cord and soft tissue structures. It is important to remember, that CT is for neuroimaging by many only considered the diagnostic imaging test of choice, if magnetic resonance imaging (MRI) is not available. The only exception is within the first 24 hours post-acute head trauma, were CT is often the go to technique for the detection of acute or subacute hemorrhage, especially in cases, where an early diagnosis for case management and treatment is necessary, as it is a fast, often more readily available and more cost effective modality compared to MRI. However, controversy about the use of CT for brain imaging exists also in human patients, especially children, where in acute or febrile seizuring patients, the yield of positive results using computed tomography is often low. MRI of the head in horses has demonstrated a beneficial diagnostic information, however, the need for anesthesia, cost and the lack of MRI facilities accessible to horses currently often limits the use of this technique.

Clinical computed tomography of the equine head has over the last few years rapidly advanced and in some places, the ability to utilize CT for standing sedated horses, has made this technique more readily available. Multidetector computed tomography (MDCT) units provide an excellent resolution and allow scanning of the head in submillimeter slices (currently as low as 0.5mm), providing outstanding detail of the osseous structures of the skull; however require the horse to be fully anesthetized and recumbent during the CT scan. Despite the excitement of utilizing standing CT units in horses, these units are still in its infancy and several limitations still remain including the size of the patient, motion of the standing sedated horse and high exposure settings to penetrate the high density osseous structures of the head. These high exposure setting can pose a high safety risk for personnel restraining the sedated horses during the exam. Additionally, the images of these standing CT units have a reduced image quality when compared with MDCT images. However, the benefit of being able to scan horses without the requirement of general anesthesia is clinically important and future technical developments will likely make this technique more readily available.

The next few paragraphs focus on disease of the head were CT can provide additional benefits in the evaluation of the disease process. Not all disease processes occurring in the head will be discussed, but information is added for disease were additional CT imaging may add value to the diagnostic workup of equine patients.

Imaging of dental disease

Young horses have 24 teeth (paired I3/3, C0/0, P0/0 and M3/3). On radiographic or CT imaging deciduous teeth are more radiolucent, have shorter reserve crowns and roots, and a shorter cross-sectional area than permanent teeth. Additionally, it is important to remember, that in normal teeth of young horses radiolucent eruption cysts can be present adjacent to the immature apices of the teeth, leaving the impression of an apical infection.
The mature horse has 40 to 42 teeth (paired I3/3, C1/1 in the male or C 0/0 in the female, P3 or 4/3 and M3/3). All

permanent teeth in horses are hypsodont, meaning that they continue to erupt throughout life compensating for the grinding wear, which is usually 2-3 mm/year in the adult horse. Due to this continues growth, the appearance of the teeth, and especially their apices, varies considerably throughout the life of a horse. Furthermore, due the variable eruption times of horse teeth, the length of the reserve crowns of the cheek teeth are variable with the first molars (09s) consistently being the shortest, as they are the first permanent cheek teeth to erupt. Additionally, the second premolar teeth (06s) are shorter than the adjacent cheek teeth. Additionally, the apices of some of the check teeth tend to extend into the paranasal sinuses with the caudal aspect of the fourth maxillary premolar (08s) and the first maxillary molar (09s) extending into the rostral maxillary sinus and the second (10s) and third maxillary molar (11s) extending into the caudal maxillary sinus.

Apical infection/inflammation
Common CT findings in horses with inflammatory dental disease are similar to radiography and include widening of the diastema, sclerosis of the alveolar bone without or with osteolysis, blunting of the tooth root, gas within or adjacent to the tooth root and fragmentation of the teeth. As a reminder, the fourth maxillary to second molar tooth roots are closely associated with the maxillary sinus and can, when dental disease is present, result in sinusitis. Most tooth root fractures are idiopathic and occur less commonly secondary to external or iatrogenic trauma such as due to a dental procedure. Tooth root fractures can be challenging to diagnose radiographically, but can easily be identified using CT.

In a study comparing the CT and radiographic findings in 32 horses with dental disease, CT had a reported sensitivity of 100%, specificity of 96.7% and a positive predictive value of 88.9%, compared to radiography, which had a sensitivity of 72.5%, specificity of 89.5% and a positive predictive value 64.4%. CT showed more teeth affected and in only about 50% of the horses CT and radiography agreed on the tooth affected. Additionally, only approximately a third of the tooth fractures were diagnosed using radiography when compared to CT. Furthermore, CT also identified more teeth as being abnormal than clinically suspected.[1] In another study were dental sinusitis was present, only in 57% of the horses dental disease was diagnosed on the initial radiographs.[2] Whereas the diagnosis of sinus in combination with dental abnormalities using CT is relatively easy and straightforward as there is no summation of surrounding anatomic structures. As a reminder, rostral maxillary tooth root infections are usually easily diagnosed on radiographs, but CT should be considered in cases of suspected dental sinusitis, especially when no response to treatment is noted.

Inflammatory/infection –infundibular caries, pulpitis
CT is an excellent technique to evaluate the individual teeth for the presence of cemental or enamel hypoplasia, infundibular caries and pulpitis, which might be missed on conventional radiographs of the head. Hyperattenuating infundibular lesions were noted in approximately 57% of the horses imaged using CT in one study, but affected teeth were only identified in about 8% of the horses using radiography in this study. Intraoral radiographs of the individual teeth, might provide similar information compared to CT; however, no comparative studies of intraoral radiography and CT are currently available.

Dental (odontogenic) tumors
Dental tumors occur infrequently; however, in equine species, they are reported more frequently than in other species. Common odontogenic tumors include ameloblastoma, cementoma and odontoma. Ameloblastoma occur more frequently in mandibular than maxillary teeth, tend to be locally destructive, are round to multilobulated in shape and are often expansile in their growth pattern. Radiographs often help to identify the lesion. However, the extent of these tumors is frequently better evaluated using CT than radiography, especially when additional information for surgical pre-planning, or radiation treatment is considered.

Oligodontia, polydontia or dysplastic teeth
The lack or presence of additional teeth are often first noted on a clinical examination. Oligodontia, the lack of a tooth, can cause abnormal occlusion and therefore abnormal wear of the teeth. In polydontia, which is the presence of extra or supernumerary teeth, the teeth may have a normal anatomic shape or could be malformed.

When teeth are dysplastic, which is not uncommon in horses, the teeth can be so mal-shaped, that it can be difficult to decide, if an apical infection is present or not. In these cases, performing a CT examination may allow to differentiate between mal-shaped teeth without or with apical inflammation.

Other dental head imaging findings

Dentigerous cyst (ectopic tooth, ear tooth, temporal teratoma, heterotopic polydontia)

Usually, this is a benign developmental abnormality resulting from an incomplete closure of the first branchial cleft, resulting in the development of a cystic structure surrounding a tooth, often close or even attached to the temporal bone. Frequently, these cystic structures are associated with a draining tract by the pinna of the ear and/or they can pose a cosmetic problem. They can be present unilateral or bilateral in the horse. On radiographs, the abnormally positioned tooth-like structure may be identified; however, often the additional temporal bone abnormality is not visualized on radiographs, and requires additional cross-sectional imaging such as CT or MRI to further evaluate the extent of the lesion.

Imaging of sinonasal disease

The equine paranasal system is a complex system and consists of paired rostral and caudal maxillary, frontal, ventral and dorsal conchal, ethmoid and sphenopalatine sinuses. The frontal and dorsal conchal sinus are often called the conchofrontal sinus. The conchofrontal, caudal maxillary, ethmoidal and sphenopalatine sinuses communicate with each other and the rostral maxillary and the ventral conchal sinuses interconnect with each other as well.[3]

The most common sinonasal disease in horses include primary sinusitis, dental sinusitis secondary to tooth root infection, sinus cysts, ethmoid hematomas or neoplasia. If mass lesions in the sinus system are present, they are more frequently secondary to sinus cysts, ethmoid hematoma and inflammatory nasal polyps than due to neoplasia. Neoplasia of the sinus system in horses are quite rare and it is even rarer, that the tumor originates from the sinuses itself. More commonly these tumors originate from the oral cavity, adjacent osseous or dental structures extending into the sinuses.[4]

Sinusitis

In primary or dental sinusitis, usually an increased amount of soft tissue attenuating material and reduced amount of air filling is noted in the sinus. In a standing position, horizontal fluid lines within the sinus may be noted on radiographs. Another form of sinusitis is caused by fungal organisms. Sinus mycosis occurs relatively infrequent in horses, however, geographic differences in the prevalence of fungal disease are present. Fungal agents noted in the nasal cavity and paranasal sinuses include *cryptococcus neoformans, blastomyces dermatides, aspergillus spp*., etc. Sinus mycosis can be associated with an increase in fluid in addition to turbinate and conchal destruction, and remodeling of the surrounding bones; however, sinus mycosis can also be associated with only a minimal increase in soft tissue attenuating material in the nasal cavity and paranasal sinuses and can therefore easily be missed on radiographs. Usually sinus mycosis has a classical appearance using endoscopy; however if osseous involvement is suspected, CT is providing a better overview of the extent of the lesion. On CT, small soft tissue attenuation plaques may be noted in the nasal cavity and paranasal sinuses, in addition to mucosal thickening, fluid within the nasal cavity and sinuses and remodeling of osseous structures.

Radiographs should always be carefully evaluated, to see if more than one sinus is involved. On radiographic studies, sinus involvement is diagnosed more likely when an involvement of the maxillary or frontal sinuses is present; however, sphenopalatine or ventral conchal sinus involvement are challenging to diagnose (Manso-Diaz reported a sensitivity ranging from 8.7 to 54.1%).[1] Radiography and CT had a good agreement in diagnosing sinusitis, when the mucosa of the sinuses measured more than 1 cm in thickness and fluid was present within the sinus or when a complete sinus obstruction was present. In cases were no fluid was present in the sinus and the mucosa was not greatly thickened, radiography only allowed to diagnose sinusitis in a limited number of cases. Furthermore, radiography is a great technique diagnosing sinusitis when fluid is present, but is often an inadequate technique diagnosing the cause of sinusitis. In horses, secondary sinusitis due to dental disease occurs

commonly, and as on radiographs the visualization of the reserve crown of the teeth may be hindered by the presence of fluid in the sinuses and therefore other imaging modalities such as CT should be considered.

Sinus cysts (maxillary follicular cysts)
Sinus cysts are radiographically often noted as a rounded, soft tissue attenuating mass within the nasal cavity or paranasal sinuses. Frequently a thin mineralized capsule-like structure may be noted. If large cysts are present distortion of adjacent frontal and maxillary bones may be noted in addition to deviation of the nasal septum. CT findings are similar in appearance; however, allow to better evaluate the extent of the lesion with respect to adjacent bones, the nasal septum and paranasal sinuses.

Ethmoid hematoma
Ethmoid hematomas may be noted radiographically as a well-defined, round to ovoid, soft tissue attenuating mass in the area of the ethmoid labyrinth and/or sphenopalatine sinus. However, when the lesion is small or when fluid is present in the sinus system, ethmoid hematomas may not be identified radiographically or using endoscopy. In difference, CT allows to differentiate between fluid and a mass lesion and therefore, allows to diagnose lesions of the ethmoid or sphenopalatine sinuses, even if they are small. However, it is important to remember, that radiographic and CT findings are nonspecific and can appear similar to neoplasia.

Sinonasal neoplasia
Sinonasal neoplasia is rare in horses. Several tumors of the nasal cavity and/or paranasal sinuses have been described and include neuroendocrine tumors, carcinoma, myxosarcoma, adenocarcinoma, hemangiosarcoma, etc. This tumors are often aggressive in nature and can lead to a moderate to marked osteolysis of adjacent osseous structures including the cribriform plate. Radiographs were inadequate to identify masses involving the sphenopalatine sinus and demonstrating extension into the cranium. Again, CT can overcome these limitations and provide more accurate information in regards to extent, location and features of malignancy.[5]

Osseous and joint disease
Head trauma occurs frequently in horses, especially in young horses. Asymmetry to the skull or nasal bleeding can be present. A good agreement between radiographic and CT findings in fractures of external osseous structures is expected; however, if fractures extending towards the retrobulbar space and calvarium are present and when fractures are very comminuted, CT allows to identify more fractures, fracture fragments and provides more detailed information about fracture location.

Standard radiographs of the head only allow a limited evaluation of the temporomandibular joints, and if no oblique views, centered on the temporomandibular joint, are available, CT allows complete evaluation of the temporomandibular joints. Additionally, ultrasound of the central and lateral aspects of the temporomandibular joints can easily be performed due to its superficial location; however, the medial aspect of the temporomandibular joint is generally not accessible using ultrasound.

The hyoid apparatus can be evaluated using radiography; but, the degree of summation of the individual parts of the hyoid apparatus in combination with the location of the temporohyoid articulation, often limits the diagnostic information gained using radiographs. Additional information can be obtained using CT for the presence of new bone formation, fractures and displacement of the hyoid apparatus.

Neuroimaging
As mentioned earlier, CT is often the method of choice in acute trauma patient as it allows to evaluate for the presence of fractures in combination with evaluation of the brain for signs of hemorrhage. However, other disease processes of the brain are difficult to evaluate using CT. Radiographs are usually insufficient evaluating intracalvarial structures.

Brain trauma
Initially, post-acute trauma, hypoattenuating areas of the brain parenchyma suggestive of edema and areas of hyperattenuation relative to normal brain parenchyma, suggestive of hemorrhage, can be noted. It is also possible, that the hemorrhage occurs sub- or epidural and in these cases, localized areas of hyperattenuation adjacent to the brain parenchyma with often displacement of the brain parenchyma are noted. Not in all cases, an osseous lesion of the skull will be present.

Brain abscess
On CT, a mass effect with a central hypoattenuating area and a peripheral, hyperattenuating rim may be noted. Post intravenous contrast agent injection, a ring enhancement may be noted.

Encephalitis
On CT examination, no abnormality may be noted or mixed areas of hypo- and hyperattenuation can be present. Post intravenous contrast agent injection, heterogeneous contrast enhancement may be present.

Pituitary adenoma and neoplasia
The pituitary gland can easily be seen on CT images, especially post intravenous iodinated contrast agent injection. The pituitary gland is surrounded by a thin rim of fat and cerebrospinal fluid allowing to differentiate the from adjacent brain parenchyma. The normal height of the pituitary gland height is reported to range between 10-12mm, width 19-21mm and length 21-24mm.[6] An enlarged pituitary gland is often present secondary to Cushing's disease; however, in cases of adenomatous enlargement, the pituitary gland, may measure normal.

Hydrocephalus
Hydrocephalus is a developmental disorder with an increase of cerebrospinal fluid in the ventricle system. Hydrocephalus can be noted in foals born prematurely, in stillbirth fetuses or dystocia foals. Some horse breeds such as the Friesian horse an autosomal recessive trait is reported. Foals born with a hydrocephalus have often severe neurological signs. On CT, a marked dilation of the ventricle system with fluid attenuating material is noted. Additionally, the cortex of the brain is thin.

Cerebellar abiotrophy or cerebella cortical abiotrophy
Cerebellar abiotrophy is a genetic, neurologic condition of the cerebellum with a recessive mode of inheritance, which is nearly exclusively only identified in Arabian horses and Arabian-cross breeds. On CT a small cerebellum can be noted.

Cholesterinic granulomas
Cholesterinic granulomas are benign growth involving the choroid plexus and occur in 15-20% of older horses. The lesion can associated with clinical signs or no clinical may be present. On CT, these lesions often occur bilateral and can be of variable density and contain small mineralized areas.[7]

Other head imaging findings
Mucocele
CT allows to evaluate the salivary glands and can provide information about the presence of fluid-filled structures within or adjacent to the salivary gland and may identify the presence of dilated salivary ducts.

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