Thyroid orbitopathy: Imaging findings and indications. Assessment of quantitative analysis methods

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Learning objectives

-To review the image findings in thyroid orbitopathy with different techniques.

-To evaluate the usefulness of these techniques in the diagnosis and follow-up of patients with emphasis on quantitative methods.
Background

Thyroid-associated orbitopathy (TAO), also known as Graves' orbitopathy, is the most common orbital disorder and the most common cause of proptosis in adults.

There appears to be a female preponderance; however, severe cases occur more often in men than in women and most patients with severe cases appearing to be more frequent in those older than 50 years. (1) The risk and severity of ophthalmopathy may be increased by several other factors including tobacco use.

This condition generally occurs in patients with Graves' hyperthyroidism but sometimes may take place in patients with euthyroid or hypothyroid autoimmune thyroiditis.

Pathogenesis

TAO is characterised by enlargement of the extraocular muscles (EOM) as well as the increase in orbital fat volume. Approximately 90% of cases of TAO are bilateral and mild asymmetric.

The exact mechanism is unknown, but because of the association of TAO with hyperthyroidism, it is hypothesized that the thyroid and orbital tissue share a common antigen. The pathogenesis of this illness could be summarized in three main phenomena: inflammation of the periorbital soft tissues, overproduction of glycosaminoglycans by orbital fibroblasts and hyperplasia of adipose tissue. (2) Fig. 1 on page 4

During the course of TAO, the disease passes through two phases. In the active or inflammatory phase, an increase in orbital fat volume and enlargement of the muscles bellies involve worsening of symptoms and signs, such as proptosis, eyelid edema and hyperemia of the periorbitarial soft tissues, painful eyes movements and in severe cases, dysthyroid optic neuropathy (DON). This active phase is self-limited and usually lasts 18 to 24 months. Gradual improvement in the inflammatory signs is followed by an inactive or chronic phase, where no inflammation is present and yet residual fibrosis and its secondary effects persist. The active phase implies the presence of inflammatory features and suggests the potential for response to immunosuppressive treatments. In the inactive phase, only surgical treatment can alter the outcome. Taking this into account, the assessment of disease activity is important for predicting the outcome of medical management because medical treatment can be effective in the active stage.
**Fig. 1:** Pathogenesis of Thyroid orbitopathy: antibodies to thyroid stimulating hormone (TSH) target the TSH receptor (TSH-R) displayed on orbital fibroblasts. Activated fibroblasts release chemokines that recruit T-lymphocytes. These lymphocytes then interact with fibroblasts, promoting cytokine production and secretion of T-cell activating factors.

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Findings and procedure details

Diagnosis. Imaging techniques

-Indications-

There are alterations in the imaging tests in 90% of patients with thyroid disease, even without evident clinical involvement. CT and MRI are the most commonly used imaging techniques; however, ultrasound may also be useful. (3)

Although its diagnosis is usually clinical, imaging studies are indicated in equivocal cases, in the assessment of inflammatory activity, predicting DON and planning orbital surgical decompression. Table 1 on page 11

-Imaging features- Table 2 on page 11

-Bilateral proptosis. It can be measured by drawing a line between the anterior tips of the zygomatic bones and measuring the distance between this line and the right anterior corneal surface, and to the posterior sclera. The normal distance is less than 23 mm and more than 9.9±1.7 mm, respectively. Fig. 2 on page 12

-Increase in orbital fat volume and secondarily, anterior displacement of the orbital septum or enlargement / prolapse of the lacrimal glands. It could be the only finding in up to 20% of cases and suggests another different diagnosis: obesity, Cushing’s disease or steroid treatment. Fig. 3 on page 13 Fig. 4 on page 14

-Bilateral enlargement of EOM bellies (> 4 mm); (asymptomatic in approximately 71% of the cases). Involvement of the EOM in decreasing order of frequency: inferior rectus (77%), medial rectus (75%), superior rectus (50%). Fig. 5 on page 15 Fig. 6 on page 16 Isolated involvement of the lateral rectus is rare and suggests another different diagnosis: myositis, lymphoma or metastasis. The anterior tendon is typically spared with the swelling largely confined to the muscle belly, opposite to the myositis. Fig. 7 on page 17 Fig. 8 on page 18 Fig. 9 on page 19 Fig. 10 on page 20 Imaging studies also can be used to distinguish the inflammatory early stage from the inactive stage of the disease. Table 3 on page 24 Fig. 11 on page 21 Fig. 12 on page 22 Fig. 13 on page 23

-Prolapse of the lacrimal gland. Fig. 14 on page 25
- *Superior ophthalmic vein distension* because of venous compression by the enlarged muscles bellies and intrinsic adipose inflammation. *Fig. 15 on page 26*

- *Bone remodelling of the lamina papyracea, and eventually, spontaneous orbital decompression.* *Fig. 16 on page 26 Fig. 17 on page 27*

- *Dysthyroid optic neuropathy (DON):* It is the most serious complication and affects approximately 4 - 8% of patients with TAO. (3)

The most commonly accepted cause of DON is compression of the optic nerve or of its blood supply resulting from an increase in the volume of orbital soft tissues at the orbital apex.

Increased retrobulbar pressure and optic nerve stretch, secondary to increased orbital volume and a narrow orbital apex, have been hypothesized to be causes in a small percentage of cases. (4) *Fig. 18 on page 28 Fig. 19 on page 29*

Despite the increasing of clinical tests, DON remains an important problem. Because diagnosing DON can be clinically difficult and because its prognosis improves significantly with early diagnosis and treatment, the identification of patients at particular risk for development a neuropathy is high desirable.

Several studies have shown that certain CT scan parameters increase the suspicion of DON, and this technique is the most frequently used imaging modality in patients with TAO because of its capacity to visualize bone and soft tissue in the orbit.

**-Quantitative analysis features- CT**

We can evaluate the relationship between neuropathy and the severity of EOM enlargement seen at CT, by applying the Nugent’s score and Barret’s muscle index and evaluating the presence of intracranial fat prolapse > 2 mm through the superior ophthalmic fissure. (5) (6)

- **Nugent’s score:** is a grading scale based on the findings from coronal imaging to assess the degree of optic nerve crowding due to enlarged EOM at the orbital apex. According to this method, apical crowding was graded as 0 if no effacement of perineural fat planes was noted; 1 (mild), with 1% to 25% effacement; 2 (moderate), with 26% to 50% effacement; and 3 (severe), with greater than 50% effacement. (7) *Fig. 20 on page 30 Table 4 on page 31*
Barret’s muscle index: is a method for correlating the degree of EOM enlargement with the development of optic neuropathy; a muscular index calculated as the percentage of orbital width occupied by vertical and horizontal muscles in relation to orbital dimensions as measured from the midpoint between the globe and the orbital apex. Fig. 21 on page 32

Previous studies have evaluated the radiologic findings associated with DON with different results.

All the studies suggest that the quantifiable findings in CT to predict DON are the degree of nerve compression, (grade 3 orbital apex crowding) and muscle thickening, (especially internal rectus muscle). Table 5 on page 32 Table 6 on page 33 (8) (9) (10) (11)

Inflammatory activity in patients with thyroid-associated orbitopathy (TAO). CT

Accurate assessment of inflammatory activity is essential in determining the appropriate time and method of treatment for TAO patients. Clinical activity score (CAS) is the metric most widely used to evaluate inflammatory activity, but it relies on subjective symptoms and patient cooperation. Table 7 on page 34

Computed tomography (CT) is the most widely used diagnostic imaging modality in patients with TAO, and technical advances in 3D image analysis have facilitated more accurate and quantitative measurement of orbital fat, muscles, and the lacrimal gland. Several studies have explored the relationships between the quantitative volumes of orbital tissues based on CT analysis and clinical features of patients with TAO. (12) (13) Fig. 22 on page 34 Table 8 on page 45

MRI

MRI is preferred for studies assessing disease activity because of its better performance in the evaluation in soft tissues.

-Imaging Protocol- (3)

-Imaging of the orbits includes thin (3 mm) non-contrast axial, coronal (align with the perpendicular orientation of the optic nerve) and sagittal T1WI and fat-saturated T2WI, (STIR, TIRM). STIR sequences suppress the signal fat and allow a more adequate evaluation of pathological tissues.
- Measurement of relaxation time (TR) in T2 of the muscles increased in size. This calculation is done by calculating the mean value T2, measured with an ROI (region of interest) in the muscle most affected, obtained in a sequence using multiple TE (TE 20-400 ms) and a prolonged TR (TR> 3000 ms). It allows obtaining objectively a measure of the degree of inflammation.

- Signal intensity ratio (SIR) measured with a region of interest set within the brightest EOM both on coronal turbo inversion recovery magnitude (TIRM). To calculate the SIR, the measured signal intensity was set in proportion to that of the ipsilateral temporalis muscle. It is a useful tool to assess the therapeutic outcome of treatment.

**-Indications- MR**

- *Clinical suspicion of dysthyroid optic neuropathy*

MRI provides better imaging of the optic nerve than CT and better assessment of the effacement of the perineural fat secondary to apical crowding. MRI is the modality of choice to identify active inflammatory changes and to assess any immunosuppressive treatment response. (14)

- *Assessment of inflammatory activity*

MRI is a valuable tool to distinguish the acute inflammatory active disease from fibrotic, inactive end stage disease based on the signal intensity of enlarged muscles. Fig. 23 on page 35 Fig. 24 on page 36 Fig. 25 on page 37 Table 9 on page 38

Several studies have been shown that using diffusion-weighted imaging (DWI) can prove useful in detecting involvement of the EOM in TAO in the early period even before it is seen on conventional orbital MRI. ADC values of patients with TAO were higher than of healthy controls for EOMs. (15)

Recently, it has been published a retrospective study to determine the efficacy of quantitative measurements of the lacrimal gland based on 3-T MR imaging in the diagnosis and staging of TAO. All the quantitative measurements of the TAO patients were significantly larger than those of the healthy controls. Only signal intensity ratio (SIR) was found to be different between the active and inactive TAO groups with 57,7% of sensitivity and 77,5% of specificity. (16)
Monitoring the response to the treatment

The response to treatment can be assessed by measuring the section on area of the most enlarged muscle and the signal intensity ratio (SIR). (17) The obtained values are compared with those previous to the treatment.

Ultrasonography (US)

The main advantages of orbital US are its low cost and the lack of ionizing radiation. The main disadvantages of US are the high intra- and interobserver variability, the inability to adequately visualize the orbital apex and the poor quality of the anatomic information obtained of the bony orbital walls compared with the information provided by CT and MRI. (3).

Sonographic findings in Graves’ orbitopathy: Table 10 on page 39

- Enlargement of the periorbital tissues.

- Enlargement of the muscle belly of, at least, two muscles. Mc Nutt et al. (18) have been established normative data of EOM dimensions: # 5,2 mm for medial rectus, # 5,1 mm for lateral rectus, # 4,8 mm for superior rectus and # 4,4 mm for inferior rectus. However, occasionally a slight oblique section can result in misinterpretation of muscle enlargement. A difference greater than 0.5 mm between both orbits is also considered pathological. Fig. 26 on page 39

- Enlargement of the subarachnoid space of the optic nerve in case of DON. Fig. 27 on page 40

- Superior ophthalmic vein distension related to orbital apex crowding.

- Measuring EOM reflectivity: appears to be a reliable method to determine disease activity, with a promising accuracy in predicting therapeutic outcome of immunosuppressive treatment. (19)

  • Reflectivity in eye muscles with the lowest echogenicity was lower in responders than in non-responders. (3)(28). Fig. 28 on page 41

Color Doppler imaging (CDI)
Orbital blood flow is altered in patients with Graves’ ophthalmopathy. (3)

In general, ophthalmic artery, central retinal artery and vein showed an increase in the blood flow velocity with a reduction in the blood flow velocity in the superior ophthalmic vein. Fig. 29 on page 42 Fig. 30 on page 43 Fig. 31 on page 44
<table>
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<th>Imaging technique</th>
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<td>Equivocal cases</td>
<td>CT</td>
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<tr>
<td>Assessment of inflammatory activity</td>
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<td>Predicting dysthyroid optic neuropathy</td>
<td>MRI</td>
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<tr>
<td>Planning orbital surgical decompression</td>
<td>CT</td>
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**Table 1:** Indications of imaging techniques

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Increase in retroocular orbital fat

Bilateral proptosis

Bilateral extraocular muscle enlargement
- *Inflammatory process*: enlargement (contrast CT)
- *Fibrotic process*: fatty infiltration and enlargement

**Optic neuropathy** due to optic nerve compression

**Prolapse of lacrimal gland**

**Increase in superior vein ophthalmic caliber**

**Displacement of the lamina papyracea**

**Table 2**: Radiographic features in CT and MRI

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**Fig. 2:** Assessment of proptosis. Axial CT images of the orbits of two patients with thyroid-associated orbitopathy (TAO) (A) Right unilateral proptosis which can be measured by drawing a line between the anterior tips of the zygomatic bones (white line) and measuring the distance between this line and the right anterior corneal surface, 23 mm (orange arrow), and to the posterior sclera, 5.8mm, (red arrow); the normal distance is less than 23 mm and more than $10 \pm 1.7$mm, respectively. These distances in the left orbit are normal. (B) Severe bilateral proptosis. The globes have been displaced anterior to the interzygomatic line (in more than $2/3$) (white line).

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Fig. 3: Increase in orbital fat volume. Graves orbitopathy. Coronal orbit CT of two patients with Graves orbitopathy (A and B). Increase in orbital fat volume in both orbits, intra and extraconal (asterisk). This finding may be the only one visualized in patients with thyroid-associated orbitopathy (TAO). Enlargement of the extraocular muscles' bellies in both patients. Reduced attenuation in right inferior rectus representing fatty infiltration as a sign of chronicity (arrow) (A).

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Fig. 4: Increase in orbital fat volume. Differential diagnosis with Graves' orbitopathy. (A) Axial T2WI of a patient with obesity. Bilateral proptosis secondary to an increase in orbital fat volume. There is no extraocular muscle enlargement. There is also an increase in subcutaneous tissues volume of the facial and nuchal region (asterisks). (B) Axial orbit CT of a patient with rheumatoid arthritis treated with corticosteroids. Bilateral proptosis secondary to increase in orbital fat volume. There is no extraocular muscle enlargement.

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**Fig. 5:** Extraocular muscle enlargement. Orbit CT of a patient with unilateral thyroid-associated orbitopathy (TAO) and left proptosis. Sagittal images of the right (A) and left (B) orbit. Axial image (C). Coronal image (D). Enlargement of the superior and inferior rectus of the left orbit (arrows).Extraocular muscle of the right orbit are normal. Sagittal image is useful to evaluate the superior and inferior rectus in all its longitude. In the same way, axial image allows to evaluate the medial and lateral rectus, identifying in this case, enlargement of the left internal rectus (curved arrows). Coronal image is especially useful for assessing the size of the muscles and the optic nerve compression.

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Fig. 6: Extraocular muscle enlargement. Graves orbitopathy. Axial (A) and coronal (B) orbit CT of a patient with thyroid-associated orbitopathy (TAO). Bilateral and symmetric extraocular muscle enlargement, mainly medial and inferior rectus and, to a lesser extent, superior rectus (arrows). The anterior tendon is typically spared, with the swelling largely confined to the muscle belly. Lateral rectus muscle is normal.

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Fig. 7: Extraocular muscle enlargement, differential diagnosis. Myositis. Coronal (A) and sagittal (B) CT of the orbits. Patient with myositis of the left superior rectus and superior oblique muscles which demonstrates enlargement of the muscle belly with involvement of their tendinous insertions and inflammation of orbital fat (arrows). Involvement of the tendinous insertion distinguishes it from thyroid associated orbitopathy (TAO) in which the insertion point is spared.

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**Fig. 8:** Extraocular muscle enlargement, differential diagnosis. Metastatic disease. Patient with metastatic breast cancer and pain with left eye movement. (A) MRI axial T2WI; (B) axial T1WI; (C) coronal contrast enhanced fatsat T1WI. (D) coronal T2WI. Extraocular muscle enlargement of the left lateral rectus (asterisk C-D), hipointense on T1 / T2 to the other muscles with involvement of the anterior tendinous insertion (arrows A and B) and enhancement (C). There is also fatty inflammation in both orbits (curved arrows). The involvement predominantly of the lateral rectus muscle suggests other etiologies than thyroid associated orbitopathy (TAO).

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Fig. 9: Extraocular muscle enlargement. Unilateral thyroid associated orbitopathy (TAO). Axial (A) and coronal (B) CT of the orbits. Patient with thyroid orbitopathy and unilateral left proptosis. Isolated unilateral enlargement of the left inferior rectus muscle (asterisks). Unlike myositis, the muscle presents a well-defined shape and no inflammatory changes are identified in the adjacent fat. In this case, extraocular muscle enlargement is associated with an increase in orbital fat volume and displacement of the lamina papyracea and left orbital floor (arrow), which suggests the diagnosis of thyroid orbitopathy.

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Fig. 10: Extraocular muscle enlargement. Thyroid associated orbitopathy. Axial (A) and sagittal (B) CT of the orbits. Patient with Graves orbitopathy. Fusiform enlargement of the medial rectus bellies muscles of both orbits (asterisks) and inferior rectus (arrowhead). In comparison to myositis, the anterior tendon insertion is spared.

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**Fig. 11:** Extraocular muscle enlargement. Thyroid associated orbitopathy. T2 weighted axial fat suppressed MR imaging scan. Bilateral and symmetric enlargement of inferior, medial and superior rectus, which have increased signal intensity T2. The anterior tendon is typically spared with the swelling largely confined to the muscle belly. The lateral rectus are spared.

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Fig. 12: Extraocular muscle enlargement. MRI features of Graves orbitopathy, inflammatory process. Axial T2WI (A), axial T1WI (B), coronal T2WI fatsat (C) and axial contrast enhanced T1WI fatsat (D). Bilateral and symmetric enlargement of the inferior, medial and superior rectus muscles which shown T2WI increased signal intensity due the inflammatory process (asterisks). They are isointense to the other muscles on T1WI (B), and demonstrate enhancement after contrast injection (D). The lateral rectus are spared (arrows).

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**Fig. 13:** CT findings of inactive or chronic phase of Graves orbitopathy. Coronal (A) and sagittal (B) CT of a patient with thyroid orbitopathy. Bilateral enlargement of both inferior rectus accompanied by reduced attenuation representing fatty infiltration (arrows). The sagittal image (B) also shows fatty infiltration of the superior rectus muscle (asterisk). Increase in orbital fat volume despite chronicity and, remodeling of the medial orbital wall are also noted (curved arrows).

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### Table 3: Radiographic features

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<table>
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<th>Active / inflammatory phase:</th>
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<td>- Contrast-CT images</td>
<td>Enlargement and enhancement extraocular muscles bellies.</td>
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<tr>
<td>- MRI:</td>
<td></td>
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<tr>
<td>• T1</td>
<td></td>
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<tr>
<td>• T2(^a):</td>
<td>• Isointense to the other muscles.</td>
</tr>
<tr>
<td>• T1 C + (Gd):</td>
<td>• Variable. Increased signal intensity may be seen due to the inflammatory process.(^a)</td>
</tr>
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<td></td>
<td>• Enhancement may be present.</td>
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<th>Inactive / chronic phase:</th>
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<td>CT and MRI</td>
<td>Enlargement and fatty infiltration. Increase in orbital fat volume persists.</td>
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\(^a\)This finding has been correlated with better respond to treatment.

![Image](image-url)
**Fig. 14:** Prolapse of the lacrimal glands. Axial CT of a patient with thyroid orbitopathy and severe proptosis. Anterior displacement of the orbital septum (arrows) and lacrimal glands due to increase in orbital volume (asterisks).

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**Fig. 15:** Ingurgitation of the superior ophthalmic vein. Coronal CT of a patient with thyroid orbitopathy and left unilateral proptosis. Congestion of the superior ophthalmic veins, which is asymmetrically larger on the left, because of venous compression by the enlarged muscles bellies and intrinsic adipose inflammation (arrow). Enlargement of the inferior rectus muscular belly rectus (asterisk). Increase in orbital fat volume of the left orbit with remodelling of the medial-inferior wall of the orbit (curved arrow).

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Fig. 16: Bone remodelling of the lamina papyracea. Axial CT through the orbits of a patient with TAO. Increase in retroocular orbital fat and the size of the muscles, produces a remodelling of the lamina papyracea of the ethmoid (arrows), with the consequent bowing.

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Fig. 17: Medial spontaneous orbital decompression. Axial non-contrast CT of the orbits in two cases of TAO. (A) Unilateral left proptosis. Remodeling of the lamina papyracea of the left ethmoid (arrow). As affectation progresses, greater remodeling occurs of the lamina papyracea with spontaneous decompression (B).

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Fig. 18: Dysthyroid optic neuropathy. (A) Axial non-contrast CT of the orbits in a patient with TAO. Bilateral proptosis secondary to an increase in orbital fat volume, which results in stretching optic nerves (arrows). (B) Coronal contrast CT in other patient with thyroid orbitopathy and left unilateral proptosis. Distension of the left superior ophthalmic vein, which is asymmetrically larger, because of venous compression (arrow). Enlargement of the inferior, medial and superior rectus muscle bellies (asterisk). Apical crowding results in dysthyroid neuropathy due to optic nerve compression (arrowhead).

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Fig. 19: Surgical orbital decompression. Preoperative coronal non-contrast CT image (A) obtained in a patient with TAO. Postoperative coronal non-contrast scan (soft window), (B). Axial image (soft window) (C), and axial (bone window) (D). The postoperative images show the effects of bilateral medial, lateral and inferior wall removal after surgery.

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Fig. 20: Nugent’s score. Coronal CT scan showing orbits with apical crowding due to enlarged extraocular muscles bellies. (A) Both orbits show no effacement of the perineural fat (grade 0) (arrow). (B) The right orbit shows effacement of the perineural fat up to 25% of the circumference (grade 1) (arrow). (C) The left orbit shows effacement of the perineural fat between 25% -50 % (grade 2) (arrow).

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Table 4: Nugent’s score

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<tr>
<td>Effacement 25-50%</td>
<td>Grade 2</td>
</tr>
<tr>
<td>Effacement &gt; 50%</td>
<td>Grade 3</td>
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Fig. 21: Barret's muscle index, schematic representation. Coronal non contrast-CT image of a patient with TAO. The vertical index is calculated by the sum of the vertical muscle diameters (A and B) divided by the vertical dimension of the orbit (C). The horizontal index is calculated by dividing the sum of the horizontal muscle diameters (D and E) by the horizontal diameter of the orbit (F). The greater of the two ratios is considered the muscle index.

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<table>
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<tr>
<th>Quantifiable findings predictors of DON</th>
<th>Fat prolapse through the superior ophthalmic fissure</th>
<th>Grade 3 orbital apex crowding</th>
<th>Muscular index</th>
<th>Orbital geometry</th>
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<td>Yes (a u)</td>
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<td>Chan et al.</td>
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<td>Yes (a m)</td>
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<td>-</td>
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Table 5: Quantifiable findings predictors of DON.

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Table 6: Quantifiable findings predictors of DON. (a m: multivariate analysis, a u: univariate analysis, RM: medial rectus)

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1. Spontaneous retrobulbar pain  
2. Gaze evoked orbital pain  
3. Eyelid erythema  
4. Conjunctival redness  
5. Eyelid swelling  
6. Swollen caruncle  
7. Conjunctival chemosis

**Table 7:** Clinical activity score (CAS). One point is given for the presence of each of the parameters assessed. The sum of all points defines clinical activity: active ophthalmopathy if the score is above 3/7 at the first examination.
**Fig. 22:** Assessment of inflammatory activity in patients with TAO. Axial non contrast-CT image. Bilateral proptosis secondary to an increase in orbital fat volume and enlargement of extraocular muscles billies. Anterior displacement of the orbital septum and prolapse of the lacrimal gland (arrow). The density of left retrobulbar fat is greater than contralateral side, in conjunction with active inflammatory change, (asterisk).

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**Fig. 23:** Assessment of inflammatory activity in patients with TAO. Coronal T2WI (A) and coronal FLAIR (B) showing an evident enlargement of the inferior rectus muscle, with hyperintense foci inside (arrows), due to inflammation status.

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**Fig. 24:** Assessment of inflammatory activity in patients with TAO. Axial T1WI (A) and coronal T2WI (B) without fat supression. Axial T2WI (C) and coronal T2WI (D) with fat supression. Bilateral enlargement of inferior, medial and superior rectus, which are isointense to the other muscles in T1WI (arrows), and demonstrating hyperintense foci inside in T2WI sequences (curve arrows), due to inflammation status.

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**Fig. 25:** Assessment of inflammatory activity in patients with TAO. Coronal T2WI with fat supression (A), coronal T1WI without fat supression (B), axial T2WI with fat supression (C) and axial T1 with fat supression after paramagnetic contrast injection (D). Bilateral enlargement of inferior, medial and superior rectus, which demonstrating hyperintense foci inside in T2WI sequences (arrows), due to inflammation status. The lateral rectus are spared (A, C). The axial T1WI enhanced MR (D) shows the inflammatory process.

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<table>
<thead>
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<th>MRI Sequences</th>
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<td>-T2WI / STIR / TIRM*</td>
<td>High signal intensity (↑ water = acute / edematous phase)</td>
</tr>
<tr>
<td>-T1WI</td>
<td>Hyperintense foci (fatty muscle degeneration)</td>
</tr>
<tr>
<td>-T1WI + fat suppression</td>
<td>Matched fat-saturated / hypointense</td>
</tr>
<tr>
<td>-T1WI + C (Gd)</td>
<td>Enhancement may be present.</td>
</tr>
</tbody>
</table>

**Table 9:** MRI Findings. *The signal intensity from enlarged EOM on STIR and TIRM sequences correlates with better respond to immunosuppressive treatment and clinical activity score (CAS). (17)
<table>
<thead>
<tr>
<th>B-scan ultrasonography examination</th>
<th>Color Doppler sonography (active phase)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-Enlargement of the muscle belly.</td>
<td><strong>Superior ophthalmic vein:</strong></td>
</tr>
<tr>
<td></td>
<td>• ↓ in flow velocity</td>
</tr>
<tr>
<td></td>
<td>• Reverse flow / absence (risk factor of ON)</td>
</tr>
<tr>
<td></td>
<td><strong>Ophthalmic artery:</strong></td>
</tr>
<tr>
<td></td>
<td>• ↑ in peak systolic velocity</td>
</tr>
<tr>
<td></td>
<td>• ↑ end-diastolic velocity</td>
</tr>
<tr>
<td></td>
<td>• ↓ RI values</td>
</tr>
<tr>
<td>-Enlargement of the subarachnoid space of the optic nerve in case of DON</td>
<td><strong>Central retinal artery:</strong></td>
</tr>
<tr>
<td></td>
<td>• ↑ in peak systolic velocity</td>
</tr>
<tr>
<td></td>
<td>• ↑ RI values</td>
</tr>
<tr>
<td>-Measuring extraocular muscle reflectivity:</td>
<td></td>
</tr>
<tr>
<td>• Acute phase: lower</td>
<td></td>
</tr>
<tr>
<td>• Inactive phase: higher (fibrosis)</td>
<td></td>
</tr>
<tr>
<td>-Superior ophthalmic vein distension related to orbital apex crowding</td>
<td></td>
</tr>
<tr>
<td>-Thickening of the periorbital tissues</td>
<td></td>
</tr>
</tbody>
</table>

RI: resistance index

**Table 10:** Sonographic findings in TAO. Doppler imaging of orbital vessels in the assessment of the activity and severity of TAO.
Fig. 26: Sonographic findings in two patients with TAO. Axial B-scan ultrasonogram reveals increase and high reflectivity in orbital fat volume (asterisk) and enlargement of the left medial rectus, which shows high reflectivity foci inside correlate with fatty muscle degeneration (curve arrow) (A). Increase reflectivity intraconal fat (asterisk) and enlargement of the left medial rectus muscle (arrow) (B).

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**Fig. 27:** Sonographic findings in a patient with TAO. Axial B-scan ultrasonogram reveals enlargement of the subarachnoid space of the optic nerve in case of DON.

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**Fig. 28:** Sonographic findings in two patients with TAO. Assessment of inflammatory activity. A) Axial B-scan ultrasonogram in active phase shows decrease of reflectivity of the extraocular muscles (edematous phase) (arrow). B) Axial B-scan ultrasonogram in inactive phase reveals high reflectivity foci inside correlate with fibrosis and fatty muscle degeneration (curve arrow)

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**Fig. 29:** Sonographic findings in TAO. Color Doppler imaging and flow velocity waveform in the ophthalmic artery, which shows an increase in peak systolic velocity (PSV), approximately 66.4 cm/s.

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Fig. 30: Sonographic findings in TAO. Color Doppler imaging and flow velocity waveform in the central retinal artery in active phase, which reveals normal peak systolic velocities.

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**Fig. 31**: Sonographic findings in TAO. Color Doppler imaging and flow velocity waveform in the superior ophthalmic vein in a patient with TAO in active phase, which reveals a decrease in flow velocity. This is characteristic of the active stage of this pathology as an indicator of stasis.

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### Increase in volume of:

- Extraocular muscles
- Lacrimal glands
- Extraorbital and intraorbital fat

### Changes in orbital soft tissues density:

- ↑Extraorbital fat
- ↓Lacrimal glands

**Table 8:** CT parameters of orbital soft tissue to predict inflammation status.

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Conclusion

- Imaging studies are not always necessary in TAO.

- Imaging studies such as CT and MRI can be helpful in establishing the diagnosis of TAO because they provide morphological and quantitative analysis methods.

- TC is the most frequently used imaging modality in patients with TAO and provides invaluable surgical planning information in patients before decompressive surgery.

- MRI is the modality of choice to identify active inflammatory changes and to predict any immunosuppressive treatment response. Diffusion-weighted imaging (DWI) can prove useful in detecting involvement of the EOMs in TAO in the early period even before it is seen on conventional orbital MRI.

- Ultrasound is still useful when it is not available or it is not possible to perform the techniques previous.
References


