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Predictive value of thyroid-related biomarkers in Graves' disease – a systematic review

Wartość predykcyjna biomarkerów czynności tarczycy w chorobie Gravesa–Basedowa – przegląd systematyczny

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Abstract

Graves' disease is the most common cause of hyperthyroidism and is characterised by a clinical course often difficult to predict. While some patients experience relapses, others achieve long-term remission. It is crucial to improve the accuracy of predicting disease course in order to identify patients who are most likely to benefit from antithyroid drug therapy, thereby avoiding potential complications associated with more radical treatments. The aim of this systematic review is to gather up-to-date knowledge in this field and, based on it, to determine whether commonly available thyroid-related biomarkers can predict the likelihood of remission after antithyroid drug therapy. Thyroid stimulating hormone (TSH), free triiodothyronine (FT3), free thyroxine (FT4) and TSH-receptor antibodies (TRAb) were evaluated. A total of 964 articles (394 from PubMed and 570 from Embase) were initially identified. After screening and eligibility assessment, 19 studies were included in the final analysis. The results of these studies were heterogenous and partly inconclusive. However, TRAb appears to be the most useful marker in predicting remission. Low baseline TRAb concentrations are associated with a higher probability of remission, while higher values correlate with a more severe clinical course and a greater risk of relapse. The predictive value of FT3 and FT4 as markers is questionable. TSH tends to be the least informative predictor of the outcome. In conclusion, looking at the nature of Graves' disease, which may be relapsing-remitting, further research in this area is warranted to enhance the quality of life of patients with Graves' disease.

Keywords: biomarkers, Graves' disease, hyperthyroidism, antithyroid drugs

Streszczenie

Choroba Gravesa–Basedowa jest najczęstszą przyczyną nadczynności tarczycy, a jej przebieg kliniczny jest trudny do przewidzenia. U części pacjentów obserwuje się nawroty, podczas gdy inni osiągają długotrwałą remisję. Zwiększenie skuteczności prognozowania odpowiedzi na terapię lekami przeciwtarczycowymi może ułatwić dobór optymalnego postępowania i uniknięcie powikłań związanych z leczeniem radykalnym. Celem przeglądu było zebranie aktualnych danych w tym zakresie oraz ocena wartości predykcyjnej powszechnie stosowanych i łatwo dostępnych biomarkerów czynności tarczycy w przewidywaniu remisji po terapii lekami przeciwtarczycowymi. Do analizy wybrano tyreotropinę (TSH), wolną trójjodotyroninę (FT3), wolną tyroksynę (FT4) i przeciwciała przeciwko receptorowi dla TSH (TRAb). Wstępnie zidentyfikowano 964 publikacje (394 z bazy PubMed i 570 – Embase). Po przeprowadzeniu selekcji do przeglądu włączono 19 z nich. Wyniki analizowanych badań są niejednoznaczne. Uzyskane wyniki wskazują, że TRAb wydają się najużyteczniejszym markerem w przewidywaniu remisji. Niska początkowa wartość TRAb jest korzystnym czynnikiem predykcyjnym, natomiast wyższe stężenia korelują z cięższym przebiegiem klinicznym i większym ryzykiem nawrotu.

Rola F3 i FT4 jako markerów predykcyjnych jest wątpliwa, a najmniejsze znaczenie prognostyczne wydaje się mieć TSH. Podsumowując, biorąc pod uwagę charakter choroby Gravesa–Basedowa, często przebiegającej z okresami remisji i nawrotów, konieczne są dalsze badania w tym obszarze w celu poprawy jakości życia pacjentów dotkniętych tą chorobą.

Słowa kluczowe: biomarkery, choroba Gravesa–Basedowa, nadczynność tarczycy, leki przeciwtarczycowe

INTRODUCTION

Aim

Graves' disease (GD) is an autoimmune condition that affects the thyroid gland and influences the function of various organs, potentially posing a threat to patient health. The primary goal of treatment is to reduce circulating thyroid hormone levels, thereby alleviating clinical symptoms. Several treatment options are available. Antithyroid drugs (ATDs) are the first-line therapy for newly diagnosed patients with GD, although in some cases treatment may also involve radioactive iodine (RAI) therapy or surgery[1]. Patients who remain in a euthyroid state for an extended period after discontinuing ATD are considered to be in remission[2]. However, a subset of patients experiences disease relapse. From a clinical perspective, the ability to predict disease outcome is crucial. Therefore, this study aims to evaluate whether basic thyroid markers are useful in predicting remission in patients treated for GD.

Background

GD is an autoimmune disorder involving both B and T lymphocytes in its pathogenesis. The resulting autoantibodies stimulate the thyroid-stimulating hormone (TSH) receptor on thyroid follicular cells, causing overproduction of thyroid hormones[3]. The course of the disease consists of remission and relapse episodes that can last for years[4]. Although the use of TSH-receptor antibodies (TRAb) as a marker for remission remains controversial[5], some studies have focused on the correlation between thyroid stimulating antibodies (TSAb) and remission rates[6]. TSAb stimulate the thyroid gland, causing Graves' hyperthyroidism and indicate the stimulatory activity of TRAb[7].

TRAb levels are useful clinical markers at the time of diagnosis. Moreover, their fluctuations may indicate which treatment method would be most beneficial for individual patients[8]. TSH, a hormone secreted by the pituitary gland, regulates thyroid function. Triiodothyronine (T3) is the fully active thyroid hormone, which is mostly produced outside the thyroid gland via deiodination of thyroxine (T4) catalysed by deiodinase enzymes. After conversion, T3 has a half-life of approximately 12 hours. Serum free triiodothyronine (FT3) is one of the markers elevated in Graves' disease. It is formed not only in the thyroid (20%), but also in other tissues (80%)[9]. FT3 is the more potent hormone and is responsible for most thyroid hormone activity[10]. Free thyroxine (FT4) is the main hormone produced by the thyroid gland. It has a relatively long half-life (~8 days) and is less active. Elevated FT4 levels may indicate hyperthyroidism due to GD.

MATERIALS AND METHODS

The characteristic of this study are described using the Patient, Indicator/Intervention, Outcome (PIO) framework. The patient population included adults (≥18 years), diagnosed with GD who completed a course of pharmacotherapy with ATDs (thionamides). The indicators/interventions were specific biomarkers significant in diagnosing GD – TSH, FT3, FT4 and TRAb – measured at the beginning of treatment. The outcome was remission of GD (clinical and biochemical absence of hyperthyroidism) and its duration following ATD withdrawal.

To collect published data related to GD, remission and the above-mentioned biomarkers, a literature search was conducted in PubMed and Embase using the following combinations:

- PubMed – ("Graves Disease"[MeSH Terms] OR "Graves' Disease" OR "Basedow's Disease") AND (("T3" OR "Triiodothyronine") OR ("T4" OR "Thyroxine") OR ("TSH" OR "Thyroid stimulating hormone") OR ("TRAb")) AND ("Remission") NOT ("Children") NOT ("Pregnancy") NOT ("Ophthalmopathy") NOT ("GO");
- Embase – 'graves disease'/exp AND ('t3' OR 'triiodothyronine' OR 't4' OR 'thyroxine' OR 'tsh' OR 'thyroid stimulating hormone' OR 'trab') AND 'remission' NOT 'child' NOT 'pregnancy' NOT 'ophthalmopathy'.

Seven authors independently evaluated study eligibility. Differences and disagreements were resolved through discussion. No restrictions were placed on publication date.

A total of 964 records (394 from PubMed and 570 from Embase) were initially identified. After removing 279 duplicates, 685 records were screened based on titles and abstracts.

The inclusion criteria were:

1. relevance to the main topic – the study focuses on GD in the context of prognosis/outcome (361 articles were excluded because they did not address the topic of the review);
2. availability in English (54 excluded);
3. availability of full text (47 excluded).

Subsequently, 223 full-text articles were assessed for eligibility.

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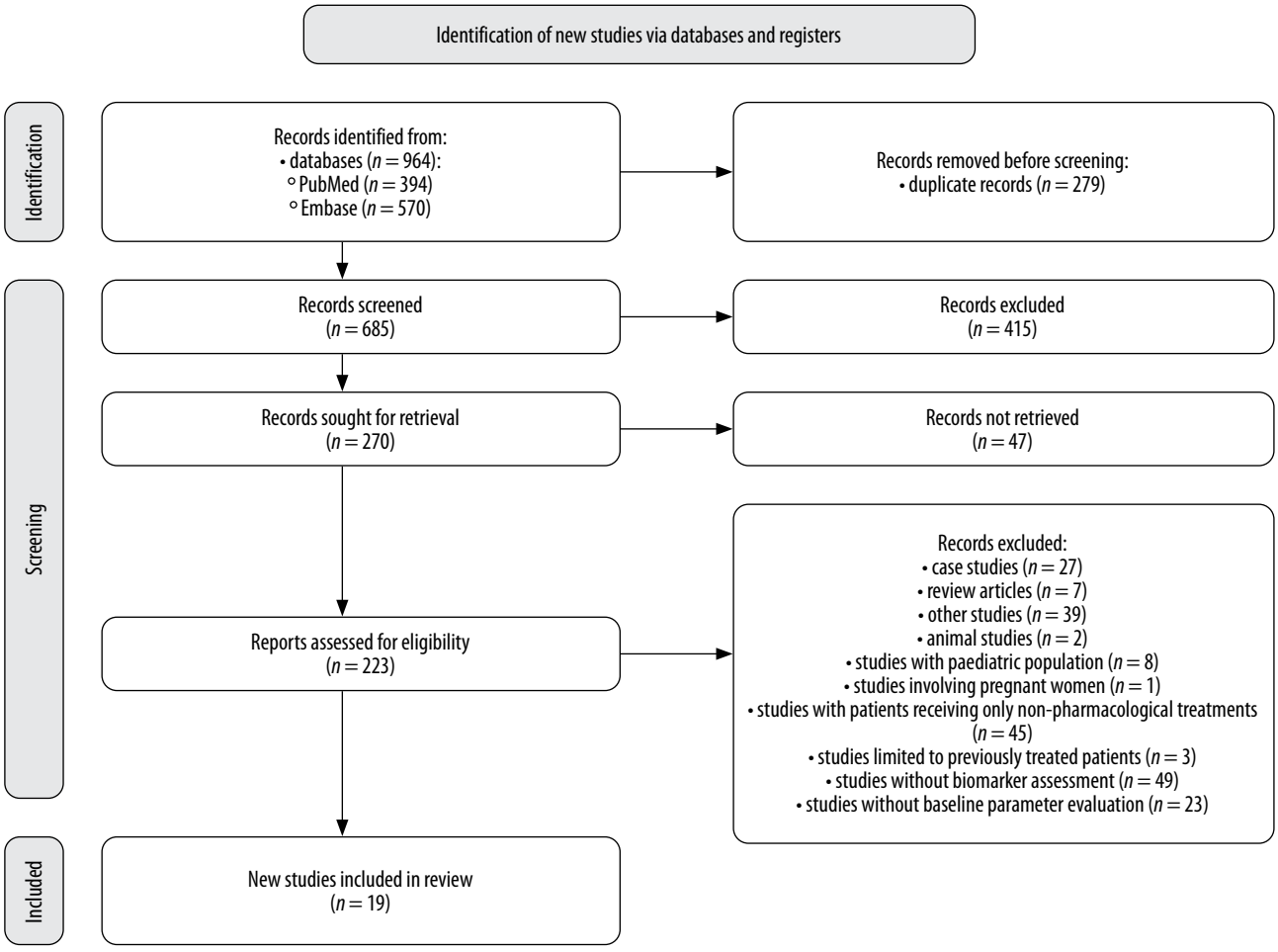

Fig. 1. Flow-chart showing the process of identifying and including papers in the systematic review

The exclusion criteria were as follows:

1. articles other than original research papers (case studies, review articles, short communications);
2. animal studies;
3. studies involving paediatric populations (patients under 18 years of age);
4. studies involving pregnant women;
5. studies involving patients receiving only non-pharmacological treatments (surgery, radioiodine therapy);
6. studies that did not involve patients with newly diagnosed GD or patients previously untreated for the disease;
7. studies without assessment of specific biomarkers – FT3, FT4, TSH, TRAb;
8. studies without assessment of mentioned biomarkers at the beginning of treatment.

After the exclusion criteria were applied, 19 core articles were selected.

Four authors extracted data using a predefined form, including author, publication year, sample size, and study design. Studies showed considerable heterogeneity with regard to the design, patient selection, and biomarker assessment criteria. Articles were divided into four groups, taking into consideration that some of the items belonged in more than one group:

- Group 1: studies focusing on TSH concentration (4 articles);
- Group 2: studies focusing on FT3 concentration (12 articles);
- Group 3: studies focusing on FT4 concentration (17 articles);
- Group 4: studies focusing on TRAb concentration (15 articles).

Subsequently, the analysis of the reported studies was carried out. It involved reviewing conclusions and analysing discrepancies. Finally, the results of the reviewed articles were fed to the model and the outcome was presented (Fig. 1)[11].

RESULTS

Role of TSH concentration in predicting the remission of GD

TSH contributes to the diagnosis of GD, but has limited predictive value for outcomes. Katahira et al. report that there was no statistical difference between the remission and non-remission groups with regard to baseline TSH concentration[12]. Also, there was no statistical correlation of

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TSH concentration between remission and relapse groups in the study by Jonas et al.[13]. Tun et al. noted that a longer time to TSH normalisation was significantly associated with a higher relapse risk ($p = 0.018$)[14].

Role of FT3 concentration in predicting the remission of GD

The importance of FT3 in predicting the outcome of GD has also been studied and documented in scientific articles. Patients who could not achieve remission by the 12th month of treatment tended to have higher FT3 level at the beginning of treatment compared to those that remitted (499.4 ng/dL vs. 398.5 ng/dL; $p = 0.03$)[15]. A similar result was observed in the other group of patients who could not achieve remission after at least 8 years of treatment (non-remission group: 15.64 pg/mL, remission group: 13.07 pg/mL; $p = 0.009$)[12]. Relapse is the other potential outcome that is worth predicting at the beginning of treatment. It is reported that the highest quartile of serum FT3 was independently associated with late relapse. Patients who experienced sustained remission were compared to those with late relapse (343.5 ng/dL vs. 428.2 ng/dL; $p = 0.001$)[16]. In another study, serum FT3 remained significant after logistic regression analysis with the odds ratio for relapse in patients with serum fT3 >300 ng/dL of 1.48 compared to the remitted group ($p = 0.008$)[17].

Role of FT4 concentration in predicting the remission of GD

The diagnostic role of FT4 is well documented in many scientific papers, but its predictive role is still uncertain. According to Peixoto et al., patients with higher baseline T4 could not achieve remission in comparison to those who remitted with lower FT4 value (5.2 ng/dL and 3.9 ng/dL, respectively; $p = 0.04$)[15]. Similarly, patients who achieved remission had lower initial FT4 values compared to the subjects who could not achieve it (27.5 pmol/L vs. 38.5 pmol/dL; $p = 0.028$)[18]. Patients who could not achieve remission in the study by Gokbulut et al. had higher initial T4 levels along with thyroid volume and presence of orbitopathy than those who responded to therapy (3.80 ng/dL vs. 2.85 ng/dL; $p = 0.04$)[19]. The multivariate analysis by Ishtiaq et al. shows that FT4 is a predictor of treatment outcome, with high FT4 initial values correlating with higher treatment failures. Patients who failed to complete treatment had 4.7 ng/dL FT4 concentration while the remission group had 2.3 ng/dL ($p = 0.025$)[20]. In contrast, other studies found no significant correlation between baseline FT4 and remission rate[13,21,22]. Among significant parameters like serum T3, T4, TRAb, TPO, TG, age and body mass index, a multivariate logistic regression model with remission as the dependent variable showed that only low TRAb levels and younger age were associated with remission[23]. Another study reported that age, sex, and FT4 levels were not statistically significantly different between the remission group and the group that could not achieve it and had to undergo ablative therapy – surgery or radiofrequency ablation[24]. Similarly, binary logistic regression did not confirm a correlation between initial FT4 concentration and relapse as an outcome[14]. Additionally, the initial FT3/FT4 ratio was not found to be statistically different between remission and relapse groups[25].

Role of TRAb concentration in predicting the remission of GD

TRAb is a biomarker that appears to have the greatest value in predicting sustained remission in GD. According to Peixoto et al., patients who reached remission had significantly lower baseline TRAb levels than those who did not (38.2 U/L vs. 180.2 U/L; $p = 0.002$)[15]. Aleksić et al. reported that there was a significant difference in remission duration in patients in relation to the level of TRAb at the beginning of suppression therapy, identifying 2 IU/mL as a threshold representing a statistically important risk factor for shorter remission ($p = 0.008$)[26]. Moreover, baseline TRAb levels higher than 12 IU/L were correlated with an 84% risk of recurrence over four years, compared with 57% when TRAbs were 10 IU/L[23]. In a large retrospective cohort study, only changes in TRAb levels were useful in predicting the individual risk of recurrence. The difference in initial TRAb concentrations between patients in remission or recurrence was not statistically significant ($p = 0.99$)[27]. Another study compared two groups – patients who underwent ablative treatment and those who experienced remission after ATD withdrawal. The authors noticed that initial TRAb titres were higher in the ablative group than in the remission group. The initial TRAb >46.5 UI/L in the ablative group identified patients who had never achieved remission with the sensitivity of 52% and specificity of 78%[24]. Guia Lopes et al. showed that lower initial TRAb serum concentrations were significantly correlated with remission compared to the no-remission group (4.6 U/L vs. 9.4 U/L; $p < 0.001$)[18]. Similarly, Daukšienė et al. showed that the group of patients who failed to achieve remission after ATD treatment had higher initial TRAb titres than the remission group (79.7 U/L vs. 31.2 U/L; $p < 0.001$). The area under the receiver-operating characteristic curve (AUC) of TRAb levels before treatment was 0.76 with the cut-off value of 30.2 U/L[21]. In the prospective study by Glinoer et al., the frequency of positive antibody titres at the beginning of treatment was identical in recurrence and remission groups. Additionally, the maintenance of positive TRAb value was associated with the risk of relapse[28]. Ozçelik et al. reported that thyroid-stimulating immunoglobulin (TSI) and thyroid-blocking immunoglobulin (TBI) positivity were present in patients who could not achieve remission at 18th months of treatment ($p = 0.023$)[29]. Aside from TSI and TBI, there is another subpopulation – TSH-binding inhibitor immunoglobulin (TBII), which may be evaluated in routine diagnostic procedures. According to Bandai et al.,

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the absence of TBII before treatment did not suggest a better prognosis than in patients in whom TBII disappeared between two and five years after treatment initiation[30].

DISCUSSION

This systematic review collected and assessed data on popular diagnostic markers in GD (TSH, FT3, FT4, TRAb) to determine their potential to predict the outcome of the disease (remission, non-remission/treatment failure, and relapse). Baseline TSH levels alone showed minimal predictive value. For instance, TSH levels before treatment only with propranolol in three groups – no remission, transient remission, and lasting remission within a period of 18 months were not statistically different in all these groups[31]. The initial type of treatment has also been considered a potential predictor[32]. Although it has been shown that changes in TSH levels during ATD therapy can be used to predict remission of the disease[33], some studies do not consider TSH normalisation a reliable predictive marker[34]. Undetectable serum TSH levels correlate with the highest serum TSI, while FT3 and FT4 can range from subnormal to supernormal values[35]. Another study observed patients after six months of methimazole treatment, revealing that initial FT3 and FT4 do not correlate with outcomes[36]. However, a decrease in the FT3/FT4 ratio during pharmacotherapy has been identified as a favourable prognostic factor in GD[37].

Regarding thyroid antibodies, initially TBII-negative patients had lower levels of FT3 and FT4 than those who were TBII-positive[38]. A number of studies indicate that baseline TRAb levels are the most important factor in predicting the outcome of GD[39–41]. A decrease in TRAb levels during therapy seems to play a key role in the normalisation of thyroid function[42], and it has also been found that low baseline TRAb levels could indicate future remission[43]. It has been suggested that a particularly mild decrease in TRAb indicates a greater likelihood of remission[44]. Thyroid antibody concentrations also serve as important indicators of disease severity[45]. TRAb levels at the end of ATD treatment have high positive predictive value and specificity[46]. Some studies have focused on identifying TRAb thresholds above which ATD is unlikely to induce remission and it is better for patients to undergo surgery or radioiodine treatment[47]. Interestingly, some researchers have tried to link the serum TRAb index with patients' HLA status, but no significant associations were found[48].

Solter et al. reported that remission rates on days 35 and 83 of MMI treatment were not correlated with initial thyroid hormone values[49]. Some researchers have suggested other markers, such as serum thyroglobulin, but their findings are rather ambiguous and do not support thyroglobulin as a useful predictive factor in GD[50,51]. It seems crucial to constantly search for new parameters in this area. Emerging methods, such as artificial neural networks (ANN), may be helpful in predicting long-term responses to ATD therapy in patients with GD[52].

Overall, it was concluded that there is no single parameter commonly used to diagnose GD that can predict outcome of the disease after ATD treatment[53].

The primary objective of such studies should be practical implementation of its results. The present review suggests that among analysed biomarkers, baseline TRAb concentration is the most important predictor of treatment outcome in patients with GD. Further research determining exact cut-off values for this marker is crucial. Consistent findings could define TRAb thresholds indicating low probability of remission in patients undergoing ATD therapy. They could be implemented into clinical decision-making algorithms. Therefore, patients unlikely to benefit from pharmacological therapy could avoid its side effects and potential future relapses of the disease, while receiving other treatment options.

LIMITATIONS

This systematic review has several important limitations. First, a formal meta-analysis, including graphical presentations (forest plots), was not performed. This was due to substantial heterogeneity among the included studies in terms of study design, patient populations, duration of ATD therapy, and length of follow-up. Consequently, a reliable meaningful synthesis was precluded. Furthermore, the presence of publication bias cannot be excluded, as studies with significant results are more likely to be published. Finally, most included studies were single-centre or retrospective, which may limit generalisability of the findings and increase the risk of information bias.

CONCLUSIONS

According to this review, TRAb appears to be the most promising predictor of GD remission. Many studies have confirmed that high baseline TRAb concentrations may be helpful in predicting the course of GD. FT3 and FT4 show inconsistent predictive value. The least possible in forecasting the course of treatment seems to be the TSH value. Most studies claim that this marker is not useful for predicting the possible outcome in GD. Further research in this area is necessary to identify other testing methods and predictive factors, which could improve long-term prognosis and support more individualised treatment strategies.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organisations which might negatively affect the content of this publication and/or claim authorship rights to this publication.

Author contribution

Original concept of study; writing of manuscript: ZF, SE. Collection, recording and/or compilation of data: ZF, SE, JW, ML, KP, MS. Analysis and interpretation of data: ZF, SE, JW. Critical review of manuscript; final approval of manuscript: JR.

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