

Research Article

Correlation Between Serum Level of TSH Receptor Antibody and Severity of Graves' Orbitopathy

Karim Nasr El Din Abbas¹, Sheriff Elwan¹, Radwa Elsherif^{1, *}, Mina Nesim², Mahmoud Elsamkary¹

¹Department of Ophthalmology, Ain Shams University, Cairo, Egypt

²Department of Internal Medicine, Ain Shams University, Cairo, Egypt

Abstract

Purpose: evaluating relationship between serum level of TSH Receptor Antibody (TRAb) and severity of Graves' ophthalmopathy (GO). **Methods:** prospective interventional follow up study included 35 newly diagnosed untreated patients with GO was carried at Ain Shams University Hospital, Cairo. patients were subjected to full ophthalmological examination, measuring proptosis degree by Hertel's Exophthalmometer, measuring TRAb serum level. patients were classified according to clinical activity score into 2 groups: Inactive [CAS < 3]: 23 patients received only antithyroid therapy and Active [CAS ≥ 3]: 12 patients received intravenous methylprednisolone at a dose of 0.5gm for 6 weeks, injected weekly. 6 weeks after treatment severity of (GO), proptosis, and TRAb serum level were reassessed. **Results:** study found the mean CAS was 2.11 ± 1.13 , the mean proptosis measured (23.26 ± 3.19) and (22.42 ± 3.27) in right and left eye respectively while mean of TRAb was 11.19 ± 6.45 . After 6 weeks of treatment, CAS was regressed significantly in relation to TRAb level as TRAb measurement decreased by -62.7%, -14.06% in group II and group I respectively while proptosis measurement of right and left eyes in group II significantly decreased, with mean changes of -10.3% and -10.7%, respectively. And, in group I (-4.5% and -3.8%) in right and left eyes respectively, but not significant to TRAb level. **Conclusion** TRAb level can be used as monitor to activity of Grave's Ophthalmopathy (GO) and in follow up but not directly related to proptosis degree.

Keywords

Proptosis, TRAb, Graves' Orbitopathy, CAS, Graves' Disease

1. Introduction

Graves' disease (GD) is the most common cause of hyperthyroidism in developed Countries. GD is characterized by hyperthyroidism, diffuse goiter, ophthalmopathy, and dermopathy, In addition to elevated free thyroid hormones and suppressed thyroid stimulating hormone (TSH) levels. It is more common between 30-60 years, 5-10 times more frequent in females [1].

Grave's Ophthalmopathy (GO) is an autoimmune inflammation of the orbital tissues and the most common extra-thyroid symptom of GD, that occurs in 25-50% of patients with GD [2].

The main clinical manifestations of the disease are periorbital edema, eyelid retraction, proptosis, restrictive myopathy, and optic neuropathy. Changes in appearance and exposure

*Corresponding author: radwa_nabil@med.asu.edu.eg (Radwa Elsherif)

Received: 14 May 2025; **Accepted:** 3 June 2025; **Published:** 21 July 2025



Copyright: © The Author(s), 2025. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

symptoms and signs are the most common initial findings in GO. Proptosis is the second most common finding in GO that may be asymmetric and results from inflammation and increased volume of orbital soft tissues, including the extraocular muscles [3].

The diagnosis is usually made clinically based on presenting ocular symptoms and signs. Abnormalities in thyroid hormonal tests (free triiodothyronine (T3), free thyroxine (T4), and TSH) and/or the presence of thyroid specific antibodies (anti-thyroglobulin, anti-thyroid peroxidase and (TRAb)) help to support the diagnosis, but sometimes it may be negative especially in late disease [4].

The close link of GO with GD underpin the hypothesis that GO is triggered by immune reactions against one or more antigens shared by thyroid and orbit. Several potential serum markers for GO disease activity have been studied with the hope of monitoring change in activity more accurately. These include urine and serum Glycosaminoglycans (GAGs) and TRAbs [5].

The onset of GO is usually closely related to GD in its pathognomonic hyperthyroidism phase. Orbitopathy most often develops synchronously, it can also precede or follow the occurrence of hyperthyroidism [6]. Thyroid stimulating hormone receptor (TSHR), present on the thyroid cells, and physiologically found on the surface of orbital fibroblasts, yet in the case of GO, it is overexpressed [7].

Recent research suggests that onset of orbital inflammation may be characterized by early infiltration of macrophage cells in the orbital region, which induce TSHR antibodies (TRAbs) followed by a subsequent infiltration of CD8+-specific T-cells and fibrocyte [8]. Activation and binding of autoantibodies to the thyrotropin receptors (TSHR) expressed on the surface of orbital fibroblasts that induce proliferation, excess adipogenesis and overproduction of the extracellular matrix. The extracellular matrix comprises glycosaminoglycans (GAGs), such as chondroitin sulfate and hyaluronan, causing local water retention and swelling of connective tissue and extraocular muscles, which in turn worsens the venous and lymphatic circulation in the orbit [8].

The disease follows a biphasic course with an active or progressive phase followed by a quiescent or stable phase: the temporal status is graded as disease activity. Grading systems for GO include Werner's NO SPECS and European Group on Graves' Orbitopathy (EUGOGO)'s severity scales, the Clinical Activity Score (CAS) and the VISA Classification (for severity and activity). Diagnosis of GO is based on recognition of clinical features and supported by thyroid function and immune testing, and orbital imaging [1].

Early diagnosis of GO allows appropriate evaluation and treatment, and ideally might prevent the development of more serious sequelae. The endocrinologist or internist can play a vital role in recognizing early ocular clinical manifestations, determining disease severity and activity, identifying those most at risk for developing serious complications, and in arranging prompt referral to an experienced ophthalmologist

so that appropriate intervention can be planned [4]. Our study aims to evaluate the relationship between serum level of TSH receptor antibody (TRAb) and severity of Grave's ophthalmopathy in order to help early diagnosis and treatment of the disease to prevent the development of complications.

The management of GO depends on the disease severity and activity. However, the guidelines emphasize the importance of individualizing the treatment strategy, so that potential benefits do not outweigh the possible side effects. It is recommended in routine clinical practice that the quality of life of the patients is estimated based on the use of a validated GO-specific quality of life tool (GO-QoL) [9].

2. Patients and Methods

A prospective interventional follow up study was carried at Ain Shams University Hospital, Cairo, Egypt from January 2022 to August 2023 and included 35 (newly diagnosed patients with GO) in accordance with the ethical standards stated by the Ethical Committee of Ain Shams University. Patients who visited the outpatient department of Endocrinology and department of Ophthalmology in El Demerdash Hospitals and newly clinically diagnosed with GO and not received any treatment before were included in the study. While patients with history of previous orbital surgery, thyroid surgery, other autoimmune diseases, and history of previous antithyroid treatment were excluded from the study. All patients were subjected: History taking including name, age and medical history, full ophthalmological examination including detection and measurement of proptosis using Hertel's exophthalmometer, classification of the patients according to CAS, measurement of serum thyroid profile, measurement of serum level of TRAb by Enzyme-Linked Immunosorbent Assay (ELISA): (Cobas e 801 analyzers, Roche Diagnostics, Mannheim, Germany), remeasurement of the degree of the proptosis and serum level of TRAb after 6 weeks of the treatment.

GO was classified according to history, proptosis (Hertel's measurement > 17mm or 2 mm differences between the eyes), eyelid retraction (>1 mm in primary gaze), optic neuropathy, ocular motility, corneal or conjunctival involvement. Grading of proptosis severity was done according to the modified NOSPECS score (proptosis <17 mm (0), proptosis 18-19 mm (1), proptosis 20-22 mm (2), proptosis >23 mm (3)).

All the GO patients underwent blood tests for surveying the titers of TRAb by Enzyme-linked immunosorbent (ELISA) as well as the concentrations of TSH, FT3 and FT4; moreover, CAS examinations were also performed for evaluating the activity of GO among the patients according to seven assessment items: spontaneous retrobulbar pain, pain on eye movement, eyelid erythema, conjunctival injection, chemosis, swelling of the lacrimal caruncle, and eyelid edema or fullness. One point was given for each item and it ranges from 0-7 scores in total. GO patients were classified according to CAS into 2 groups: inactive group (CAS<3) (n=23) and active

group (CAS ≥ 3) (n=12) (Figure 1).

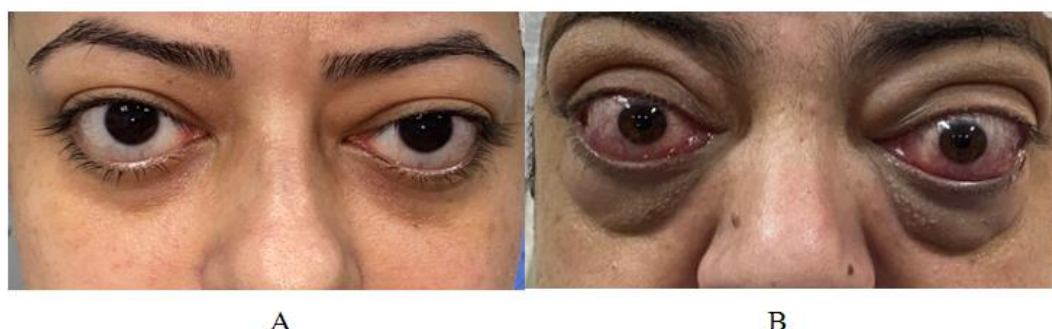


Figure 1. A- patient with inactive GO group I, B- patient with active GO group II.

Inactive patients received only antithyroid treatment, however active patients received antithyroid treatment and intravenous methylprednisolone (IVMP) injected weekly for 6 weeks on the same day at a dose of 0.5 gm. After 6 weeks of treatment, we remeasured proptosis, serum level of TRAb, FT3 and FT4.

3. Statistical Analysis

Data were collected, revised, coded and entered to the Statistical Package for Social Science (IBM SPSS) version 23. The quantitative data were presented as mean, standard deviations and ranges when parametric and median, inter-quartile range (IQR) when data found non-parametric. Also, qualitative variables were presented as number and percentages. The p-value was considered significant as the following: P-value > 0.05 : Non-significant (NS), P-value ≤ 0.05 : Significant (S), P-value < 0.01 : Highly significant (HS).

4. Ethical Considerations

After Approval of the Research Ethical Committee (REC) at the faculty of medicine, Ain Shams University (under the number code FWA 000017585 FAMSU MD 239/2021 and administrative approval was obtained from the manager of Ain Shams University hospitals to carry out the study. A verbal Informed consent was taken from each participant before examination. Confidentiality and privacy of the participants was assured, collected data was dealt in complete confidentiality and used for research purposes.

5. Results

The study included a total of 35 patients ranged from (18-60) years old with mean \pm SD 33.97 ± 9.48 years, most of the participants were females (62.9%), non-smoker (80%), non-hypertensive (60%), and non-diabetic (54.3%). All patient before treatment were taken all biochemical parameters [Table 1] as The mean CAS was 2.11 ± 1.13 , proptosis in 48.6% of the right eye and 40% of the left eye measuring greater than or equal to 23 mm and the mean TRAb 11.19 ± 6.45 . There is a significant correlation between CAS and proptosis [Table 2] and a significant correlation between TRAb and CAS [Table 3] [Figure 2] while TRAb and proptosis non-significant. The thyroid parameters are non-significant with CAS but TRAb is significant with TSH [Tables 2, 3]. All patients received antithyroid treatment while group 11 received also steroid treatment and mean TRAb $9 (4.2 \pm 11)$ in group I and $5.3 (2.8 \pm 7.07)$ in group II in comparison to results before treatment there was a significant drop in the TRAb measurement in the inactive group by -14.06% (-25% - -8.33%) and in the active group by -62.7% (-65.69% - -54.27%) while TSH, FT3, and FT4 significant different before and after the treatment [table 4]. Also, the proptosis measurement of the right and left eyes in active group have significantly decreased, with mean changes of -10.3% (-11.1% - 8%) and -10.7% (-11.1% - -7.4%), respectively. On the other hand, the right and left eyes in the inactive group changed by -4.5% (-4.8% - 0%) and -3.8% (-4.8% - 0%), respectively [Table 4] [Figure 2]. The multiple linear regression analysis was used to evaluate the factors associated with TRAb after treatment [Table 5].

Table 1. Basic characteristics and biochemical parameters before treatment.

| Variables | Mean \pm SD | Range |
|--------------------|-------------------|---------------|
| b (IU/L) | 11.19 \pm 6.45 | (1.99 - 27) |
| TSH (μ IU/ml) | 0.008 \pm 0.003 | (0.01 - 0.02) |
| FT3 (pg/dL) | 12.31 \pm 6.30 | (4.5 - 25) |
| FT4 (ng/dL) | 4.08 \pm 1.79 | (1.88 - 8.53) |
| CAS | 2.11 \pm 1.13 | (1-4) |
| Proptosis | | |
| Right eye | 23.26 \pm 3.19 | (19 - 30) |
| Grade 1: 18-19 mm | 5.7% | |
| Grade 2: 20-22 mm | 45.7% | |
| Grade 3: > 23 mm | 48.6% | |
| Left eye | 22.42 \pm 3.27 | (18 - 29) |
| Grade 1: 18-19 mm | 22.9% | |
| Grade 2: 20-22 mm | 37.1% | |
| Grade 3: > 23 mm | 40.0% | |

(*) P value \leq 0.05 is considered statistically significant ¥ independent t test

Table 2. Correlation between CAS and thyroid related parameters and proptosis before treatment.

| Parameter | R | P value | Sig. |
|---------------------|--------|---------|------|
| Right eye proptosis | 0.374 | 0.027 | S |
| Left eye proptosis | 0.439 | 0.008 | S |
| TSH | 0.033 | 0.852 | NS |
| FT3 | -0.272 | 0.115 | NS |
| FT4 | -0.257 | 0.136 | NS |

(*) P value \leq 0.05 is considered statistically significant ¥ spearman's correlations

Table 3. Correlations between TRAb and thyroid-related parameters, proptosis and CAS before treatment.

| Parameters | R | P value | Sig |
|------------|--------|---------|-----|
| TSH | -0.501 | 0.002* | S |
| FT3 | 0.190 | 0.274 | NS |
| FT4 | 0.235 | 0.174 | NS |
| Right eye | 0.164 | 0.346 | NS |
| Left eye | 0.188 | 0.279 | NS |
| CAS | -0.498 | 0.002* | S |

(*) P value \leq 0.05 is considered statistically significant ¥ pearson correlation was used

Table 4. Biochemical parameters before and after treatment.

| | Inactive # n=23 | Active # n=12 |
|--|-------------------------|----------------------------|
| | Median (IQR) | Median (IQR) |
| TRAb before treatment | 10 (5.3 - 14) | 14.7 (6.4 - 21.15) |
| TRAb after treatment | 9 (4.2 - 11) | 5.3 (2.8 - 7.07) |
| TRAb Change (%) | -14.06% (-25% - -8.33%) | -62.7% (-65.69% - -54.27%) |
| P-Value | <0.001* | 0.002* |
| TSH before treatment | 0.01 (0.005 - 0.01) | 0.005 (0.005 - 0.01) |
| TSH after treatment | 0.01 (0.005 - 0.01) | 0.01 (0.01 - 0.01) |
| P-Value | 0.059 | 0.014* |
| FT3 before treatment | 14.5 (9.19 - 19.5) | 5.82 (5.12 - 8) |
| FT3 after treatment | 7.9 (5.81 - 9.9) | 3.16 (2.5 - 3.9) |
| P-Value | <0.001* | 0.005* |
| FT4 before treatment | 4.8 (2.91 - 5.69) | 2.68 (2.2 - 2.8) |
| FT4 after treatment | 2.2 (2 - 3.1) | 1.3 (1.3 - 1.4) |
| P-Value | <0.001* | 0.005* |
| Proptosis Rt eye (mm) before treatment | 21 (20 - 23) | 27.5 (25 - 29) |
| Rt eye (mm) after treatment | 21 (20 - 22) | 24.5 (23 - 26) |
| Change (%) | -4.5% (-4.8% - 0%) | -10.3% (-11.1% - -8%) |
| P-Value | <0.001* | 0.004* |
| Lt eye (mm) before treatment | 21 (19 - 22) | 27 (26 - 27) |
| Lt eye (mm) after treatment | 20 (19 - 22) | 24 (23 - 25) |
| Change (%) | -3.8% (-4.8% - 0%) | -10.7% (-11.1% - -7.4%) |
| P-Value | <0.001* | 0.004* |

(*) P value ≤ 0.05 is considered statistically significant ¥independent t test**Table 5.** Multiple linear regression between TRAb and thyroid related parameters and CAS after treatment.

| | Unstandardized Coefficients | | Standardized Coefficients | T | P value | Sig |
|------------|-----------------------------|------------|---------------------------|--------|---------|-----|
| | B | Std. Error | Beta | | | |
| (Constant) | -0.378 | 2.982 | | -0.127 | 0.90 | NS |
| TSH | 64.153 | 119.566 | 0.084 | 0.537 | 0.59 | NS |
| FT3 | 0.981 | 0.321 | 0.737 | 3.053 | 0.10 | NS |
| FT4 | -1.247 | 1.152 | -0.275 | -1.083 | 0.28 | NS |
| CAS | 1.023 | 0.618 | 0.293 | 1.655 | 0.01 | S |

(*) P value ≤ 0.05 is considered statistically significant ¥independent t test

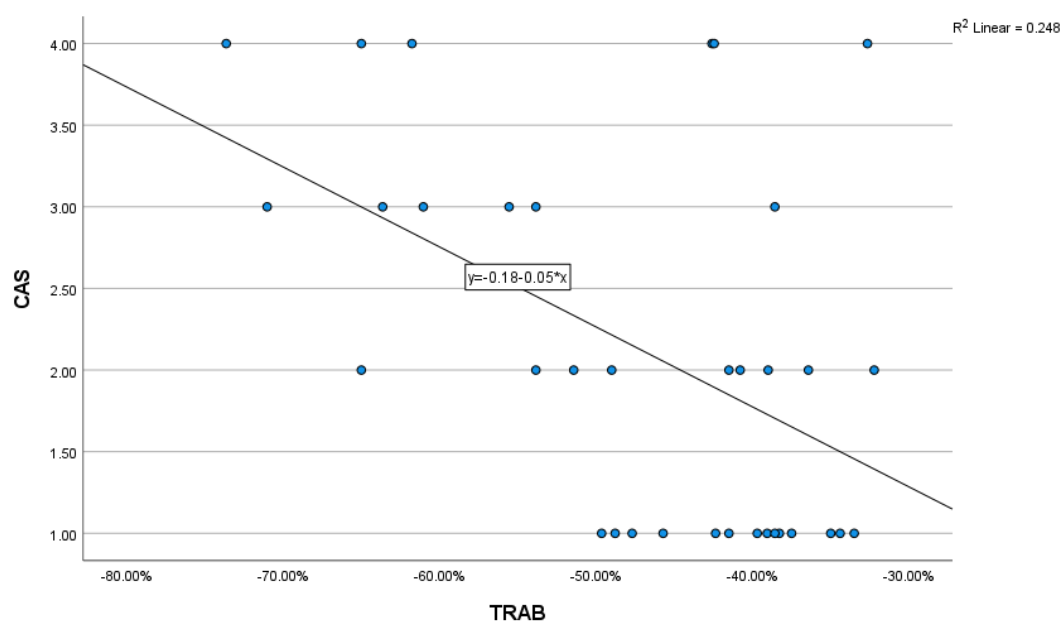


Figure 2. Correlation between TRAb and CAS.

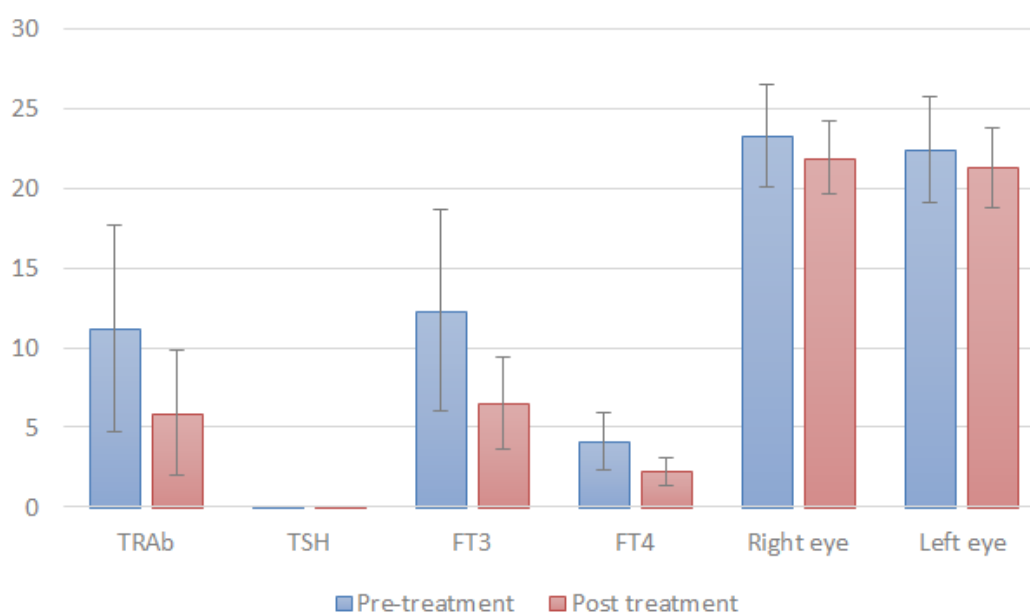


Figure 3. Comparison between measurements before and after treatment. (Steroid group).

6. Discussion

Graves' orbitopathy (GO) is a common complication that is clinically relevant in about 50% of patients with GD. The symptoms are often mild, but severe forms of GO occur in 3-5% of patients [10], and the GO is the primary cause of exophthalmos in adults as it appears in 30 to 50% of patients with Graves' disease. About 5% are moderate-to-severe cases that might be see-threatening or lead to long-term disabling sequelae. GO may start early in the course of disease or appears

later during the follow-up period. In the Middle East, the prevalence of TED among patients with GD is 48% (CI: 0.19 to 0.78) and in Southeast Asia, 35% (CI: 0.24 to 0.47). Regions with a predominance of Caucasians (37%; CI: 0.28 to 0.46) have a lower prevalence of TED than Asian regions (45%; CI: 0.33 to 0.58) [11].

Several studies support the involvement of TRAb in the pathogenesis of GO, and a correlation between GO features and TRAb has been reported, but not confirmed by all studies specially in the initial phase of disease. So, we conducted a follow up interventional study to determine whether there is a correlation between TRAb, CAS and proptosis measurement

in the initial phase of the eye disease. In our study we measure of TRAb level by Enzyme -linked immunosorbent (ELISA) which the sensitivity and specificity of TRAb assay are relatively comparable, ranging from 79.5 to 94.4% and 87.5 to 97.9%, respectively [12].

The correlation between CAS and TRAb level was significant in all patients whose diagnosed GD with GO without initial treatment in our study and this matching with results of Moledina et al [13] and Nicol iet al. [5] also TRAb level is significant correlation between with TSH level before treatment, similar to the results of Lin et al [14]. Our study's the correlation analysis between CAS and thyroid-related parameters (TSH, FT3, and FT4) showed no significant correlation between CAS and thyroid hormones as Similar results to a study by Topcu et al [15] this means that more hormonal changes not actually more clinical activity but more changes of the immunity to TSR.

CAS is a significant correlation with proptosis but the severity of proptosis not related to TRAb level and this is matching with other studies by Nicol iet al. [5] and Lin et al [14], also after treatment the TRAb level, CAS and Proptosis is improved and decreased as matching with Zang et al [16], which reported a minimum 2-mm reduction in proptosis after IVMP therapy but in our study proptosis in group 11 was decrease larger, at least 3mm while TRAb level in the group 11 that took steroids by -62.7% and in the group 1 by -14.06% (-25% - -8.33%), in line with the findings of Kahaly et al. [17] that the TRAb titer significantly decreased following IVMP therapy. The treatment by antithyroid drugs to well control of thyroid function well helping to decrease the stimulus of the immune cascade as the accumulation and overproduction of the extracellular matrix which TRAb will stope stimulating the orbital fibroblast and also the treatment by steroid exaggerate the effect on the TRAb and the infiltration of the activated B and T lymphocytes, as well as bone marrow derived CD34 + and fibrocytes in tissues will stopped this is may be the explanation of the improvement in CAS and proptosis in group 11, further studies for pathophysiology in the future my helping in the management, so TRAb level by ELISA is monitoring for activity of GO in initial diagnosis and after beginning of treatment more less with TSH level for a well control of orbital tissue activity.

7. Conclusion

There has been a significant correlation between the clinical activity of GO and the serum levels of TRAb in patients with a recent-onset, untreated GO as the TRAb level with ELISA can used as monitoring tool in early diagnosis and in follow-up during treatment for the orbital tissue activity.

8. Limitations of the Study

Small number of cases, Further investigations may be re-

quired for more accurate correlation between degree of proptosis and TRAb.

Abbreviations

| | |
|--------|---------------------------------------|
| TRAb | Thyroid Receptor Antibody |
| CAS | Clinical Activity Score |
| GO | Grave's Ophthalmopathy |
| GD | Grave's Disease |
| TED | Thyroid Eye Disease |
| GAGs | Glycosaminoglycans |
| EUGOGO | Eutopian Group on Grave's Orbitopathy |
| TSHR | Thyroid Stimulating Hormone Receptor |

Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] Antonelli A, Ferrari SM, Ragusa F, Elia G, Paparo SR, Ruffilli I, et al. Graves' disease: Epidemiology, genetic and environmental risk factors and viruses. Best practice & research. Clinical endocrinology & metabolism. 2020; 34(1).
- [2] Oh S-R, Tung JD, Priel A, Levi L, Granet DB, Korn BS, et al. Reduction of orbital inflammation following decompression for thyroid-related orbitopathy. Biomed Res Int [Internet]. 2013; 2013: 794984. Available from: <http://dx.doi.org/10.1155/2013/794984>
- [3] Bartley GB, Fatourehchi V, Kadrmas EF, Jacobsen SJ, Ilstrup DM, Garrity JA, et al. Clinical features of Graves' ophthalmopathy in an incidence cohort. Am J Ophthalmol [Internet]. 1996; 121(3): 284-90. Available from: [http://dx.doi.org/10.1016/s0002-9394\(14\)70276-4](http://dx.doi.org/10.1016/s0002-9394(14)70276-4)
- [4] Diana T, Ponto KA, Kahaly GJ. Correction to: Thyrotropin receptor antibodies and Graves' orbitopathy. J Endocrinol Invest [Internet]. 2022; 45(1): 233. Available from: <http://dx.doi.org/10.1007/s40618-021-01632-2>
- [5] Nicol iF, Lanzolla G, Mantuano M, Ionni I, Mazzi B, Leo M, et al. Correlation between serum anti-TSH receptor autoantibodies (TRAbs) and the clinical feature of Graves' orbitopathy. J Endocrinol Invest [Internet]. 2021; 44(3): 581-5. Available from: <http://dx.doi.org/10.1007/s40618-020-01353-y>
- [6] Gontarz-Nowak K, Szychlińska M, Matuszewski W, Stefanowicz-Rutkowska M, Bandurska-Stankiewicz E. Current knowledge on Graves' orbitopathy. J Clin Med [Internet]. 2020; 10(1): 16. Available from: <http://dx.doi.org/10.3390/jcm10010016>
- [7] Bartalena L. Graves' orbitopathy: imperfect treatments for a rare disease. Eur Thyroid J [Internet]. 2013; 2(4): 259-69. Available from: <http://dx.doi.org/10.1159/000356042>

- [8] Philipp, S.; Horstmann, M.; Hose, M.; Daser, A.; Görtz, G. E.; Jesenek, C.; Flögel, U.; Hansen, W.; Bechrakis, N.; Banga, J. P. S.; et al. An Early Wave of Macrophage Infiltration Intertwined with Antigen-Specific Proinflammatory T Cells and Browning of Adipose Tissue Characterizes the Onset of Orbital Inflammation in a Mouse Model of Graves' Orbitopathy. *Thyroid* 2022, 32, 283-293. [Google Scholar] [CrossRef].
- [9] Bartalena L, Baldeschi L, Boboridis K, Eckstein A, Kahaly GJ, Marcocci C, et al. The 2016 European thyroid association/European group on Graves' orbitopathy guidelines for the management of Graves' orbitopathy. *Eur Thyroid J* [Internet]. 2016; 5(1): 9-26. Available from: <http://dx.doi.org/10.1159/000443828>
- [10] Wiersinga WM, Bartalena L. Epidemiology and prevention of Graves' ophthalmopathy. *Thyroid* 2002; 12: 855-860. <https://doi.org/10.1089/105072502761016476>
- [11] Chin YH, Ng CH, Lee MH, Koh JWH, Kiew J, Yang SP, et al. Prevalence of thyroid eye disease in Graves' disease: A meta-analysis and systematic review. *Clin Endocrinol (Oxf)* [Internet]. 2020; 93(4): 363-74. Available from: <http://dx.doi.org/10.1111/cen.14296>
- [12] Struja T, Jutzi R, Imahorn N, et al. Comparison of five TSH - receptor antibody assays in Graves' disease: results from an observational pilot study. *BMC Endocr Disord*. 2019; 19(1): 38. <https://doi.org/10.1186/s12902-019-0363-6>
- [13] Moledina M, Roos J, Murthy R. 'Thyrotropin Receptor Autoantibody Assessment in Thyroid Eye Disease: Does the Assay Type Matter? *Korean Journal of Ophthalmology*. 2023; 37(2): 147-56.
- [14] Lin C-C, Chiu L-W, Lee P-Y, Chen K-J, Cheng K-C. Comparison of the correlation between serum autoantibodies against aldehyde dehydrogenase 2 and thyrotropin receptor in patients with Graves' ophthalmopathy. *Indian J Ophthalmol* [Internet]. 2024; 72(2): 298-9. Available from: http://dx.doi.org/10.4103/IJO.IJO_673_23
- [15] Topcu H, Atik BK, Ozkocak BY, Efe AC, Ulas MG, Cabuk KS. Evaluation of aqueous flare in Graves' ophthalmopathy and its relationship with thyroid hormones, antibodies, and clinical activity score. *Beyoglu Eye J* [Internet]. 2023; 8(3): 208-13. Available from: <http://dx.doi.org/10.14744/bej.2023.80557>
- [16] Zang S, Ponto KA, Pitz S, Kahaly GJ. Dose of intravenous steroids and therapy outcome in Graves' orbitopathy. *J Endocrinol Invest* [Internet]. 2011; 34(11): 876-80. Available from: <http://dx.doi.org/10.1007/BF03346732>
- [17] Kahaly GJ, Olivo PD. Graves' disease. *N Engl J Med* [Internet]. 2017; 376(2): 184. Available from: <http://dx.doi.org/10.1056/NEJMc1614624>