CT and MRI of the eye and orbit

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Advances in cross sectional imaging methods such as ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI) have greatly contributed to the understanding and diagnosis of intraocular and retrobulbar diseases. While ultrasound is an excellent method for assessing the intraocular structure it is less capable to fully assess the retrobulbar space due to the osseous boundaries that absorb the ultrasound beam and cannot be penetrated. The intracranial portion of the optic nerve and the optic chiasm are therefore only accessible with CT and MR imaging. Both methods have their advantages and disadvantages that will be discussed in the following. Understanding the basic principles of CT and MR imaging helps with the deciding which modality would provide the best information on any given patient, and will aid in interpretation of the acquired study.

**COMPUTED TOMOGRAPHY:**

Computed Tomography (CT) uses x-ray techniques to produce cross-sectional images, by passing a narrow beam of x-rays through the body as the tube rotates around the patient. Detectors on the opposite side of the patient measure the remaining intensity of the x-ray beam. Multislice CT is able to acquire several slices at the same time and therefore is capable of very fast imaging with excellent image resolution. Using complex mathematical algorithms, an attenuation coefficient is then calculated for each volume unit or voxel within the patient. The attenuation coefficient is then transformed into a CT number or Hounsfield unit (HU). Water has a HU of 0, air -1000, bone 400-1000 and metal and contrast media >1000. The different HU are displayed on the monitor as shades of gray, with air being black, bone white and all the soft tissues have gradations of gray in between. The viewer has the option to distribute those grayscales differently for each region that is evaluated, for soft tissue imaging the shades of gray are usually distributed over a narrow range of HU (narrow or “soft tissue” window), whereas they are distributed over a wider range to evaluate bone (“bone window”).

Reformatted images in all imaging planes as well as 3-dimensional image reconstruction can be helpful especially in complex anatomical regions such as the skull, particularly in presence of orbital fractures. In single slice CT imaging, the quality of the reformatted images is inferior to the original scan, which is a disadvantage for ocular imaging since images through the central axis of the globe are important. Repositioning the head or angling the CT gantry can be used to obtain dorsal and sagittal oblique image planes. Slice thickness is usually between one and three mm, thicker slices result in too much volume average artifact. Image series with thin slices (1mm) and a bone algorithm, and image series with a soft tissue algorithm and slightly thicker slices (2-3mm), pre- and post intravenous contrast administration are usually acquired. Intravenous contrast administration is recommended in almost all cases as it highlights inflamed or neoplastic tissues and helps outlining normal anatomy such as the zygomatic salivary gland which is normally strongly contrast enhancing.

The orbit is composed of six bones (frontal, lacrimal, maxillary, zygomatic, palatine and sphenoid) and varies in size and shape between breeds and skull types. Within the globe the normal lens is hyperattenuating, relatively poorly delineated and ovoid in shape. The normal vitreous and the anterior chamber are hypoattenuating. The iris may be visible as a thin line, but most of the smaller structures such as the ciliary body cannot be differentiated. Surrounding the vitreous are the sclera, choroid and retina which enhance quite strongly after contrast administration. The different layers however cannot be differentiated from one another. The optic disc is sometimes visible as a small round hyperattenuating ring with a hypoattenuating center. The pterygopalatine fossa contains the extracocular muscles, the optic nerve and the zygomatic salivary gland and a small amount of interposed fat. Contrast medium administration greatly facilitates differentiation of these structures, as the salivary gland enhances strongly.

In summary, for CT evaluation of the orbital structures thin slice (1mm), bone algorithm images should be viewed in a bone window to assess small osseous changes. A soft tissue window should then be applied to evaluate and compare pre- and post-contrast images acquired in a soft tissue algorithm. Reformatted images in dorsal and sagittal planes as well as oblique planes aligned with the optic cone can be helpful. 3D reconstructions may be helpful in cases with complex skull fractures.
MAGNETIC RESONANCE IMAGING:

Unlike CT, MRI does not use ionizing radiation but uses a powerful magnetic field to align the hydrogen atoms in the body. Alignment of this magnetization is then systematically altered with radiofrequency (RF) fields, causing the protons to produce a rotating magnetic field detectable by the scanner. Depending on the composition of the tissues, different signal strengths are registered and used to build an image. Several acquisitions with different parameters and in different image planes are always acquired in MR imaging. The image planes can directly be adjusted to the anatomy under investigation. Both transverse and dorsal plane images are typically most helpful for assessment of the orbit, occasionally oblique images aligned with the optic cone are acquired as well. Image sequences used to evaluate the ocular structures vary between different MR scanners and between institutions. The most commonly used image sequences include T2-weighted, T1-weighted pre- and post-contrast images with and without fat saturation, Proton Density (PD), fluid-attenuated inversion recovery (FLAIR), and gradient echo (T2*) sequences. Occasionally short tau inversion recovery (STIR) sequences are added. T2-weighted images display fluid but also inflammation and most neoplastic tissues with a bright or hyperintense signal, and are best suited to detect pathology. Since fluid and fat also have a high signal additional sequences need to be consulted to delineate these tissues. FLAIR images are T2-weighted images with added fluid suppression with the result that free fluid (for example in the vitreous, within a cyst or possibly within an abscess) will be displayed with decreased signal intensity compared to the T2-weighted images whereas tissues with a high water content such as edema, neoplasia remain hyperintense. In T1-weighted images fluid will be dark or hypointense. T1-weighted images provide the best delineation of anatomical details, but does not highlight pathology very well as tissues with a high fluid content will be hypoattenuating. Intravenous gadolinium contrast medium is thus administered to highlight pathologic processes that are associated with increased vascular permeability. Especially important is administration of contrast medium in intracranial lesions, as a breakdown of the blood brain barrier will allow contrast enhancement. The retrobulbar space contains a fair amount of fat surrounding the muscles and optic nerve and fat is hyperintense in T1-weighted images as well. Fat suppression techniques are therefore essential and frequently used in ocular imaging. STIR image sequences are basically T2 weighted with suppression of the fat signal, however the image resolution tends to be less than that of T1 fat saturated images. PD images provide excellent bone detail and are an option of areas of lysis are suspected. Finally, gradient echo sequences are consulted to detect areas of hemorrhage which result in a strong susceptibility artifact with a visible signal void.

DISEASES OF THE EYE AND ORBIT:

Since ultrasound examination is limited to the globe and the retrobulbar space, CT or MRI are often used to investigate disease processes that are suspected to extend significantly beyond the orbit and causes for postretinal blindness. CT has the advantage of superb bone delineation and is therefore especially useful for evaluation of trauma to the skull and orbit. Exact location and extent of injury such as presence of fractures, location of fracture fragments as well as soft tissue lesions can be assessed simultaneously. The treatment plan is often influenced by coexisting injuries affecting the nasal passages and airways for example. While CT is the best option to assess subtle bone lesions, Magnetic resonance imaging is the best method to characterize a soft tissue lesion and delineate its borders accurately. It allows assessment of the entire visual pathway, and compared with CT has the advantage of direct multiplanar imaging that does not require changes in patient or gantry positioning, and better soft tissue characterization. Bone structures on the other hand are more difficult to assess, and acquisition time is longer than with CT imaging.

Infections of the retrobulbar space may be caused by penetrating foreign bodies, dental abscesses, bite wounds or hematogenous spread of infectious organisms. Abscesses typically result in mass lesions with a non-enhancing center and a peripheral rim of enhancement, whereas retrobulbar cellulitis results in diffusely increased, patchy contrast enhancement and soft tissue thickening, without loss of the normal architecture. Increased signal intensity in the adjacent musculature is commonly seen on MRI in patients with inflammatory disease. Metallic foreign bodies create strong artifacts on both MR and CT imaging. Small pieces of hydrated wood or plant material however can be difficult to detect, as they have imaging characteristics similar to soft tissue. Often the surrounding inflammation and abscess formation is what is detected on imaging. Dental disease is common in older dogs and cats and tooth root abscesses of the last molar and premolar teeth may result in peri orbital inflammation. Changes in the periapical area such as bone lysis, resorption of the periodontal ligament, tooth fractures etc. may be seen.
Masticatory myositis occurs mainly in younger, large breed dogs and is caused by production of antibodies against a specific myosin present in the masticatory musculature. Swelling of the masticatory muscles or muscle atrophy may be seen depending on the stage of the disease. Ocular abnormalities include exophthalmos and conjunctival hyperemia. The CT findings with masticatory myositis have been described. Inhomogeneous contrast enhancement with areas of poor contrast uptake is seen in the affected muscles of mastication. The digastric muscles are typically spared by the disease. Orbital pseudotumor is a rare sclerosing orbital disease that results in thickening of the sclera and adjacent tissues. It is a non-specific benign inflammatory disease, but may lead to vision loss and oculomotor dysfunction. The disease is usually unilateral and results in a poorly demarcated, contrast enhancing mass. Optic nerve neuritis is mostly bilateral and results in thickening and increased contrast enhancement of the optic nerves. A CSF tap may be helpful to look for evidence of inflammation.

Neoplastic lesions affecting the eye or visual pathways can occur at the level of the optic nerve, in the retrobulbar space or intracranially affecting the optic chiasm and optic tracts. Carcinoma (adenocarcinoma and squamous cell carcinoma) are common tumors affecting the orbit in dogs and cats, and are often associated with a large degree of bone lysis. In fact, extension of the lesion beyond the orbit and presence of bone lysis have been described as reliable signs of malignancy. Lymphoma, osteosarcoma, fibrosarcoma, chondrosarcoma, mast cell tumors and others may affect the orbit as well. Nasal tumors may erode the orbital lamina and extend into the retrobulbar space. A tumor type that appears to have a predilection for the retrobulbar space is myxosarcoma. The imaging characteristics of myxosarcoma include complex cystic masses in the orbit that may extend along the fascial planes and involve the temporomandibular joint, bone lysis can be present. Other differentials for cystic lesions in the orbit include zygomatic salivary gland abscessation or mucoceles, and dermoid cysts. Tumors affecting the optic nerve include optic nerve meningioma and glioma. Granulomatous meningoencephalitis occasionally affects the optic nerve as well and produces imaging findings similar to neoplastic lesions with thickening and increased contrast enhancement of the nerve. Intracranial tumors such as meningioma or pituitary neoplasms and craniofaryngiomas can lead to compression of the optic chiasm or may affect the cavernous sinus. Meningiomas tend to be broad based, strongly enhancing lesions often with associated skull bone thickening and focal contrast enhancement along the meninges (“dural tail”). Pituitary neoplasms are recognized by their origin in the pituitary fossa and central location in the thalamus region. Both tumor types may be cystic. Lesions affecting the cavernous sinus often produce ocular clinical signs due to their close association with the vessels and nerves of the orbit. Cranial nerve III thought VI are typically affected, but decreased venous drainage of the orbit may also result in exophthalmos.

**SELECTED REFERENCES:**


