Spectrum of Globe Abnormalities on MRI and CT

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Learning objectives

Globe abnormalities can be readily detected on both dedicated and non-dedicated CT and MRI studies. Accurate interpretation of the imaging requires an in depth understanding of the anatomy of the globe. In fact, this poster will provide a novel approach to the subject by classifying diagnoses based on the anatomical location. We hope this will reinforce an understanding of the topic from first principals rather than pattern recognition. We therefore propose the following learning objectives:

- Outline the cross-sectional anatomy of the globe.
- Illustrate the spectrum of globe abnormalities detected on CT and MR using fundamental anatomical knowledge.
- Illustrate additional CT or MRI characteristics of globe abnormalities to narrow the differential diagnosis. A wide range of cases will be provided with fundoscopic correlation as appropriate.
Background

Background:

The majority of globe imaging is performed secondary to CT and MRI imaging of the brain for a multitude of indications ranging from trauma to neoplasia. Incidental detection of an abnormality is commonplace, especially given recent advances in MR and CT technology, which allows for the globe to be visualised in ever finer detail. In order to interpret the globe abnormality a primary understanding of the globe anatomy is key.

Knowledge of the imaging features of both traumatic and non-traumatic globe abnormalities is necessary to provide appropriate ophthalmology referral and accurate diagnosis, thereby preventing devastating consequences such as vision loss. In addition knowledge of incidental degenerative changes, globe implants and fillers is important to prevent unnecessary work-up.

Globe anatomy overview (Figs 1 and 2)

- Globe occupies one third of the volume of the orbit (~6.5 mls).
- The vitreous humour represents two-thirds of the volume.
- The wall of the globe comprises three layers;
  - Fibrous coat (outer) enveloped by Tenon’s capsule.
  - Uvea (middle)
  - Retina (inner layer)

1. Fibrous coat (outer layer)

Constitutes the sclera and transparent cornea anteriorly.

1.1 Tenon’s capsule

- The sclera is enveloped by the fibroelastic Tenon's capsule, which fuses with the bulbar conjunctiva.
- A potential space, termed the episcleral space can extend between the fascia and the sclera.
- Effusions due to infection or inflammation of adjacent structures and haemorrhage due to trauma or neoplasms can distend the episcleral space (Figs 3, 4 & 5).

1.2 Cornea
• Protects the anterior chamber and is a key component of the refractive system.
• 90% of the thickness provided by the stroma.
• On MRI the cornea is a predominantly low intensity structure. On T1W images (T1WI) can be highlighted by an overlying, thin, slightly hyperintense tear film.

1.3 Sclera
  • Merges with cornea at the limbus, composed of collagen and is hypointense on MRI.
  • Maintains intraocular pressure and protects the globe.
  • Disruption of the sclera can result from trauma (globe rupture; Figs 6 & 7) or secondary to degeneration, infection or inflammation.
  • Sclera alters in thickness and shape throughout life.
  • Sustained intraocular pressure in childhood can lead to diffused increased size of the globe termed buphthalmos.
  • In adults the more rigid scleral structure results in more focal thinning and protrusions termed staphylomas (Fig 8).
  • Other globe shape abnormalities include colobomas (congenital defects in the layers of the globe including the optic disc) and phthisis bulbi representing an end-stage atrophic globe (Figs 9 & 10).
  • Other scleral lesions include calcifications, which form at the insertions of the recti in elderly patients (Fig 11) and iatrogenic causes such as scleral buckles for treatment of retinal detachment (Fig 12).
  • Episcleritis is typically a self-limiting idiopathic disorder, where as scleritis is a more serious condition associated with connective tissue diseases such as rheumatoid arthritis. Scleritis may be complicated by exudative chorioretinal detachment and glaucoma (Fig 5).

2. Uveal tract (middle layer) and retina (inner layer)

2.1 Uveal tract
  • Consists of the iris, ciliary body and choroid. Highly vascular and contains pigmented melanocytes.
  • Iris is a pigmented circular structure controlling the size of the pupil and attaches to the ciliary body.
  • The ciliary body consists of the anterior pars plicata (produces aqueous humour) and posterior pars plana. Ciliary musculature attaches to the lens via the zonules of Zinn and are important for accommodation.
• The choroid merges with the ciliary body at the ora serrata and extends posteriorly to the optic nerve head. Provides retinal nourishment and absorbs reflected light.
• Choroid attaches firmly to the sclera at the optic disk and where the vortex veins exit the globe.

2.2 Retina

• Innermost sensory layer consists of:
  • Outer retinal pigment epithelium (RPE)
  • Inner sensory retina containing photoreceptors.
• Layers tightly bound at the optic disc and ora serrata where the RPE becomes continuous with the ciliary body.
• Otherwise only weak apposition of the two retinal layers.

2.3 MRI appearance of the uveal tract and retina

• T1WI: Hyperintense (likely related to melanocytes)
• T2WI: Hypointense
• Provides good contrast between the hypointense outer sclera and hyperintense inner vitreous.

2.4 Retinal and Ciliochoroidal detachment

Potential spaces for fluid accumulation resulting in detachment:

• Between the retinal layers (subretinal space).
• Ciliary body/choroid and sclera (suprachoroidal space)
• Hyaloid base and retina (posterior hyaloid space).

Ciliochoroidal detachments (Figs 13, 14 & 15) occur due to haemorrhage (trauma, prior intervention, underlying neoplasm) or serous effusions (ocular hypotony or inflammation).

Retinal detachments (Figs 3 and 15) commonly associated with a hole (regma) classified as rhegmatogenous versus nonrhegmatogenous.

Fundoscopy readily allows for detection of retinal detachments with MRI useful for detection of an underlying cause, e.g. neoplasm.

• MRI distinction of ciliochoroidal from retinal detachment not always possible although several patterns exist.
• Anteriorly, ciliochoroidal detachments commonly extend into the ciliary body where as retinal detachments are limited by the ora serrata.
• Posteriorly, ciliochoroidal detachments are limited by the insertions of the vortex veins where as retinal detachments are limited by the optic disc producing a characteristic V shape.

Retinal detachments can be treated using scleral buckling, pneumatic retinopexy, pars plana vitrectomy or injection of intraocular silicone oil (Figs 16 and 17).

2.5 Ocular neoplasms

Malignant melanoma represents the most common intraocular malignancy in adults and occurs in the pigmented uveal tract. Other neoplasms involving the highly vascular uveal tract include metastases and benign neoplasms such as haemangiomas.

2.51 Malignant melanoma (Fig 18)

• Commonly unilateral, less common than the cutaneous form, and may present with pain or decreased vision.
• On MRI typically seen as a focal mass at the periphery of the globe with propensity for chorioretinal detachment
• Appearance is non-uniform on imaging due to varying melanin:
  • Melanocytic: CT; Slightly hyperdense, MRI; #T1WI, iso/↓ on T2WI. Enhancement on both.
• In exudative/haemorrhagic retinal detachment difficult to distinguish a melanocytic melanoma.
• Contrast enhancement is a key discriminator.
  • Amelanotic: Similar to other ocular neoplasms.
• MRI is the technique of choice for assessing episcleral extension (occurs in ~13% and is an important prognostic feature).

2.52 Ocular metastases (Fig 19)

• Highly vascular uveal tract most common site.
• Breast and lung primaries most common.
• Can lead to chorioretinal detachment with accompanying haemorrhage or exudates.
• T1WI useful to distinguish from melanocytic melanoma with the exception of hyperintense haemorrhagic or mucinous adenocarcinomas.

2.53 Retinoblastoma

• Most common intraocular childhood malignancy (Rb gene mutation; 13q14).
• Typically in children < 5 years of age who present with leucocoria. Other causes of leucocoria include Coat’s disease and persistent hyperplastic primary vitreous (PHPV).
• CT is useful in establishing bilateral disease due to calcifications in 90%. Other differential diagnoses for this finding includes cytomegalovirus chorioretinitis and coloboma.
• MRI useful for optic nerve and intracranial extension:
• Retinoblastoma typically appears as hyperintense on T1WI images to normal vitreous and hypointense on T2WI with mild to intense post-contrast enhancement.
• Fat-suppressed, post contrast T1WI is the best imaging method for optic nerve and episcleral extension.

2.54 Vascular neoplasms and phakomatoses/neurocutaneous syndromes (Figs 20 and 21)

• Vascular neoplasms of the choroid uncommon benign lesions.
• Cavernous malformations associated with Sturge-Weber syndrome; can be complicated by retinal tears and detachment.
• Capillary haemangiomas of the retina occur in a quarter to half of patients with Von Hippel-Lindau syndrome:
  • Usually supplied by large feeder vessels with propensity for leakage and subsequent exudative/haemorrhagic retinal detachment.
  • Often small but sometimes visualised on MRI as hyperintense on T1WI, and hyperintense on T2WI allowing distinction from melanocytic melanomas.

2.6 Uveitis (Fig 22)

Inflammation of the uveal tract commonly involves the adjacent retina and sclera.

• Often idiopathic with numerous infective and inflammatory causes described in the literature including sarcoidosis, rheumatoid arthritis, and toxoplasma.
• CT or MR evaluation may be useful in posterior uveitis for assessment of chorioretinal detachment, abscesses or foreign bodies providing a nidus for infection.

3. Vitreous body

• Gel-like fluid consisting of 99% water.
• Bounded by the posterior and anterior hyaloid membranes and provides support to the posterior lens and pressure to ensure apposition of the retinal layers.
• In old age the vitreous may shrink and thicken forming clumps of material (‘floaters’). This process may result in traction causing separation of the posterior hyaloid membrane from the sensory retina (posterior vitreous detachment).
• Accelerated vitreous degeneration may result from trauma, surgery, inflammation or significant myopia.
3.1 *Posterior vitreous detachment*

On MR and CT posterior vitreous detachment can be seen as a membrane within the vitreous cavity detached from the optic disc and attached at the ora serrata.

3.2 *Endophthalmitis*

- Inflammation/infection predominantly involving the anterior chamber and vitreous humour.
- Despite aggressive therapy the outcome remains poor.
- Causative organisms may enter the globe haematogenously or exogenously secondary to penetrating trauma or surgery.
- Most common organisms include skin commensals such as staphylococcus epidermis, candida and parasites including cysticercosis and toxocarasis.
- CT and MRI may demonstrate uveal thickening and enhancement, chrorioretinal or vitreous detachment and increased density or T1W intensity of the vitreous due to proteinaceuous exudates.

4. *Lens (Fig 23)*

- Forms the posterior boundary of the anterior chamber.
- Transparent ovoid crystalline structure hypointense on T2WI.
- Prostheses are readily identifiable on CT and MRI.
- Dislocation also identified secondary to trauma or degeneration of the zonular fibers.
Fig. 1: Globe anatomy illustration

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**Fig. 2:** Normal globe MRI anatomy. The lens shows hypointense signal on all sequences, (a) On axial T2W images, the vitreous and aqueous humour are diffusely hyperintense; (b) Axial T1W image of the right globe. The retina, choroid and ciliary bodies are hyperintense and show enhancement on the fat suppressed axial T1W post gadolinium images (c).

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**Fig. 3:** Axial T2W images (a) following direct left globe trauma. There is iso to hypointense episcleral material consistent with a haematoma. Choroidal and retinal detachment is seen in the left globe with underlying suprachoroidal and subretinal fluid respectively. Figure (b) shows a corresponding photograph with extensive periorbital swelling and subconjunctival haemorrhage.

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**Fig. 4:** An axial non-contrast image from a CT brain for assessment of traumatic head and facial injuries (a). An episcleral hyperdense haematoma is seen in conjunction with a periorbital haematoma. The globe appears intact. Extension of the haematoma posterior to the globe, likely in the intra-conal space is seen. The corresponding photograph (b) shows marked periorbital swelling and bruising with subconjunctival haemorrhage. This patient also had an orbital floor fracture (not shown) with limited left upgaze.
Fig. 5: An axial non-contrast enhanced image from a CT orbits (a). This patient had a history of Wegener's granulomatosis with posterior scleritis. There are bilateral episcleral fluid collections with distortion of the globes likely due to scleral degeneration or necrosis. Corresponding fundoscopy (b) and a photograph (c) show engorged scleral vessels. Additional fundoscopic images (d) and (e) show bilateral choroid detachments with a characteristic orange-brown, solid appearing elevation with a smooth, convex surface. This is not well visualised on the CT images.
**Fig. 6:** Axial (a,b) non-contrast images from a CT brain for assessment of traumatic head injury. There is right globe rupture with loss of the normal scleral contour, hyperdense material consistent with haemorrhage in the vitreous, and surrounding periorbital and episcleral haematomas. There is traumatic lens dislocation seen protruding through a scleral defect in the lateral globe (b). Another coronal non-contrast CT image in a different patient shows left globe rupture with a superolateral lens dislocation and protrusion through a scleral defect (c).

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Fig. 7: Axial (a) and coronal (b) non-contrast images from a CT brain for assessment of direct globe injury. There is left globe rupture with complete loss of the normal scleral contour, vitreous haemorrhage and surrounding periorbital and episcleral haematomas. The lens is dislocated and seen outside the globe in the left inferolateral orbit.

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**Fig. 8:** An axial non-contrast image (a) from a CT orbits for assessment of homonymous hemianopia. There are bilateral focal protrusions through the thinned sclera posteriorly consistent with staphylomas. Corresponding fundoscopic images from the right (b) and left (c) eyes show bilateral myopic degeneration, peri-papillary atrophy, and bilateral staphylomas.

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**Fig. 9:** An axial non-contrast image from a CT brain for assessment of altered mental state. There is right phthisis bulbi with an irregular, scarred, shrunken right globe and dense internal calcification.

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**Fig. 10:** An axial non-contrast image from a CT brain for assessment of traumatic head injury. There is left phthisis bulbi with an irregular, scarred, shrunken globe and left optic disc calcification. Incidental right scleral calcifications are seen at the insertions of the medial and lateral recti.

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Fig. 11: Axial non-contrast images from a CT brain for assessment of altered mental state. There are bilateral lens prostheses with incidental scleral calcifications at the insertion of the medial rectus on the right and both the medial and lateral recti on the left. These calcifications represent a normal part of aging.

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Fig. 12: Axial (a) and coronal (b) non-contrast images from a CT brain for assessment of frequent falls. There are bilateral bands of hyperdensity, which do not conform to the insertions of the extra-ocular muscles. These are consistent with prior bilateral, scleral buckles for treatment of retinal detachment, although the characteristic concavity at the site of banding is not seen in this case.

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Fig. 13: Axial T1W (a) T1W post gadolinium (b) and coronal (T2W) images for suspected chorioretinal detachment and evaluation for an underlying lesion. There is ciliochoroidal detachment (a) and underlying suprachoroidal fluid (c) seen extending anterior to the expected location of the ora serrata (a). Enhancement of the choroid is noted, which is expected in detachment due to an inflammatory response. No enhancing lesion is detected to suggest a neoplastic cause.

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Fig. 14: Coronal T1W post gadolinium (a) and axial T1W post gadolinium images (b) from an MRI orbits for right sided visual loss. There is right choroidal detachment seen limited posteriorly at the expected location of the vortex vein insertion. Enhancement of the detached choroid is also apparent as seen in the prior case.

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**Fig. 15:** Axial T2W (a) gradient echo (b) T1W (c) and sagittal T2W images (d,e) from an MRI orbits were performed following trauma to assess for globe rupture. There is retinal and choroidal detachment noted, the latter involving the ciliary body medially (a). An underlying subretinal/suprachoroidal collection is noted with T1W shortening and foci of susceptibility. These findings are consistent with traumatic haemorrhagic chorioretinal detachment. There are additional episcleral and periorbital haematomata which are hyperintense on T1W images. (d) On the sagittal view the retinal detachment is well demonstrated limited anteriorly by the ora serrata. Buckling of the superior sclera and loss of globe volume is consistent with globe rupture. The hypointense material in the vitreous is also likely consistent with haemorrhage. (e) Coronal T2W images also show the scleral defect.

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**Fig. 16:** Axial non-contrast images from a CT brain for assessment of altered mental state. Hyperdense material is seen filling the vitreous cavity on the right with no evidence of overlying trauma or a periorbital haematoma. This patient had undergone silicone oil injection for treatment of retinal detachment.

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Fig. 17: Axial non-contrast images from a CT brain for assessment of altered mental state. Gas is noted in the anterior vitreous compartment consistent with pneumatic retinopexy typically used in the treatment of superior rhegmatogenous retinal detachments.

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**Fig. 18:** Dedicated MRI orbits for gradual left visual loss. (a) Axial T2WI: There is a lobulated hypointense lesion arising in the anteromedial left globe with endophytic extension into the vitreous. (b) T1WI: The lesion is hyperintense and (c) T1WI post gadolinium shows enhancement. A corresponding photograph (d) shows a pigmented lesion arising from the inferomedial globe wall with surrounding haemorrhage. This lesion was consistent with an uveal melanoma on histology.

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Fig. 19: A gentleman with a known primary lung adenocarcinoma presenting with left sided blindness. Axial T2W(a) and axial T1W(b) post gadolinium images from an MRI orbits. There are hypointense intraocular lesions arising adjacent to the sclera in the left medial globe and close to the left optic nerve head. The medial lesion shows contrast enhancement. These lesions are consistent with choroidal metastases with no choroidal detachment detected.

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Fig. 20: Coronal T2W (a) and T1W post gadolinium (b) images from an MRI orbits performed for a suspected intra-ocular tumour. There is a small hypointense, enhancing lesion in the inferior globe forming a broad base against the sclera. This is likely to arise from the choroid given the enhancement and is most likely consistent with a haemangioma or haemangioblastoma. A metastasis is unlikely as there was no history of a primary malignancy. An amelanocytic melanoma is another consideration.

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Fig. 21: Axial T1W post gadolinium MRI images of the posterior fossa (a) and the orbits (b). This patient had presented with headaches. A markedly enhancing lesion is seen arising in the region of the fourth ventricle complicated by hydrocephalus (not shown). An additional avidly enhancing lesion is seen arising from the choroidal layer of the left lateral globe with suggestion of an associated chorioretinal detachment. These findings are suggestive of cerebellar and retinal/choroidal haemangioblastomas, although an associated cystic component for the cerebellar lesion is more typical. Underlying Von Hippel-Lindau disease should be considered. Resection of the cerebellar lesion was performed with confirmation of a haemangioblastoma on histology.

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**Fig. 22:** Axial T1WI (a) T1WI post gadolinium (b) from an MRI orbits performed for orbital pain and acute visual loss. On the T1WI there is isointense thickening and enhancement of the retina, posterior choroid and optic disc. These features are likely consistent with posterior uveitis, which may be associated with inflammatory conditions such as sarcoidosis or infections such as toxoplasma or cytomegalovirus. The patient did not attend for follow-up.

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Fig. 23: An axial T2W image from an MRI orbits for evaluation of left visual loss. Left sided lens dislocation (lens luxation) is seen with the hypointense lens lying dependently adjacent to the retina in the posterior vitreous humour. No history of trauma or prior ocular inflammation was noted. A right-sided lens prosthesis is noted.

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Imaging findings OR Procedure details

CT

CT scans were obtained on a 32 or 320-row scanner. Non-contrast scans are typically performed for initial assessment of trauma or suspected cerebrovascular accident, with incidental imaging of the orbits.

CT is useful in the initial evaluation of orbital and globe trauma for the assessment of fractures, extra-ocular muscle herniation and suspected globe rupture. CT is the technique of choice for evaluating for metallic or paramagnetic foreign bodies, where MRI is contraindicated due to potential migration and local heating. CT is also useful for evaluation of globe calcifications, especially in the case of retinoblastoma as described in the prior section.

MRI

MRI scans of the brain or dedicated studies of the orbits were performed on a 1.5 or 3 Tesla platform. For the dedicated protocol the following sequences are commonly performed; axial and coronal T1WI with and without fat suppression, axial and coronal STIR or fat suppressed T2WI, and multiplanar fat suppressed T1W images post gadolinium.

High resolution MRI allows depiction of the sclera from the choroid and retina. Table 1 shows the common MRI characteristics of the various structures in the globe. MRI provides exquisite soft tissue contrast for the evaluation of chorioretinal detachments and potential underlying neoplasms. The technique is limited by lengthy scanning time, increased cost compared to CT and requirements for sedation in children and other non-compliant patient groups.

Table 1: T1W and T2W characteristics of the globe structures.

<table>
<thead>
<tr>
<th>Layer</th>
<th>MRI sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tenon's capsule</td>
<td>Not usually visible. Can be distended by fluid/haemorrhage accumulating in the potential episcleral space.</td>
</tr>
<tr>
<td>Structure</td>
<td>T1WI</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Cornea</td>
<td>Hypointense</td>
</tr>
<tr>
<td>Sclera</td>
<td>Hypointense</td>
</tr>
<tr>
<td>Uveal tract, choroid</td>
<td>Hyperintense</td>
</tr>
<tr>
<td>Retina</td>
<td>Hyperintense- Not usually seen separately from the underlying choroid</td>
</tr>
<tr>
<td>Aqueous/vitreous humour</td>
<td>Hypointense</td>
</tr>
<tr>
<td>Lens</td>
<td>Hypointense</td>
</tr>
</tbody>
</table>
Conclusion

A multitude of globe abnormalities can be detected and characterised on CT and MRI studies. Understanding the anatomy is a key component in the structured approach to producing a differential diagnosis. An understanding of the CT attenuation and MRI signal characteristics can also help characterise lesions, especially in the case of uveal melanoma.

The radiologist fulfils an important role in the primary diagnosis of clinically significant and potentially treatable globe abnormalities contributing to rapid referral and improved outcomes.
References


