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The Effect of Macro- and Microelements on Thyroid Function (Literature Review)

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KEYWORDS

thyroid gland, thyroid diseases, trace elements, macroelements, iodine deficiency, biogeochemical conditions, hygienic conditions, socio-economic conditions

ABSTRACT:

Introduction In recent years, active research has been conducted on the relationship between micronutrient status in patients and the development of certain thyroid diseases, as well as the influence of micronutrient balance on the etiology and pathogenesis of this pathology.

Objectives: to study the literature on the influence of micro- and macronutrients on the function and condition of the thyroid gland.

Methods: The review presents the results of large population and biomedical studies

Results: Selenium is found in thyroid tissue in the form of selenoproteins. Selenium is involved in the conversion of thyroxine to triiodothyronine. Zinc deficiency leads to impaired production of thyroid hormones and increased levels of antithyroid antibodies. Cobalt inhibits the binding of iodide by the thyroid gland, and cobalt overdose in children sometimes leads to hypothyroidism and thyroid hyperplasia. Elevated manganese levels are an additional pathogenetic factor in iodine deficiency in goiter-endemic regions.

Conclusions: There is a complex of biogeochemical, hygienic, and socioeconomic conditions that contribute to iodine deficiency.

1. Introduction

In recent years, the relationship between the trace element status of patients and the development of certain thyroid diseases, as well as the influence of trace element balance on the etiology and pathogenesis of this pathology, has been actively studied [1, 2, 3, 4,5].

2. Objectives

To review the literature on the influence of micro- and macroelements on thyroid function and condition.

3. Methods

The review presents the results of large population and biomedical studies.

4. Results

According to the literature, a number of causes lead to the development of thyroid pathology [6,7]. However, iodine deficiency and an imbalance in the trace element composition of patients' blood are the most common factors in the development of goiter [8,9].

Virtually the entire territory of the Russian Federation is iodine-deficient, with more than 50% of children having

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below-normal average iodine levels and 5.6–38% of schoolchildren having goiter [10,11]. Iodine deficiency is most often found as a stable natural phenomenon, most characteristic of highlands and flat areas remote from seas and oceans. Such areas with reduced iodine content in all objects of the biosphere represent iodine biogeochemical provinces [12,13].

The most unfavorable regions in terms of the prevalence of endemic and other forms of non-toxic goiter were the Bryansk region, the Altai Territory, the Chuvash Republic, the Republics of Karelia, Crimea, and others.

When iodine levels in the thyroid gland are low, autocrine growth factors such as insulin-like growth factor type 1, epidermal growth factor, and fibroblast growth factor have a powerful stimulating effect on thyrocytes [14]. Thyroid cell proliferation is inversely proportional to intratyroid iodine content. In conditions of chronic iodine deficiency, there is a decrease in the formation of iodolipids — substances that inhibit the proliferative effects of autocrine growth factors (insulin-like growth factor type 1, fibroblast growth factor, epidermal growth factor) [15]. Iodine deficiency also increases the sensitivity of these autocrine growth factors to the growth effects of TSH, reduces the production of growth factor-b proliferation inhibitor, and activates angiogenesis.

In regions with mild to moderate iodine deficiency, toxic multinodular goiter is a common cause of thyrotoxicosis in the elderly, which is associated with a high risk of cardiovascular events in this patient group [16]. The role of iodine deficiency in the development of thyroid cancer (TC) remains controversial [17]. Studies have shown different distributions of histological variants of PTC: follicular and anaplastic variants were more common in iodine-deficient areas, while papillary variants were more common in areas with normal iodine availability [18,19].

In regions with adequate iodine intake, Graves' disease is the cause of hyperthyroidism in about 80% of patients, while in areas with iodine deficiency, toxic multinodular goiter and toxic adenoma are the cause of hyperthyroidism in 50% of patients [20]. This is explained by the fact that against the background of a long-standing iodine deficiency , some of the formed thyroid nodules acquire autonomy over time [10].

The literature also presents data on the correlation between the spread of goiter disease and abnormalities in the content of fluorine, bromine, calcium, manganese, cobalt, strontium, zinc, molybdenum, chromium, copper, and mercury in the environment.

Selenium plays a significant role in the functioning of the thyroid gland, which contains the highest amount of selenium in the form of selenoproteins [21]. Selenium is involved in the conversion of thyroxine to triiodothyronine and also has antioxidant and anti-inflammatory effects. Selenoproteins are necessary for the normal functioning of the thyroid gland. In particular, glutathione peroxidase removes excess hydrogen peroxide formed during the iodination of thyroglobulin, which is necessary for the formation of thyroid hormones. According to some studies, selenium in the form of selenoproteins can reduce the concentration of antibodies to thyroid peroxidase and reduce the manifestations of hypothyroidism and postpartum thyroiditis [4]. Another effect of selenium is its relationship with another trace element important for the functioning of the thyroid gland - iodine.

Selenium deficiency is considered a factor in iodine conservation, but in conditions of iodine deficiency, concomitant selenium deficiency contributes to a decrease in thyroid function [22] and increases the sensitivity of thyrocytes to necrosis.

Selenium deficiency reduces the proliferation of thyroid cells and increases the proliferation of fibroblasts, which contributes to the development of fibrosis and prevents the restoration of thyroid tissue. In addition, selenium deficiency has a negative effect on the immune system [23]. Selenium is an antagonist of mercury and arsenic, capable of protecting the body from these elements and cadmium, and to a lesser extent, lead and thallium. This trace element also has radioprotective properties.

Zinc levels also affect the normal functioning of the thyroid gland. It has been established that a deficiency of this trace element leads to a disruption in the production of thyroid hormones and an increase in the level of antithyroid antibodies. Zinc is a component of more than 200 metalloproteins, including the nuclear receptor triiodothyronine, which explains the need for this trace element for the biological effect of thyroid hormones. Zinc deficiency affects the characteristics of T-cell immunity. It has been established that zinc

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supplementation in patients with autoimmune thyroiditis leads to the restoration of thyroid function [24].

The main significance of cobalt is that it is a component of vitamin B12. At the same time, it is known that cobalt inhibits the binding of iodide by the thyroid gland through an unknown mechanism, and cobalt overdose in children sometimes leads to hypothyroidism and thyroid hyperplasia.

Manganese is a component of many enzymes, including superoxide dismutase, which protect against peroxide radicals.

The spread of endemic goiter in southern Central Siberia, which is not associated with iodine deficiency, is explained by the increased content of manganese and lead in the environment (50-70% higher than the physiological requirement for these elements) and reduced cobalt content. Elevated manganese content is an additional pathogenetic factor in iodine deficiency in the endemic goiter region of the Baikal region. Similar data on the role of manganese have been published by other authors. It is noteworthy that in southern Central Siberia, endemic goiter was most often found in people over 40 years of age, i.e., the effect of micronutrient imbalance is detected after a fairly long period of residence in the region—10 years or more.

According to some authors, the imbalance of certain trace elements may underlie autoimmune diseases of the thyroid gland [25, 26, 27].

An example of a region with iodine deficiency and trace element imbalance is the Chuvash Republic, which is endemic for goiter.

Depending on the content and ratio of chemical elements, three ecological and biogeochemical regions have been identified in the Chuvash Republic [28]. Ecological and biogeochemical zoning and mapping of the territory of the Chuvash Republic, carried out under the guidance of Professor V. L. Suslikov in 2001, identified three biosphere regions: 1) Volga; 2) Prikubninsk-Tsivilsky; 3) Prisursky. (Fig. 1).

Fig. 1. Map of ecological and biogeochemical zoning of the Chuvash Republic (V. L. Suslikov, 2001)

The Volga subregion includes the Yadrinsky, Morgaushsky, Cheboksarsky, Marposadsky, Kozlovsky, and parts of the Tsivilsky and Krasnoarmeysky administrative districts. This subregion is characterized by a deficiency of iodine (content in the daily diet is 126 μg/day), zinc, molybdenum, and cobalt, a moderate excess of silicon, and an imbalance in the ratio of trace elements to iodine and silicon. There are disturbances in phosphorus and calcium metabolism. These characteristics of the subregion contribute to the development of endemic goiter and dental caries among the population.

The Prikubninsky subregion includes the administrative districts of Urmarsky, Yantikovsky, Kanashsky, Alikovsky, Krasnochetaisky, Vurnarsky, Tsivilsky, and Krasnoarmeysky. There is a moderate deficiency of iodine (150 mcg/day), cobalt, zinc, copper, molybdenum, and manganese, and a favorable ratio of trace elements to iodine and silicon. This subregion is considered a control for comparative biogeochemical studies.

The Prisursky subregion includes the Alatyrsky, Poretsky, Ibresinsky, and Shumerlinsky administrative districts. It is characterized by a moderate deficiency of iodine (161 μg/day) and cobalt, a sharp excess of silicon, and an unfavorable ratio of trace elements to iodine and silicon. There is a disruption in the synthesis of thyroid hormones and triiodothyronine thyrotoxicosis.

5. Conclusion

Thus, the leading role of trace element imbalance and iodine deficiency due to low content in food and feed should be recognized, as well as the fact that the influence of goitrogenic factors in many cases is mediated by a violation of iodine circulation (metabolism) in the body. Iodine deficiency is the most important etiological factor in euthyroid endemic goiter. At the same time, its development in each specific region presupposes the existence of its own complex of biogeochemical, hygienic, and socio-economic conditions that contribute to iodine deficiency.

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