CT, MRI and Ultrasound of the Orbit

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Orbital imaging

Principles and Indications of Computed Tomography and Magnetic Resonance Imaging

Relevant Imaging Parameters

Imaging of Orbital Diseases with Case Examples
Tomographic Benefit

Exophthalmos, OS
Squamous cell carcinoma
Mixbreed dog, 1 year history of nasal and ocular discharge, initially responded to antibiotics
Cross-Sectional Imaging

- Computed Tomography
- Magnetic Resonance Imaging
- Diagnostic Ultrasound

Pixel - picture element
Voxel - volume element
# Principles of Cross-sectional imaging

<table>
<thead>
<tr>
<th>MODALITY</th>
<th>SPATIAL RESOLUTION</th>
<th>CONTRAST RESOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiography</td>
<td>&lt;1 mm</td>
<td>Good</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>1-2mm</td>
<td>Better</td>
</tr>
<tr>
<td>CT</td>
<td>0.4 mm</td>
<td>Even better</td>
</tr>
<tr>
<td>MRI</td>
<td>1-3 mm</td>
<td>Best!</td>
</tr>
</tbody>
</table>
Computed Tomography “Cat Scan”
Computed Tomography

First CT scanner was built by Sir Godfrey Hounsfield at the EMI Research Laboratories in 1972.
Anatomy of a CT scanner

X-ray detectors
X-ray tube
Most CTs are helical or spiral CTs

X-ray tube and an array of receptors rotate around the patient
Image Reconstruction

Images acquired by rapid rotation of X-ray tube 360° around patient as couch moves.

The transmitted radiation is then measured by a ring of radiation sensitive ceramic detectors.

An image is generated from these measurements.
Image Reconstruction

Complex mathematical algorithms allow each voxel to be assigned a numerical value based on the x-ray attenuation within that volume of tissue.

Known as Hounsfield Unit

Sir Godfrey Hounsfield (1919-2004)

1979 Nobel Laureate in Medicine

‘for the development of computer assisted tomography’.
The Hounsfield Scale

- A 12-bit number defines the scale. \(2^{12} = 4,096\)
- Water is assigned a value of 0,
- Air is assigned a value of -1,024.
- Range is -1,024 for air (lung) to +3,071 for the densest object that can be measured by the CT scanner (compact bone).
- Tissues of most clinical interest range from -100 to +100.
# Hounsfield Unit Measurements

<table>
<thead>
<tr>
<th>Tissue</th>
<th>HU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone</td>
<td>300 to 3000</td>
</tr>
<tr>
<td>Mineralized disc</td>
<td>100 to 300</td>
</tr>
<tr>
<td>Acute hemorrhage</td>
<td>42 to 58</td>
</tr>
<tr>
<td>Brain- gray matter</td>
<td>35</td>
</tr>
<tr>
<td>Brain- white matter</td>
<td>30</td>
</tr>
<tr>
<td>Water</td>
<td>0</td>
</tr>
<tr>
<td>Fat</td>
<td>-50 to -100</td>
</tr>
<tr>
<td>Air</td>
<td>-1000</td>
</tr>
</tbody>
</table>
Digital Image Display

- Not all gray scale data can be differentiated by the human eye
- Monitors can display 8 bits or 256 + shades of gray (color)
- Human eye can perceive about 30-50 shades of gray
- Post processing techniques are applied to CT images to allow optimal evaluation
Window Width

Describes the range of Hounsfield Units (HU) displayed.

Lowest number in the window is displayed as black, highest number as white, everything in between is grouped into approximately 30 shades of gray.

- Example:
  - if the window width is 300 HU then each shade of gray contains 10 HU
  - if the window width is 3000 HU each shade of gray contains 100 HU
Window Level

Describes the HU in the center of the window width

Example:

- A window level of 50 is centered on soft tissue, with a window width of 300, HU from -100 to +200 are displayed.
- Everything below -100 will be black, everything above will be white.
- Soft tissue contrast will be good as every 10HU has a different gray value
Window level and width

WL: 50, WW: 300
Soft tissue window

WL: 300, WW: 3000
Bone window
Image acquisition and display

- CT images can be acquired with different kernels
- Shades of gray can be re-distributed in CT images by changing window level and width to better display bones or soft tissue

Bone: WL 500, WW 2000
Soft tissue: WL 40, WW 400
Contrast medium administration

Always use pre- and post contrast image series for brain and ocular imaging

Exception: orbital fracture evaluation, particularly in large animals
Magnetic Resonance Imaging (MRI)

- Contrast resolution much greater than CT
- Image appearance dependent upon chemical composition
  - Water (free or in tissues)
  - Fat
- No ionizing radiation
- Image in any plane
  - No reformatting
- Longer scan times
MRI – how does it work?

- Patient is placed in magnet
- Radiowaves are pulsed in
- Patient emits a signal
- Signal is used to construct an image

1.5 T = 15,000 Gauss (G)  Earth’s magnetic field 0.5G
(150 x stronger than a refrigerator magnet) – safety concerns!
MRI facts – all you need to know

We are imaging hydrogen protons (water, tissue, fat)

Protons themselves can act like mini magnets (moving nuclear proton induces a magnetic field – Faraday’s law of electromagnetic induction)

In “field free” space:
- Protons are randomly oriented

In the absence of an external magnetic field, a proton rotates about its own axis and generates a magnetic field
If you apply an external magnetic field to protons, the Net Magnetic Vector (NMV ~ average proton orientation) aligns with the magnetic field. The protons precess relative to the magnetic field strength.

Inside magnetic field

In an external magnetic field, \( B_0 \) a proton rotates on its own axis and wobbles (precess) about the main magnetic field.

oriented with or against \( B_0 \)

\( M = \) net magnetization
MRI – T1 Relaxation

Overall Magnetic Field

Signal
MRI – T2 Decay

Signal
A radiofrequency pulse is applied at a specific frequency. Some aligned protons absorb that energy (resonate) and align against the magnetic field.

When the pulse is turned off, the absorbed energy is released in the form of a radiofrequency pulse. The character of the energy release is determined by the tissue type (fluid vs fat vs grey matter etc) the H\(^+\) is in.

Numerous ‘pulse sequences’ are run modifying tissue excitation and signal capture (listening) parameters. From this data, images are created.
Basic Sequences

- **T2** – fat, fluid and most pathology is bright (juicy)
- **Proton Density** – anatomy + some pathology
- **T1** – fat is bright, fluid is dark – good anatomy
- **T1 – post C+ ‘enhancement’**
T1-weighted post contrast images

Pre

Post – brainstem meningioma
FLAIR = Fluid Attenuated Inversion Recovery

- Remove signal from true fluid (CSF, vitreous, urine etc)
- Increases conspicuity of periventricular pathology
Fat saturated images

In most sequences, fat is bright. Removing fat signal increases conspicuity of pathology

2 methods to remove fat signal
- STIR Short Tau Inversion Recovery
- Fat suppression

Equine distal metacarpal bone:
- T2 - normal

STIR – bone bruise visible as signal from marrow fat is suppressed.
<table>
<thead>
<tr>
<th>Name</th>
<th>Signal Based On:</th>
<th>Water</th>
<th>FAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton Density</td>
<td>All Protons</td>
<td>hyperintense</td>
<td>hyperintense</td>
</tr>
<tr>
<td>T1</td>
<td>Protons in <strong>FAT</strong></td>
<td>hypointense</td>
<td>hyperintense</td>
</tr>
<tr>
<td>T2</td>
<td>Protons in all <strong>WATER and FAT</strong></td>
<td>hyperintense</td>
<td>hyperintense</td>
</tr>
<tr>
<td>FLAIR</td>
<td>Nulls signal from water</td>
<td>hypointense</td>
<td>hyperintense</td>
</tr>
<tr>
<td>STIR</td>
<td>Nulls signal from fat</td>
<td>hyperintense</td>
<td>hypointense</td>
</tr>
</tbody>
</table>
MRI

Unparalleled contrast resolution
Modality of choice for most all neuro disorders
Basic images are T2, PD and T1, but lots of image sequence options
High field magnets superior to low field
Physics is really complicated!
Protocols for orbital imaging

<table>
<thead>
<tr>
<th>CT</th>
<th>MRI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin slices with bone algorithm</td>
<td>Minimum sequences:</td>
</tr>
<tr>
<td>Thicker slices with soft tissue algorithm</td>
<td>T1 pre- and post contrast, at least</td>
</tr>
<tr>
<td>Pre- and post contrast</td>
<td>one image plane with fat saturation</td>
</tr>
<tr>
<td>Reformat images as needed</td>
<td>– dorsal for orbit!</td>
</tr>
<tr>
<td></td>
<td>T2</td>
</tr>
<tr>
<td></td>
<td>Proton Density (PD)</td>
</tr>
<tr>
<td></td>
<td>FLAIR</td>
</tr>
<tr>
<td></td>
<td>Gradient echo for hemorrhage</td>
</tr>
</tbody>
</table>
Slice alignment with the orbit improves sensitivity for subtle changes

Dorsal oblique = 30-33 deg to the hard palate
Oblique sagittal = 33 deg (dog), 28 deg (cat) from sagittal
CT vs. MRI

Good for osseous detail:
- Trauma (peracute intracranial hemorrhage)
- Aggressive bone lesions
- Dental disease

Good for nasal tumors with orbital extension
- Because inherent contrast in nasal cavity

Insensitive/poor for soft tissue contrast/pathology
- Highly insensitive for intracranial lesions

Best soft tissue contrast and highlights pathology
- Best for intracranial extension of disease
- Involvement of the cranial nerves

Insensitive for subtle bone lesions
Thicker slices = less spatial resolution
Orbital fractures MR vs. CT
CT/MRI VS. ULTRASOUND

CT/MRI:
1. More global overview of the orbital structures
2. Can use contrast medium to differentiate tissues
3. CT-guided aspirates

Ultrasound:
1. Limited window into the pterygopalatine fossa
2. No anesthesia required
3. Tissue sampling may be possible
Dalmatian, 3rd eyelid prolapse, ocular reddening, reduced retropulsion of the right eye, EPISTAXIS

Ultrasound: retrobulbar mass
Dalmatian, 3rd eyelid prolapse, ocular reddening, reduced retropulsion of the right eye, EPISTAXIS

CT: retrobulbar mass with bone lysis and extension into the nasal cavity
Ocular diseases

CT and MRI are limited in image resolution and detail
Ultrasound is the method of choice
CT and MRI often chosen when other clinical signs are present as well

Bilateral posterior lenticous
Ultrasound of retrobulbar abnormalities

Use lower frequencies to look “deep” or adjacent to the eye
Uses: Masses, inflammation, foreign bodies....
Don’t forget to look at bone surface for lysis or proliferation
Case – Two year old Bloodhound, acute onset of pain over right eye, mild exophthalmos
Aspirate for culture results
Guided aspirates or biopsy
9 year old Mixed breed dog

- Acute onset redness of right eye
- Exophthalmos
- Intraocular structures normal
9 year old Mixed breed dog

- Acute onset redness of right eye
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- Acute onset redness of right eye
- Exophthalmos
- Intraocular structures normal
Zygomatic sialoadenitis

Zygomatic salivary gland adjacent to the eye

Normally these are difficult to see as they are small and inaccessible

Dog improved on antibiotics
Labrador retriever 9y mc

Presented for exophthalmos OD
Zygomatic Sialadenitis and Pterygoid Myositis
CT and MRI of the orbit– image interpretation

Take your time!
Know normal anatomy
Use symmetry to identify and interpret abnormalities
Look for:
  ◦ Contrast enhancement
  ◦ Muscle atrophy
  ◦ Bone destruction
  ◦ Lymph node enlargement
  ◦ Disease extension into adjacent spaces – nasal cavity and brain
CT and MRI of retrobulbar diseases

Abscess / Foreign bodies
Masticatory and extraocular muscle myositis
Sialadenitis/sialoceles
Neoplasia
Orbital fractures
Tooth root abscesses
Labrador retriever male 5y

Mild exophthalmos and swelling behind the eye OS
Ocular discharge OS
Reformatted images are very helpful to detect a geometrical shape of a suspected foreign body.
Wirehair pointer, mc, 3y

Had an encounter with a porcupine 4 months ago...
Since then RDVM had been removing migrated quills from the head
last 2 months progressive exophthalmos OD, pawing at face and sneezing

proptosis
thickened sclera
retrobulbar abscess
Multiple contrast-enhancing tracts in the right temporal muscle that are consistent with inflammatory tracts associated with porcupine quill penetration
5yo Labrador Retriever, mc

4 week history of nasal discharge, first clear then mucoid
Progressively worse
Now ocular discharge on the right
Mild epistaxis
CT nose – bone window

- Large amount of turbinate destruction
- No mass seen
CT +C

- Periocular swelling
- Thickened sclera and choroid
- Increased density of the vitreous
- Detached retina
CT findings

Bilateral destructive rhinitis, most consistent with fungal disease (aspergillosis)

Right ophthalmitis, chorioretinitis, vitreous body inflammation or hemorrhage, retinal detachment – suspect ocular aspergillosis
Ocular aspergillosis

Can cause chorioretinitis and retinal detachment

Cellular infiltrates posterior to the detached retina have also been associated with other fungal diseases such as blastomycosis
Norwegian forest cat, mc, 4y.

- Upper airway noise
- Reduced airflow from both nostrils
- Left eye retropulses less than right

➢ Suspicion of a nasal mass
Bone algorithm: multifocal lysis
Soft tissue algorithm: soft tissue in nasopharynx and nasal passages
Contrast enhancement:
Summary and Outcome

Destructive nasal mass invading the pterygopalatine fossa and the brain

Owners elect euthanasia

Necropsy:

- Severe diffuse pyogranulomatous rhinitis with multifocal bone necrosis with numerous intrahistiocytic and free fungal yeasts (Cryptococcus neoformans)
Feline sinonasal disease

Erosive lesions of orbital lamina present

- Unilaterally
  - 24-75% cats with neoplasia
  - 36% cats with non-neoplastic dz
- Bilaterally
  - Only neoplastic processes

Exophthalmos present with neoplasia

Domestic Shorthair cat, 13yo, MC

Chronic rhinitis

Now Horner’s syndrome and swollen left eye
T2W, fat saturation

- Diffuse enhancement of retrobulbar structures
- Muscle and fascial plane inflammation
- Left medial retropharyngeal lymphomegaly
- The tympanic bulla is fluid-filled

MR appearance is most consistent with retrobulbar cellulitis and inflammation
MRI findings T1 post contrast

Nasal cavity and frontal sinus inflammation with secondary turbinate destruction and distortion. Left otitis media and extensive left retrobulbar inflammation, with probable intracranial extension via the optic canal.
Maine coon cat mc 12y

Anisocoria, exophthalmos, nasal discharge

T2 hyperintense, contrast enhancing mass in the right retrobulbar space, extending into the calvarium through the orbital fissure and into the retropharyngeal space
Maine coon cat mc 12y

Anisocoria, exophthalmos, nasal discharge

Bilateral otitis media, meningeal enhancement

Final diagnosis: lymphoma
Lacrimal Duct Cyst
Mixbreed dog 2y mc

2 month history of intermittently pain on opening its mouth
Intermittent exophthalmos and reddening of eye
No abnormalities seen on radiographs of the skull
Mild muscle atrophy along the head and jaw
Normal head post C  2 yo Mixbreed dog post C
Pterygoid muscle
Temporal muscle
Masseter muscle
Digastric muscles
Summary and outcome

Temporal muscle biopsy:
- Masticatory myositis
- Inhomogeneous enhancement pattern results from areas of inflammation with increased vascularity and interspersed hypoattenuating areas of necrosis

Masticatory muscle myositis

Autoantibodies against masticatory muscle type 2M fibers
   ◦ The serum 2M antibody test is both highly sensitive (85% to 90%) and specific (100%) for diagnosis of masticatory muscle myositis
   ◦ Ocular signs present in 44% of patients with MMM with exophthalmos in the acute phase, and possible blindness due to stretching of the optic nerve
   ◦ Differential Diagnosis Extraocular myositis
8 yo FS Golden Retriever

3 month history of ocular discharge, 1 mo behavior change, painful on retropulsion OD, nonpainful when opening mouth, possible deficits in CN 5-7
T2W and FLAIR
T1W AND T1C
Findings

MRI report: Extensive right nasal-intracranial tumor with regional bone effacement, right ocular displacement and compression of right optic neurovascular bundle, right nasofrontal obstruction with secondary sinusitis, and secondary brain edema; tumor is consistent with olfactory neuroblastoma but other etiologies are possible and biopsy will be needed for diagnosis.

Retrobulbar aspirates: carcinoma with chronic suppuration
Communicating, fluid-filled cavities with small areas of solid tissues, occasionally complex and multiloculated
Myxoma/myxosarcoma - primitive fibroblastic origin

Present for exophthalmos, third eyelid protrusion

Large breed dogs, middle aged to geriatric, retropulsion painless, fluctuant soft tissue swelling periocular tissues
Orbital myxoma/myxosarcoma

In all five dogs, involvement of TMJ present, suggesting a resemblance to human juxta-articular form (knee in humans)

Osteolysis present in dogs, but not humans, suggesting more aggressive behavior

Zygomatic sialocele is main ddx, with anechoic fluid filled structure
  - Uncommon, usually associated with trauma

Abscess or hematoma other differentials to consider
Orbital fractures – ct modality of choice
Multiplanar reconstructions
Tooth root abscess and osteomyelitis
CT And MRI of Optic Nerve and Intracranial Disease

- Optic nerve neuritis
- Granulomatous meningoencephalitis
- Optic nerve neoplasia
- Cavernous sinus syndrome
- Brain lesions affecting vision
Anatomy

- Optic nerve
- Optic tract
- Lateral geniculate nucleus
- Optic radiations
- Occipital cortex
Skull foramina anatomy
Optic nerve imaging

MRI best modality

Fat in the pterygopalatine fossa can obscure pathology – need fat suppressed sequences!
Schipperke fs 4y

Acute Blindness

Suspect optic nerve lesion
Thickened optic nerves
Meningitis
Jack Russell terrier fs 7y

One week history of acute blindness and dilated pupils

Optic nerve and optic chiasm thickening, regional meningitis

208578
Jack Russell terrier fs 7y

T2 hyperintense forebrain lesions
Jack Russell terrier fs 7y

Extraocular muscle and optic nerve enhancement
Jack Russell terrier fs 7y

T2 hyperintense forebrain lesions, optic nerve and optic chiasm thickening, regional meningitis, extraocular muscle enhancement – most consistent with granulomatous meningoencephalitis, round cell neoplasia is considered as well
Lymphoplasmacytic and pyogranulomatous meningitis, choroiditis and optic neuritis in a cat – FIP suspected
Optic Cone Imaging – Need Fat Saturated Dorsal Plane Images!

T1+C - no fat saturation
T2 - fat saturation

2 year old German Shepherd dog, blind OS, cranial nerve deficits
Optic cone imaging – need fat saturated dorsal plane images!

Suprasellar mass with invasion of the optic chiasm and orbital fissure
Mixbreed dog fs 6y

Complete internal and partial external ophthalmoplegia

Mass lesion in the region of the oculomotor nerve
Mixbreed dog fs 11y

Exophthalmos OS
Blind OS
No menace response OD
Optic nerve and chiasm thickening

Meningioma of the optic nerve
German Shepherd, fs, 7y

- cranial nerve abnormalities; blepharospasms and ptosis of the right eye
- mass effacing the pituitary gland and cavernous sinus.
Findings

Relatively intensely contrast enhancing mass within the floor of the calvarium effacing the pituitary gland and cavernous sinus. The mass is primarily on the right side but crosses midline.

A meningioma is a likely diagnosis but other differentials include histiocytic sarcoma, lymphoma and possibly a pituitary carcinoma.
Cavernous sinus

Cavernous sinuses paired channels in middle fossa, drain orbit and brain, flank hypophyseal fossa & dorsum sella

Communicate w/ ophthalmic plexus through orbital fissure (rostrally) and caudally into ventral petrosal sinuses through petrooccipital foramina

- CN III, IV, VI and ophthalmic branch of V course through cavernous sinus before exiting orbital fissure

Cavernous sinus syndrome:
- CN III-VI dysfunction—extraocular motor deficits, mydriasis, ptosis, corneal hyper- or analgesia, absent PLR
- +/- exophthalmos

Weimaraner MC, 11y
Acute blindness

Weimaraner

Comparison dog
Weimaraner, acute blindness

Sphenoid bone mass with compression/infiltration of the optic nerves
Cairn terrier fs 10y

elevated liver enzymes, lethargy, seizures, blindness and change in behavior
T1 pre-contrast images

Mass effect with displacement of neurosecretory granules (T1 hyperintense) of the pituitary gland
T1 post contrast

Meningioma extending into sella, pituitary, cavernous sinus and optic chiasm
Thank you!