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SPECIAL ARTICLE

2016 American Thyroid Association Guidelines for Diagnosis and Management of Hyperthyroidism and Other Causes of Thyrotoxicosis

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Background: Thyrotoxicosis has multiple etiologies, manifestations, and potential therapies. Appropriate treatment requires an accurate diagnosis and is influenced by coexisting medical conditions and patient preference. This document describes evidence-based clinical guidelines for the management of thyrotoxicosis that would be useful to generalist and subspecialty physicians and others providing care for patients with this condition.
Methods: The American Thyroid Association (ATA) previously cosponsored guidelines for the management of thyrotoxicosis that were published in 2011. Considerable new literature has been published since then, and the ATA felt updated evidence-based guidelines were needed. The association assembled a task force of expert clinicians who authored this report. They examined relevant literature using a systematic PubMed search supplemented with additional published materials. An evidence-based medicine approach that incorporated the knowledge and experience of the panel was used to update the 2011 text and recommendations. The strength of the recommendations and the quality of evidence supporting them were rated according to the approach recommended by the Grading of Recommendations, Assessment, Development, and Evaluation Group.
Results: Clinical topics addressed include the initial evaluation and management of thyrotoxicosis; management of Graves' hyperthyroidism using radioactive iodine, antithyroid drugs, or surgery; management of toxic multinodular goiter or toxic adenoma using radioactive iodine or surgery; Graves' disease in children, adolescents, or pregnant patients; subclinical hyperthyroidism; hyperthyroidism in patients with Graves' orbitopathy; and management of other miscellaneous causes of thyrotoxicosis. New paradigms since publication of the 2011 guidelines are presented for the evaluation of the etiology of thyrotoxicosis, the management of Graves' hyperthyroidism with antithyroid drugs, the management of pregnant hyperthyroid patients, and the preparation of patients for thyroid surgery. The sections on less common causes of thyrotoxicosis have been expanded.
Conclusions: One hundred twenty-four evidence-based recommendations were developed to aid in the care of patients with thyrotoxicosis and to share what the task force believes is current, rational, and optimal medical practice.

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DEDICATION

These guidelines are dedicated to the memory of Peter Laurberg, our friend and colleague, who died tragically during their preparation.

INTRODUCTION

THYROTOXICOSIS IS A CONDITION HAVING multiple etiologies, manifestations, and potential therapies. The term ''thyrotoxicosis'' refers to a clinical state that results from inappropriately high thyroid hormone action in tissues generally due to inappropriately high tissue thyroid hormone levels. The term ''hyperthyroidism,'' as used in these guidelines, is a form of thyrotoxicosis due to inappropriately high synthesis and secretion of thyroid hormone(s) by the thyroid. Appropriate treatment of thyrotoxicosis requires an accurate diagnosis. For example, thyroidectomy is an appropriate treatment for some forms of thyrotoxicosis and not for others. Additionally, β-blockers may be used in almost all forms of thyrotoxicosis, whereas antithyroid drugs (ATDs) are useful in only some.

In the United States, the prevalence of hyperthyroidism is approximately 1.2% (0.5% overt and 0.7% subclinical); the most common causes include Graves' disease (GD), toxic multinodular goiter (TMNG), and toxic adenoma (TA) (1). Scientific advances relevant to this topic are reported in a wide range of literature, including subspecialty publications in endocrinology, pediatrics, nuclear medicine, and surgery, making it challenging for clinicians to keep abreast of new developments. Although guidelines for the diagnosis and management of patients with thyrotoxicosis were published previously by the American Thyroid Association (ATA) and the American Association of Clinical Endocrinologists (AACE) in 2011, the ATA determined that thyrotoxicosis represents a priority area in need of updated evidence-based practice guidelines.

The target audience for these guidelines includes general and subspecialty physicians and others providing care for patients with thyrotoxicosis. In this document, we outline what we believe is current, rational, and optimal medical practice. These guidelines are not intended to replace clinical judgment, individual decision making, or the wishes of the patient or family. Rather, each recommendation should be evaluated in light of these elements so that optimal patient care is delivered. In some circumstances, the level of care required may be best provided in centers with specific expertise, and referral to such centers should be considered.

METHODS OF DEVELOPMENT OF EVIDENCE-BASED GUIDELINES

Administration

The ATA Executive Council selected a chairperson to lead the task force and this individual (D.S.R.) identified the other 10 members of the panel in consultation with the ATA board of directors. Membership on the panel was based on clinical expertise, scholarly approach, and representation of adult and pediatric endocrinology, nuclear medicine, and surgery. The task force included individuals from North America, South America, and Europe. Panel members declared whether they had any potential conflict of interest at the initial meeting of the group and periodically during the course of deliberations. Funding for the guidelines was derived solely from the general funds of the ATA, and thus the task force functioned without commercial support.

The task force reviewed the 2011 guidelines and published editorials regarding those guidelines. It then developed a revised list of the most common causes of thyrotoxicosis and the most important questions that a practitioner might pose when caring for a patient with a particular form of thyrotoxicosis or special clinical condition. One task force member was assigned as the primary writer for each topic. One or more task force members were assigned as secondary writers for each topic, providing their specific expertise and critical review for the primary writer. The relevant literature was reviewed using a systematic PubMed search for primary references and reviews published after the submission of the 2011 guidelines, supplemented with additional published materials found on focused PubMed searches. Recommendations were based on the literature and expert opinion where appropriate. A preliminary document and a series of recommendations concerning all the topics were generated by each primary writer and then critically reviewed by the task force at large. The panel agreed recommendations would be based on consensus of the panel and that voting would be used if agreement could not be reached. Task force deliberations took place between 2014 and 2016 during several lengthy committee meetings and through electronic communication.

Rating of the recommendations

These guidelines were developed to combine the best scientific evidence with the experience of seasoned clinicians and the pragmatic realities inherent in implementation. The task force elected to rate the recommendations according to the system developed by the Grading of Recommendations, Assessment, Development, and Evaluation Group (3–6). The balance between benefits and risks, quality of evidence, applicability, and certainty of the baseline risk are all considered in judgments about the strength of recommendations (7). Grading the quality of the evidence takes into account study design, study quality, consistency of results, and directness of the evidence. The strength of a recommendation is indicated as a strong recommendation (for or against) that applies to most patients in most circumstances with benefits of action clearly outweighing the risks and burdens (or vice versa), or a weak recommendation or a suggestion that may not be appropriate for every patient, depending on context, patient values, and preferences. The quality of the evidence is indicated as low-quality evidence, moderate-quality evidence, or high-quality evidence, based on consistency of results between studies and study design, limitations, and the directness of the evidence. In several instances, the evidence was insufficient to recommend for or against a test or a treatment, and the task force made a statement labeled ''no recommendation.'' Table 1 describes the criteria to be met for each rating category. Each recommendation is preceded by a description of the evidence and, is followed in some cases by a remarks section including technical suggestions on issues such as dosing and monitoring.

Table 1. Grading of Recommendations, Assessment, Development, and Evaluation System

Type of grading	*Definition of grades*
Strength of the recommendation	Strong recommendation (for or against) Applies to most patients in most circumstances Benefits clearly outweigh the risk (or vice versa) Weak recommendation (for or against) Best action may differ depending on circumstances or patient values Benefits and risks or burdens are closely balanced, or uncertain No recommendation (insufficient evidence for or against)
Quality of the evidence	High quality; evidence at low risk of bias, such as high quality randomized trials showing consistent results directly applicable to the recommendation Moderate quality; studies with methodological flaws, showing inconsistent or indirect evidence Low quality; case series or unsystematic clinical observations Insufficient evidence

Presentation of recommendations

The organization of the task force's recommendations is presented in Table 2. The page numbers and the location key can be used to locate specific topics and recommendations. Specific recommendations are presented within boxes in the main body of the text. Location keys can be copied into the Find or Search function in a file or Web page to rapidly navigate to a particular section. A listing of the recommendations without text is provided as Supplementary Appendix A (Supplementary Data are available online at www.liebertpub.com/thy).

Table 2. Organization of the Task Force's Recommendations

Location key	*Description*	*Page*
[A]	Background	1347
	[A1] Causes of thyrotoxicosis	1347
	[A2] Clinical consequences of thyrotoxicosis	1347
[B]	How should clinically or incidentally discovered thyrotoxicosis be evaluated and initially managed?	1348
	[B1] Assessment of disease severity	1348
	[B2] Biochemical evaluation	1348
	[B3] Determination of etiology	1349
	[B4] Symptomatic management	1350
[C]	How should overt hyperthyroidism due to GD be managed?	1350
[D]	If RAI therapy is chosen, how should it be accomplished?	1352
	[D1] Preparation of patients with GD for RAI therapy	1352
	[D2] Administration of RAI in the treatment of GD	1353
	[D3] Patient follow-up after RAI therapy for GD	1354
	[D4] Treatment of persistent Graves' hyperthyroidism following RAI therapy	1355
[E]	If ATDs are chosen as initial management of GD, how should the therapy be managed?	1355
	[E1] Initiation of ATD therapy for the treatment of GD	1355
	[E2] Adverse effects of ATDs	1356
	[E3] Agranulocytosis	1356
	[E4] Hepatotoxicity	1356
	[E5] Vasculitis	1356
	[E6] Monitoring of patients taking ATDs	1357
	[E7] Management of allergic reactions	1358
	[E8] Duration of ATD therapy for GD	1358
	[E9] Persistently elevated TRAb	1358
	[E10] Negative TRAb	1358
[F]	If thyroidectomy is chosen for treatment of GD, how should it be accomplished?	1359
	[F1] Preparation of patients with GD for thyroidectomy	1359
	[F2] The surgical procedure and choice of surgeon	1359
	[F3] Postoperative care	1360
[G]	How should thyroid nodules be managed in patients with GD?	1361
[H]	How should thyroid storm be managed?	1361
[I]	Is there a role for iodine as primary therapy in the treatment of GD?	1363

(*continued*)

TABLE 2. (CONTINUED)

Location key	*Description*	*Page*
[J]	How should overt hyperthyroidism due to TMNG or TA be treated?	1363
[K]	If RAI therapy is chosen as treatment for TMNG or TA, how should it be accomplished?	1365
	[K1] Preparation of patients with TMNG or TA for RAI therapy	1365
	[K2] Evaluation of thyroid nodules prior to RAI therapy	1366
	[K3] Administration of RAI in the treatment of TMNG or TA	1366
	[K4] Patient follow-up after RAI therapy for TMNG or TA	1366
	[K5] Treatment of persistent or recurrent hyperthyroidism following RAI therapy for TMNG or TA	1367
[L]	If surgery is chosen, how should it be accomplished?	1367
	[L1] Preparation of patients with TMNG or TA for surgery	1367
	[L2] The surgical procedure and choice of surgeon	1367
	[L3] Postoperative care	1368
	[L4] Treatment of persistent or recurrent disease following surgery for TMNG or TA	1368
[M]	If ATDs are chosen as treatment of TMNG or TA, how should the therapy be managed?	1368
[N]	Is there a role for ethanol or radiofrequency ablation in the management of TA or TMNG?	1369
	[N1] Ethanol ablation	1369
	[N2] Radiofrequency ablation	1369
[O]	How should GD be managed in children and adolescents?	1369
	[O1] General approach	1369
[P]	If ATDs are chosen as initial management of GD in children, how should the therapy be managed?	1370
	[P1] Initiation of ATD therapy for the treatment of GD in children	1370
	[P2] Symptomatic management of Graves' hyperthyroidism in children	1371
	[P3] Monitoring of children taking MMI	1371
	[P4] Monitoring of children taking PTU	1371
	[P5] Management of allergic reactions in children taking MMI	1371
	[P6] Duration of MMI therapy in children with GD	1372
[Q]	If radioactive iodine is chosen as treatment for GD in children, how should it be accomplished?	1372
	[Q1] Preparation of pediatric patients with GD for RAI therapy	1372
	[Q2] Administration of RAI in the treatment of GD in children	1373
	[Q3] Side effects of RAI therapy in children	1373
[R]	If thyroidectomy is chosen as treatment for GD in children, how should it be accomplished?	1374
	[R1] Preparation of children with GD for thyroidectomy	1374
[S]	How should subclinical hyperthyroidism be managed?	1375
	[S1] Prevalence and causes of SH	1375
	[S2] Clinical significance of SH	1375
	[S3] When to treat SH	1376
	[S4] How to treat SH	1377
	[S5] End points to be assessed to determine effective therapy of SH	1378
[T]	How should hyperthyroidism in pregnancy be managed?	1378
	[T1] Diagnosis of hyperthyroidism in pregnancy	1378
	[T2] Management of hyperthyroidism in pregnancy	1379
	[T3] The role of TRAb level measurement in pregnancy	1384
	[T4] Postpartum thyroiditis	1385
[U]	How should hyperthyroidism be managed in patients with GO?	1386
	[U1] Assessment of disease activity and severity	1386
	[U2] Prevention of GO	1387
	[U3] Treatment of hyperthyroidism in patients with no apparent GO	1389
	[U4] Treatment of hyperthyroidism in patients with active GO of mild severity	1389
	[U5] Treatment of hyperthyroidism in patients with active and moderate-to-severe or sight-threatening GO	1390
	[U6] Treatment of GD in patients with inactive GO	1390
[V]	How should iodine-induced and amiodarone-induced thyrotoxicosis be managed?	1390
	[V1] Iodine-induced thyrotoxicosis	1390
	[V2] Amiodarone-induced thyrotoxicosis	1391

(*continued*)

TABLE 2. (CONTINUED)

ATD, antithyroid drug; GD, Graves' disease; GO, Graves' orbitopathy; MMI, methimazole; PTU, propylthiouracil; RAI, radioactive iodine; SH, subclinical hyperthyroidism; TA, toxic adenoma; TMNG, toxic multinodular goiter; TRAb, thyrotropin receptor antibody; TSH, thyrotropin.

RESULTS

[A] Background

[A1] Causes of thyrotoxicosis

In general, thyrotoxicosis can occur if (i) the thyroid is excessively stimulated by trophic factors; (ii) constitutive activation of thyroid hormone synthesis and secretion occurs, leading to autonomous release of excess thyroid hormone; (iii) thyroid stores of preformed hormone are passively released in excessive amounts owing to autoimmune, infectious, chemical, or mechanical insult; or (iv) there is exposure to extrathyroidal sources of thyroid hormone, which may be either endogenous (struma ovarii, metastatic differentiated thyroid cancer) or exogenous (factitious thyrotoxicosis).

Hyperthyroidism is generally considered overt or subclinical, depending on the biochemical severity of the hyperthyroidism, although in reality the disease represents a continuum of overactive thyroid function. Overt hyperthyroidism is defined as a subnormal (usually undetectable) serum thyrotropin (TSH) with elevated serum levels of triiodothyronine (T_3) and/or free thyroxine estimates (free T_4). Subclinical hyperthyroidism is defined as a low or undetectable serum TSH with values within the normal reference range for both T_3 and free T_4. Both overt and subclinical disease may lead to characteristic signs and symptoms, although subclinical hyperthyroidism is usually considered milder. Overzealous or suppressive thyroid hormone administration may cause either type of thyrotoxicosis, particularly subclinical thyrotoxicosis. Endogenous overt or subclinical thyrotoxicosis is caused by excess thyroid hormone production and release or by inflammation and release of hormone by the gland.

Endogenous hyperthyroidism is most commonly due to GD or nodular thyroid disease. GD is an autoimmune disorder in which thyrotropin receptor antibodies (TRAb) stimulate the TSH receptor, increasing thyroid hormone production and release. The development of nodular thyroid disease includes growth of established nodules, new nodule formation, and development of autonomy over time (8). In TAs, autonomous hormone production can be caused by somatic activating mutations of genes regulating thyroid growth and hormone synthesis. Germline mutations in the gene encoding the TSH receptor can cause sporadic or familial nonautoimmune hyperthyroidism associated with a diffuse enlargement of the thyroid gland (9). Autonomous hormone production may progress from subclinical to overt hyperthyroidism, and the administration of pharmacologic amounts of iodine to such patients may result in iodine-induced hyperthyroidism (10). GD is the most common cause of hyperthyroidism in the United States (11,12). Although toxic nodular goiter is less common than GD, its prevalence increases with age and in the presence of dietary iodine deficiency. Therefore, toxic nodular goiter may actually be more common than GD in older patients, especially in regions of iodine deficiency (13,14). Unlike toxic nodular goiter, which is progressive (unless triggered by excessive iodine intake), remission of mild GD has been reported in up to 30% of patients without treatment (15).

Less common causes of thyrotoxicosis include the entities of painless and subacute thyroiditis, which occur due to inflammation of thyroid tissue with release of preformed hormone into the circulation. Painless thyroiditis caused by lymphocytic inflammation appears to occur with a different frequency depending on the population studied: in Denmark it accounted for only 0.5% of thyrotoxic patients, but it was 6% of patients in Toronto and 22% of patients in Wisconsin (16–18).

Painless thyroiditis may occur during lithium (19), cytokine (e.g., interferon-α) (20), or tyrosine kinase inhibitor therapy (21), and in the postpartum period it is referred to as postpartum thyroiditis (22). A painless destructive thyroiditis (not usually lymphocytic) occurs in 5%–10% of amiodarone-treated patients (23). Subacute thyroiditis is thought to be caused by viral infection and is characterized by fever and thyroid pain (24).

[A2] Clinical consequences of thyrotoxicosis

The cellular actions of thyroid hormone are mediated by T_3, the active form of thyroid hormone. T_3 binds to two specific nuclear receptors (thyroid hormone receptor α and β) that regulate the expression of many genes. Nongenomic actions of thyroid hormone include regulation of numerous important physiologic functions.

Thyroid hormone influences almost every tissue and organ system. It increases tissue thermogenesis and basal metabolic rate and reduces serum cholesterol levels and systemic

vascular resistance. Some of the most profound effects of increased thyroid hormone levels occur within the cardiovascular system (25). Untreated or partially treated thyrotoxicosis is associated with weight loss, osteoporosis, atrial fibrillation, embolic events, muscle weakness, tremor, neuropsychiatric symptoms, and rarely cardiovascular collapse and death (26,27). Only moderate correlation exists between the degree of thyroid hormone elevation and clinical signs and symptoms. Symptoms and signs that result from increased adrenergic stimulation include tachycardia and anxiety and may be more pronounced in younger patients and those with larger goiters (28). The signs and symptoms of mild, or subclinical, thyrotoxicosis are similar to those of overt thyrotoxicosis but differ in magnitude. Measurable changes in basal metabolic rate, cardiovascular hemodynamics, and psychiatric and neuropsychological function can be present in mild thyrotoxicosis (29).

[B] How should clinically or incidentally discovered thyrotoxicosis be evaluated and initially managed?

[B1] Assessment of disease severity

Assessment of thyrotoxic manifestations, and especially potential cardiovascular and neuromuscular complications, is essential in formulating an appropriate treatment plan. Although it might be anticipated that the severity of thyrotoxic symptoms is proportional to the elevation in the serum levels of free T_4 and T_3, in one small study of 25 patients with GD, the Hyperthyroid Symptom Scale did not strongly correlate with free T_4 or T_3 and was inversely correlated with age (28). The importance of age as a determinant of the prevalence and severity of hyperthyroid symptoms has recently been confirmed (30). Cardiac evaluation may be necessary, especially in the older patient, and may require an echocardiogram, electrocardiogram, Holter monitor, or myocardial perfusion studies (31). The need for evaluation should not postpone therapy of the thyrotoxicosis. In addition to the administration of β-blockers (31), treatment may be needed for concomitant myocardial ischemia, congestive heart failure, or atrial arrhythmias (25). Anticoagulation may be necessary in patients in atrial fibrillation (32). Goiter size, obstructive symptoms, and the severity of Graves' orbitopathy (GO), the inflammatory disease that develops in the orbit in association with autoimmune thyroid disorders, can be discordant with the degree of hyperthyroidism or hyperthyroid symptoms.

All patients with known or suspected hyperthyroidism should undergo a comprehensive history and physical examination, including measurement of pulse rate, blood pressure, respiratory rate, and body weight. Thyroid size, tenderness, symmetry, and nodularity should also be assessed along with pulmonary, cardiac, and neuromuscular function (29,31,33) and the presence or absence of peripheral edema, eye signs, or pretibial myxedema.

[B2] Biochemical evaluation

Serum TSH measurement has the highest sensitivity and specificity of any single blood test used in the evaluation of suspected thyrotoxicosis and should be used as an initial screening test (34). However, when thyrotoxicosis is strongly suspected, diagnostic accuracy improves when a serum TSH, free T_4, and total T_3 are assessed at the initial evaluation. The relationship between free T_4 and TSH when the pituitary–thyroid axis is intact is an inverse log-linear relationship; therefore, small changes in free T_4 result in large changes in serum TSH concentrations. Serum TSH levels are considerably more sensitive than direct thyroid hormone measurements for assessing thyroid hormone excess (35).

In overt hyperthyroidism, serum free T_4, T_3, or both are elevated, and serum TSH is subnormal (usually <0.01 mU/L in a third-generation assay). In mild hyperthyroidism, serum T_4 and free T_4 can be normal, only serum T_3 may be elevated, and serum TSH will be low or undetectable. These laboratory findings have been called "T_3-toxicosis" and may represent the earliest stages of hyperthyroidism caused by GD or an autonomously functioning thyroid nodule. As with T_4, total T_3 measurements are affected by protein binding. Assays for estimating free T_3 are less widely validated and less robust than those for free T_4. Therefore, measurement of total T_3 is frequently preferred over free T_3 in clinical practice. Subclinical hyperthyroidism is defined as a normal serum free T_4 and normal total T_3 or free T_3, with subnormal serum TSH concentration. Laboratory protocols that store sera and automatically retrieve the sample and add on free T_4 and total T_3 measurements when the initial screening serum TSH concentrations are low avoid the need for subsequent blood draws.

In the absence of a TSH-producing pituitary adenoma or thyroid hormone resistance, or in the presence of spurious assay results due to interfering antibodies, a normal serum TSH level precludes the diagnosis of thyrotoxicosis. The term "euthyroid hyperthyroxinemia" has been used to describe a number of entities, primarily thyroid hormone–binding protein disorders, which cause elevated *total* serum T_4 concentrations (and frequently elevated total serum T_3 concentrations) in the absence of hyperthyroidism (36). These conditions include elevations in T_4 binding globulin (TBG) or transthyretin (37); the presence of an abnormal albumin which binds T_4 with high capacity (familial dysalbuminemic hyperthyroxinemia); a similarly abnormal transthyretin; and, rarely, immunoglobulins that directly bind T_4 or T_3. TBG excess may occur as a hereditary X-linked trait, or it may be acquired as a result of pregnancy or estrogen administration, hepatitis, acute intermittent porphyuria or during treatment with 5-fluorouracil, perphenazine, or some narcotics. Other causes of euthyroid hyperthyroxinemia include drugs that inhibit T_4 to T_3 conversion, such as amiodarone (23) or high-dose propranolol (31), acute psychosis (38), extreme high altitude (39), and amphetamine abuse (40). Estimates of free thyroid hormone concentrations frequently also give erroneous results in these disorders. Spurious free T_4 elevations may occur from heterophilic antibodies or in the setting of heparin therapy, due to *in vitro* activation of lipoprotein lipase and release of free fatty acids that displace T_4 from its binding proteins.

Heterophilic antibodies can also cause spurious high TSH values, and this should be ruled out by repeating the TSH in another assay, measurement of TSH in serial dilution, or direct measurement of human anti-mouse antibodies.

Ingestion of high doses of biotin may cause spurious results in assays that utilize a streptavidin–biotin separation technique (41,42). In immunometric assays, frequently used to measure TSH, excess biotin displaces biotinylated antibodies and causes spuriously low results, while in competitive binding assays, frequently used to measure free T_4, excess biotin competes with biotinylated analogue and results in

falsely high results. Patients taking high doses of biotin or supplements containing biotin, who have elevated T_4 and suppressed TSH, should stop taking biotin and have repeat measurements at least 2 days later.

After excluding euthyroid hyperthyroxinemia, TSH-mediated hyperthyroidism should be considered when thyroid hormone concentrations are elevated and TSH is normal or elevated. A pituitary lesion on magnetic resonance imaging (MRI) and a disproportionately high ratio of the serum level of the α-subunit of the pituitary glycoprotein hormones to TSH supports the diagnosis of a TSH-producing pituitary adenoma (43). A family history and genetic testing for mutations in the thyroid hormone receptor β (*THRB*) gene supports the diagnosis of resistance to thyroid hormone (44).

[B3] Determination of etiology

■ **RECOMMENDATION 1**

The etiology of thyrotoxicosis should be determined. If the diagnosis is not apparent based on the clinical presentation and initial biochemical evaluation, diagnostic testing is indicated and can include, depending on available expertise and resources, (1) measurement of TRAb, (2) determination of the radioactive iodine uptake (RAIU), or (3) measurement of thyroidal blood flow on ultrasonography. A ^{123}I or ^{99m}Tc pertechnetate scan should be obtained when the clinical presentation suggests a TA or TMNG.

Strong recommendation, moderate-quality evidence.

In a patient with a symmetrically enlarged thyroid, recent onset of orbitopathy, and moderate to severe hyperthyroidism, the diagnosis of GD is likely and further evaluation of hyperthyroidism causation is unnecessary. In a thyrotoxic patient with a nonnodular thyroid and no definite orbitopathy, measurement of TRAb or RAIU can be used to distinguish GD from other etiologies. In a study using a model of a theoretical population of 100,000 enrollees in a managed care organization in the United States, the use of TRAb measurements to diagnose GD compared to RAIU measurements reduced costs by 47% and resulted in a 46% quicker diagnosis (45).

RAIU measures the percentage of administered RAI that is concentrated into thyroid tissue after a fixed interval, usually 24 hours. Technetium uptake measurements utilize pertechnetate that is trapped by the thyroid, but not organified. A technetium (TcO_4) uptake measures the percentage of administered technetium that is trapped by the thyroid after a fixed interval, usually 20 minutes.

Uptake measurements are indicated when the diagnosis is in question (except during pregnancy and usually during lactation (see Section [T4]) and distinguishes causes of thyrotoxicosis having elevated or normal uptake over the thyroid gland from those with near-absent uptake (Table 3). Uptake is usually elevated in patients with GD and normal or high in toxic nodular goiter, unless there has been a recent exposure to iodine (e.g., radiocontrast). The RAIU will be near zero in patients with painless, postpartum, or subacute thyroiditis; factitious ingestion of thyroid hormone; or recent excess iodine intake. The RAIU may be low after exposure to iodinated contrast in the preceding 1–2 months or with ingestion of a diet unusually rich in iodine such as seaweed soup or kelp. However, RAIU is rarely <1% unless the iodine exposure is reoccurring, such as during treatment with amiodarone. When exposure to excess iodine is suspected (e.g., when the RAIU is lower than expected from the clinical history), assessment of urinary iodine concentration (spot urine iodine adjusted for urine creatinine concentration or a 24-hour urine iodine concentration) may be helpful. The uptake over the neck will also be absent in a patient with struma ovarii, where the abnormal thyroid tissue is located in an ovarian teratoma.

Table 3. Causes of Thyrotoxicosis

Thyrotoxicosis associated with a normal or elevated RAI uptake over the neck[a]
GD
TA or TMNG
Trophoblastic disease
TSH-producing pituitary adenomas
Resistance to thyroid hormone (T_3 receptor β mutation, THRB)[b]
Thyrotoxicosis associated with a near-absent RAI uptake over the neck
Painless (silent) thyroiditis
Amiodarone-induced thyroiditis
Subacute (granulomatous, de Quervain's) thyroiditis
Palpation thyroiditis
Iatrogenic thyrotoxicosis
Factitious ingestion of thyroid hormone
Struma ovarii
Acute thyroiditis
Extensive metastases from follicular thyroid cancer

[a]In iodine-induced or iodine-exposed hyperthyroidism (including amiodarone type 1), the uptake may be low.
[b]Patients are not uniformly clinically hyperthyroid. T_3, triiodothyronine.

Thyroid scans provide a planar image of the thyroid gland using a gamma camera to assess potential variability in the concentration of the radioisotope within thyroid tissue. RAI scans may be obtained coincident with the RAIU and technetium scans may be obtained coincident with the technetium uptake. While technetium scans result in a low range of normal uptake and high background activity, total body radiation exposure is less than for ^{123}I scans; either type of scan can be useful in determining the etiology of hyperthyroidism in the presence of thyroid nodularity.

A thyroid scan should be obtained if the clinical presentation suggests a TA or TMNG. The pattern of RAIU in GD is diffuse unless coexistent nodules or fibrosis is present. The pattern of uptake in a patient with a single TA generally shows focal uptake in the adenoma with suppressed uptake in the surrounding and contralateral thyroid tissue. The image in TMNG demonstrates multiple areas of focal increased and suppressed uptake. If autonomy is extensive, the image may be difficult to distinguish from that of GD (46). Additionally, GD and nontoxic nodular goiter may coincide, resulting in positive TRAb levels and a nodular ultrasound or heterogeneous uptake images (47).

Where expertise is available, ultrasonography with color flow Doppler can distinguish thyroid hyperactivity (increased flow) from destructive thyroiditis (48). Quantitative Doppler evaluation requires careful adjustments to prevent artifacts and measures the peak systolic velocity from intrathyroidal arteries or the inferior thyroidal artery (49). This test may

be particularly useful when radioactive iodine (RAI) is contraindicated, such as during pregnancy or breastfeeding. Doppler flow has also been used to distinguish between subtypes of amiodarone-induced thyrotoxicosis (see Section [V2]) and between GD and destructive thyroiditis (see Section [W2]).

The ratio of total T_3 to total T_4 can also be useful in assessing the etiology of thyrotoxicosis when scintigraphy is contraindicated. Because a hyperactive gland produces more T_3 than T_4, T_3 will be elevated above the upper limit of normal more than T_4 in thyrotoxicosis caused by hyperthyroidism, whereas T_4 is elevated more than T_3 in thyrotoxicosis caused by thyroiditis (50); in one study the ratio of total T_3 to total T_4 (ng/μg) was >20 in GD and toxic nodular goiter, and <20 in painless or postpartum thyroiditis (51). A high T_4 to T_3 ratio may be seen in thyrotoxicosis factitia (from exogenous levothyroxine).

The choice of initial diagnostic testing depends on cost, availability, and local expertise. TRAb is cost effective because if it is positive it confirms the diagnosis of the most common cause of thyrotoxicosis. If negative it does not distinguish among other etiologies, however, and it can be negative in very mild GD. If third-generation TRAb assays are not readily available, RAIU is preferred for initial testing.

Diagnostic testing may be influenced by the choice of therapy (see Section [C]). For example, measuring TRAb in a patient with GD who plans on taking methimazole (MMI) with the hope of achieving a remission will provide a baseline measurement for disease activity. Obtaining a RAIU in a patient who prefers RAI treatment will provide both diagnostic information and facilitate the calculation of the RAI dose (see Section [D2]).

In most patients, distinction between subacute and painless thyroiditis is not difficult. Subacute thyroiditis is generally painful, the gland is firm to hard on palpation, and the erythrocyte sedimentation rate is usually >50 mm/h and sometimes over 100 mm/h. Patients with painless thyroiditis presenting within the first year after childbirth (postpartum thyroiditis) often have a personal or family history of autoimmune thyroid disease and typically have measurable serum concentrations of anti–thyroid peroxidase antibodies (52).

Thyroglobulin is released along with thyroid hormone in subacute, painless, and palpation thyroiditis (following manipulation of the thyroid gland during surgery), whereas its release is suppressed in the setting of exogenous thyroid hormone administration. If not elucidated by the history, factitious ingestion of thyroid hormone can be distinguished from other causes of thyrotoxicosis by a low serum thyroglobulin level, a near-zero RAIU, and a T_3 to T_4 ratio (ng/μg) <20 if due to exogenous levothyroxine (53). In patients with antithyroglobulin antibodies, which interfere with thyroglobulin measurement, an alternative but not widely available approach is measurement of fecal T_4 (54); mean values were 1.03 nmol/g in euthyroid patients, 1.93 nmol/g in Graves' hyperthyroidism, and 12–24 nmol/g in factitious thyrotoxicosis.

Technical remarks: There are two methods for measuring Thyroid Receptor Antibodies (TRAb) (55). Third generation TSH Binding Inhibition Immunoglobulin (TBII) assays are competition assays which measure inhibition of binding of either a labeled monoclonal anti-human TSH-R antibody or labeled TSH to a recombinant TSH-R. These TRAb or TBII assays are unable to distinguish the TSH-R antibody types. Bioassays for the Thyroid Stimulating Immunoglobulin (TSI) measure the ability of TSI to increase the intracellular level of cAMP directly or indirectly, e.g. from engineered Chinese Hamster Ovary (CHO) cells transfected with hTSH-R reported through increased luciferase production. Such assays specifically detect simulating antibodies (TSI) and can differentiate between the TSH-R antibody types. In the setting of overt thyrotoxicosis, newer TRAb binding and bioassays have a sensitivity of 96–97% and a specificity of 99% for GD (56,57).

[B4] Symptomatic management

■ **RECOMMENDATION 2**

Beta-adrenergic blockade is recommended in all patients with symptomatic thyrotoxicosis, especially elderly patients and thyrotoxic patients with resting heart rates in excess of 90 beats per minute or coexistent cardiovascular disease.

Strong recommendation, moderate-quality evidence.

In a randomized controlled trial of MMI alone versus MMI and a β-adrenergic blocking agent, after 4 weeks, patients taking β-adrenergic blockers had lower heart rates, less shortness of breath and fatigue, and improved ''physical functioning'' on the SF-36 health questionnaire (58).

Technical remarks: Since there is not sufficient β-1 selectivity of the available β-blockers at the recommended doses, these drugs are generally contraindicated in patients with bronchospastic asthma. In patients with quiescent bronchospastic asthma in whom heart rate control is essential, or in patients with mild obstructive airway disease or symptomatic Raynaud's phenomenon, a relative β-1 selective agent can be used cautiously, with careful monitoring of pulmonary status (Table 4). Occasionally, very high doses of β-blockers are required to manage symptoms of thyrotoxicosis and to reduce the heart rate to near the upper limit of normal (31), but most often low to moderate doses (Table 4) give sufficient symptom relief. Oral administration of calcium channel blockers, both verapamil and diltiazem, have been shown to affect rate control in patients who do not tolerate or are not candidates for β-adrenergic blocking agents.

[C] How should overt hyperthyroidism due to GD be managed?

■ **RECOMMENDATION 3**

Patients with overt Graves' hyperthyroidism should be treated with any of the following modalities: RAI therapy, ATDs, or thyroidectomy.

Strong recommendation, moderate-quality evidence.

Once it has been established that the patient is hyperthyroid and the cause is GD, the patient and physician must choose between three effective and relatively safe initial treatment options: RAI therapy, ATDs, or thyroidectomy (59). In the United States, RAI has been the therapy most preferred by physicians, but a trend has been present in recent years to increase use of ATDs and reduce the use of RAI. A 2011 survey of clinical endocrinologists showed that 59.7%

TABLE 4. BETA-ADRENERGIC RECEPTOR BLOCKADE IN THE TREATMENT OF THYROTOXICOSIS

Drug[a]	*Dosage*	*Frequency*	*Considerations*
Propanolol[b]	10–40 mg	3–4 times per day	Nonselective β-adrenergic receptor blockade Longest experience May block T_4 to T_3 conversion at high doses Preferred agent for nursing and pregnant mothers
Atenolol	25–100 mg	1–2 times per day	Relative β-1 selectivity Increased compliance Avoid during pregnancy
Metoprolol[b]	25–50 mg	2–3 times per day	Relative β-1 selectivity
Nadolol	40–160 mg	1 time per day	Nonselective β-adrenergic receptor blockade Once daily Least experience to date May block T_4 to T_3 conversion at high doses
Esmolol	IV pump 50–100 μg/kg/min		In intensive care unit setting of severe thyrotoxicosis or storm

[a]Each of these drugs has been approved for treatment of cardiovascular diseases, but to date none has been approved for the treatment of thyrotoxicosis.
[b]Also available in once daily preparations.
T_4, thyroxine.

of respondents from the United States selected RAI as primary therapy for an uncomplicated case of GD, compared with 69% in a similar survey performed 20 years earlier (60). In Europe, Latin America, and Japan, there has been a greater physician preference for ATDs (61). The long-term quality of life (QoL) following treatment for GD was found to be the same in patients randomly allocated to one of the three treatment options (62). Currently, no scientific evidence exists to support the recommendation of alternative therapies for the treatment of hyperthyroidism (63).

Technical remarks: Once the diagnosis has been made, the treating physician and patient should discuss each of the treatment options, including the logistics, benefits, expected speed of recovery, drawbacks, potential side effects, and costs (64). This sets the stage for the physician to make recommendations based on best clinical judgment and allows the final decision to incorporate the personal values and preferences of the patient. The treatment selection should also take into account the local availability and the associated costs. Whenever surgery is selected as treatment one should consider the use of expert high-volume thyroid surgeons with on average lower risk of complications; lack of that expertise should be considered against the known risk of alternative choices. Long-term continuous treatment of hyperthyroidism with ATDs may be considered in selected cases (65,66).

Clinical situations that favor a particular modality as treatment for Graves' hyperthyroidism (Table 5):

a. RAI therapy: Women planning a pregnancy in the future (in more than 6 months following RAI administration, provided thyroid hormone levels are normal), individuals with comorbidities increasing surgical risk, and patients with previously operated or externally irradiated necks, or lack of access to a high-volume thyroid surgeon, and patients with contraindications to ATD use **or** failure to achieve euthyroidism during treatment with ATDs. Patients with periodic thyrotoxic hypokalemic paralysis, right heart failure pulmonary hypertension, or congestive heart failure should also be considered good candidates for RAI therapy.
b. ATDs: Patients with high likelihood of remission (patients, especially women, with mild disease, small goiters, and negative or low-titer TRAb); pregnancy; the elderly or others with comorbidities increasing surgical risk or with limited life expectancy; individuals in nursing homes or other care facilities who may have limited longevity and are unable to follow radiation safety regulations; patients with previously operated or irradiated necks; patients with lack of access to a high-volume thyroid surgeon; patients with moderate to severe active GO; and patients who need more rapid biochemical disease control.
c. Surgery: Women planning a pregnancy in <6 months provided thyroid hormone levels are normal (i.e., possibly before thyroid hormone levels would be normal if RAI were chosen as therapy); symptomatic compression or large goiters (≥80 g); relatively low uptake of RAI; when thyroid malignancy is documented or suspected (e.g., suspicious or indeterminate cytology); large thyroid nodules especially if greater than 4 cm or if nonfunctioning, or hypofunctioning on ^{123}I or ^{99m}Tc pertechnetate scanning; coexisting hyperparathyroidism requiring surgery; especially if TRAb levels are particularly high; and patients with moderate to severe active GO.

Contraindications to a particular modality as treatment for Graves' hyperthyroidism:

a. RAI therapy: Definite contraindications include pregnancy, lactation, coexisting thyroid cancer, or suspicion of thyroid cancer, individuals unable to comply with radiation safety guidelines and used with informed caution in women planning a pregnancy within 4–6 months.
b. ATDs: Definite contraindications to ATD therapy include previous known major adverse reactions to ATDs.

Table 5. Clinical Situations That Favor a Particular Modality as Treatment for Graves' Hyperthyroidism

Clinical situations	*RAI*	*ATD*	*Surgery*
Pregnancy[a]	x	√√ / !	√ / !
Comorbidities with increased surgical risk and/or limited life expectancy	√√	√	x
Inactive GO	√	√	√
Active GO	[b]	√√	√√
Liver disease	√√	!	√
Major adverse reactions to ATDs	√√	x	√
Patients with previously operated or externally irradiated necks	√√	√	!
Lack of access to a high-volume thyroid surgeon	√√	√	!
Patients with high likelihood of remission (especially women, with mild disease, small goiters, and negative or low-titer TRAb)	√	√√	√
Patients with periodic paralysis	√√	√	√√
Patients with right pulmonary hypertension, or congestive heart failure	√√	√	!
Elderly with comorbidities	√	√	!
Thyroid malignancy confirmed or suspected	x	-	√√
One of more large thyroid nodules	-	√	√√
Coexisting primary hyperparathyroidism requiring surgery	-	-	√√

√√ = preferred therapy; √ = acceptable therapy; ! = cautious use; - = not first-line therapy but may be acceptable depending on the clinical circumstances; X = contraindication.
[a]For women considering a pregnancy within 6 months, see discussion in Section [T2].
[b]Table 14 describes the use of RAI in GO in detail, considering disease activity, severity, and other risk factors for GO progression.

c. Surgery: Factors that may mitigate against the choice of surgery include substantial comorbidity such as cardiopulmonary disease, end-stage cancer, or other debilitating disorders, or lack of access to a high-volume thyroid surgeon. Pregnancy is a relative contraindication, and surgery should only be used in the circumstance when rapid control of hyperthyroidism is required and antithyroid medications cannot be used. Thyroidectomy is best avoided in the first and third trimesters of pregnancy because of teratogenic effects associated with anesthetic agents and increased risk of fetal loss in the first trimester and increased risk of preterm labor in the third. Optimally, thyroidectomy is performed in the second trimester; however, although it is the safest time, it is not without risk (4.5%–5.5% risk of preterm labor) (67,68). Thyroid surgery in pregnancy is also associated with a higher rate of complications, including hypoparathyroidism and recurrent laryngeal nerve (RLN) injury (68).

Patient values that may impact choice of therapy:

a. RAI therapy: Patients choosing RAI therapy as treatment for GD would likely place relatively higher value on definitive control of hyperthyroidism, the avoidance of surgery, and the potential side effects of ATDs, as well as a relatively lower value on the need for lifelong thyroid hormone replacement, rapid resolution of hyperthyroidism, and potential worsening or development of GO (69).
b. ATDs: Patients choosing ATD as treatment for GD would place relatively higher value on the possibility of remission and the avoidance of lifelong thyroid hormone treatment, the avoidance of surgery, and exposure to radioactivity and a relatively lower value on the avoidance of ATD side effects (see Section [E]), and the possibility of disease recurrence.
c. Surgery: Patients choosing surgery as treatment for GD would likely place a relatively higher value on prompt and definitive control of hyperthyroidism, avoidance of exposure to radioactivity, and the potential side effects of ATDs and a relatively lower value on potential surgical risks, and need for lifelong thyroid hormone replacement.

[D] If RAI therapy is chosen, how should it be accomplished?

[D1] Preparation of patients with GD for RAI therapy

■ **RECOMMENDATION 4**

Because RAI treatment of GD can cause a transient exacerbation of hyperthyroidism, β-adrenergic blockade should be considered even in asymptomatic patients who are at increased risk for complications due to worsening of hyperthyroidism (i.e., elderly patients and patients with comorbidities).

Weak recommendation, low-quality evidence.

■ **RECOMMENDATION 5**

In addition to β-adrenergic blockade (see Recommendations 2 and 4), pretreatment with MMI prior to RAI therapy for GD should be considered in patients who are at increased risk for complications due to worsening of hyperthyroidism. MMI should be discontinued 2–3 days prior to RAI.

Weak recommendation, moderate-quality evidence.

■ **RECOMMENDATION 6**

In patients who are at increased risk for complications due to worsening of hyperthyroidism, resuming MMI 3–7 days after RAI administration should be considered.

Weak recommendation, low-quality evidence.

■ **RECOMMENDATION 7**

Medical therapy of any comorbid conditions should be optimized prior to RAI therapy.

Strong recommendation, low-quality evidence.

RAI has been used to treat hyperthyroidism for more than seven decades. It is well tolerated and complications are rare, except for those related to orbitopathy (see Section [U]). Thyroid storm occurs only rarely following the administration of RAI (70–72). In one study of patients with thyrotoxic cardiac disease treated with RAI as the sole modality, no clinical worsening in any of the cardinal symptoms of thyrotoxicosis was seen (73). However, RAI can induce a short-term increase of thyroid hormone levels (74,75). To prevent a clinical exacerbation of hyperthyroidism, the use of MMI or carbimazole, the latter of which is not marketed in the United States, before and after RAI treatment may be considered in patients with severe hyperthyroidism, the elderly, and individuals with substantial comorbidity that puts them at greater risk for complications of worsening thyrotoxicosis (75,76). The latter includes patients with cardiovascular complications such as atrial fibrillation, heart failure, or pulmonary hypertension and those with renal failure, infection, trauma, poorly controlled diabetes mellitus, and cerebrovascular or pulmonary disease (70). These comorbid conditions should be addressed with standard medical care and the patient rendered medically stable before the administration of RAI if possible. If possible iodinated radiocontrast should be avoided. In addition, β-adrenergic blocking drugs should be used judiciously in these patients in preparation for RAI therapy (25,77). MMI (75) and carbimazole (78) have shown to reduce thyroid hormone levels after RAI treatment in randomized controlled trials. However, a recent meta-analysis of randomized controlled trials also found that MMI, carbimazole, and propylthiouracil (PTU) reduce the success rate if given in the week before or after RAI treatment (71). Use of higher activities of RAI may offset the reduced effectiveness of RAI therapy following antithyroid medication (75,76).

A special diet is not required before RAI therapy, but nutritional supplements that may contain excess iodine and seaweeds should be avoided for at least 7 days. A low-iodine diet may be useful for those with relatively low RAIU to increase the proportion of RAI trapped.

Technical remarks: Patients that might benefit from adjunctive MMI or carbimazole may be those who tolerate hyperthyroid symptoms poorly. Such patients frequently have free T_4 at 2–3 times the upper limit of normal. Young and middle-aged patients who are otherwise healthy and clinically well compensated despite significant biochemical hyperthyroidism can generally receive RAI without pretreatment. If given as pretreatment, MMI and carbimazole should be discontinued before the administration of RAI. Discontinuation of ATDs for 2–3 days prevents a short-term increase of thyroid hormone levels (79), which is found after 6 days (75,76). In elderly patients or in those with underlying cardiovascular disease, resuming MMI or carbimazole 3–7 days after RAI administration should be considered and generally tapered as thyroid function normalizes. In one study, if MMI was restarted 7 days after RAI, the free T_4 measured 3 weeks after RAI was 6% lower than the values at the time of RAI administration, and if MMI was not restarted after RAI, the free T_4 values were 36% higher than the values at the time of RAI administration (80). Over several decades, there have been reports that pretreatment with lithium reduces the activity of RAI necessary for cure of Graves' hyperthyroidism and may prevent the thyroid hormone increase seen upon ATD withdrawal (81–83). However, this approach is not used widely, and insufficient evidence exists to recommend the practice. In selected patients with Graves' hyperthyroidism who would have been candidates for pretreatment with ATDs because of comorbidities or excessive symptoms, but who are allergic to ATDs, the duration of hyperthyroidism may be shortened by administering iodine (e.g., saturated solution of potassium iodide [SSKI]) beginning 1 week after RAI administration (84).

[D2] Administration of RAI in the treatment of GD

■ **RECOMMENDATION 8**

Sufficient activity of RAI should be administered in a single application, typically a mean dose of 10–15 mCi (370–555 MBq), to render the patient with GD hypothyroid.

Strong recommendation, moderate-quality evidence.

■ **RECOMMENDATION 9**

A pregnancy test should be obtained within 48 hours prior to treatment in any woman with childbearing potential who is to be treated with RAI. The treating physician should obtain this test and verify a negative result prior to administering RAI.

Strong recommendation, low-quality evidence.

The goal of RAI therapy in GD is to control hyperthyroidism by rendering the patient hypothyroid; this treatment is very effective, provided a sufficient radiation dose is deposited in the thyroid. This outcome can be accomplished equally well by either administering a fixed activity or by calculating the activity based on the size of the thyroid and its ability to trap RAI (85).

The first method is simple, while the second method requires two unknowns to be determined: the uptake of RAI and the size of the thyroid. The therapeutic RAI activity can then be calculated using these two factors and the quantity of radiation (μCi or Bq) to be deposited per gram (or cc) of thyroid (e.g., activity [μCi] = gland weight [g] $\times$ 50–200 μCi/g $\times$ [1/24 hour uptake in % of administered activity]). The activity in microcuries or becquerels is converted to millicuries or megabecquerel by dividing the result by 1000. The most frequently used uptake is calculated at 24 hours, and the size of the thyroid is determined by palpation or ultrasound. One study found that this estimate by experienced physicians is accurate compared with anatomic imaging (86); however, other investigators have not confirmed this observation (87).

Alternately, a more detailed calculation can be made to deposit a specific radiation dose (in rad or Gy) to the thyroid.

Using this approach, it is also necessary to know the effective half-life of RAI (88). This requires additional time and computation, and because the outcome has not shown to be better, this method is seldom used in the United States. Evidence shows that to achieve a hypothyroid state, >150 μCi/g (5.55 MBq/g) needs to be delivered (88–90). Patients who are on dialysis or who have jejunostomy or gastric feeding tubes require special care and management when being administered RAI treatment (91).

The success of RAI therapy in GD strongly depends on the administered activities. In patients without adjunctive ATD, randomized controlled trials found 61% success with 5.4 mCi (200 MBq) (92), 69% with 8.2 mCi (302 MBq) (93), 74% with 10 mCi (370 MBq) (94), 81% with 15 mCi (555 MBq) (94), and 86% with 15.7 mCi (580 MBq) (95) RAI. Because of the high proportion of patients requiring retreatment, RAI therapy with low activities is generally not recommended.

A long-term increase in cardiovascular and cerebrovascular deaths has been reported after RAI therapy not resulting in hypothyroidism as opposed to unchanged mortality in RAI-treated patients on levothyroxine therapy, reflecting the role of persistent hyperthyroidism as opposed to that of RAI therapy on mortality (96,97). A recent meta-analysis found no increase in the overall cancer risk after RAI treatment for hyperthyroidism; however, a trend towards increased risk of thyroid, stomach, and kidney cancer was seen, requiring further research (98). In some men, a modest fall in the testosterone to luteinizing hormone (LH) ratio occurs after RAI therapy that is subclinical and reversible (99). Conception should be delayed in women until stable euthyroidism is established (on thyroid hormone replacement following successful thyroid ablation). This typically takes 4–6 months or longer. Conception should be delayed 3–4 months in men to allow for turnover of sperm production. However, once the patient (either sex) is euthyroid, there is no evidence of reduced fertility, and offspring of treated patients show no congenital anomalies compared to the population at large (100).

Technical remarks: Rendering the patient hypothyroid can be accomplished equally well by administering either a sufficient fixed activity or calculating an activity based on the size of the thyroid and its ability to trap iodine. Fetuses exposed to RAI after the 10th to 11th week of gestation may be born athyreotic (101,102) and are also at a theoretical increased risk for reduced intelligence and/or cancer. In breastfeeding women, RAI therapy should not be administered for at least 6 weeks after lactation stops to ensure that RAI will no longer be actively concentrated in the breast tissues. A delay of 3 months will more reliably ensure that lactation-associated increase in breast sodium iodide symporter activity has returned to normal (103). Breastfeeding should not be resumed after RAI therapy.

■ RECOMMENDATION 10

The physician administering RAI should provide written advice concerning radiation safety precautions following treatment. If the precautions cannot be followed, alternative therapy should be selected.

Strong recommendation, low-quality evidence.

All national and regional radiation protection rules regarding RAI treatment should be followed (104,105). In the United States, the treating physician must ensure and document that no adult member of the public is exposed to 0.5 mSv (500 milli-roentgen equivalent in man [mrem]) when the patient is discharged with a retained activity of 33 mCi (1.22 GBq) or greater, or emits ≥7 mrem/h (70 μSv/h) at 1 m.

Technical remarks: Continuity of follow-up should be provided and can be facilitated by communication between the referring physician and the treating physician, including a request for therapy from the former and a statement from the latter that the treatment has been administered.

[D3] Patient follow-up after RAI therapy for GD

■ RECOMMENDATION 11

Follow-up within the first 1–2 months after RAI therapy for GD should include an assessment of free T_4, total T_3, and TSH. Biochemical monitoring should be continued at 4- to 6-week intervals for 6 months, or until the patient becomes hypothyroid and is stable on thyroid hormone replacement.

Strong recommendation, low-quality evidence.

Most patients respond to RAI therapy with a normalization of thyroid function tests and improvement of clinical symptoms within 4–8 weeks. Hypothyroidism may occur from 4 weeks on, with 40% of patients being hypothyroid by 8 weeks and >80% by 16 weeks (106). This transition can occur rapidly but more commonly between 2 and 6 months, and the timing of thyroid hormone replacement therapy should be determined by results of thyroid function tests, clinical symptoms, and physical examination. Transient hypothyroidism following RAI therapy can rarely occur, with subsequent complete recovery of thyroid function or recurrent hyperthyroidism (107). In such patients the thyroid gland often remains palpable.

Beta-blockers that were instituted prior to RAI treatment should be tapered when free T_4 and total T_3 have returned to the reference range. As free T_4 and total T_3 improve, MMI can usually be tapered, which allows an assessment of the response to RAI.

Most patients eventually develop hypothyroidism following RAI, which is indicated by a free T_4 below normal range. At this point, levothyroxine should be instituted. TSH levels may not rise immediately with the development of hypothyroidism and should not be used initially to determine the need for levothyroxine. When thyroid hormone replacement is initiated, the dose should be adjusted based on an assessment of free T_4. The required dose may be less than the typical full replacement, and careful titration is necessary owing to nonsuppressible residual thyroid function. Overt hypothyroidism should be avoided, especially in patients with active GO (see Section [U2]). Once euthyroidism is achieved, lifelong annual thyroid function testing is recommended at least annually, or if the patient experiences symptoms of hypothyroidism or hyperthyroidism.

Technical remarks: Since TSH levels may remain suppressed for a month or longer after hyperthyroidism resolves, the levels should be interpreted cautiously and only in concert with free T_4 and total T_3.

[D4] Treatment of persistent Graves' hyperthyroidism following RAI therapy

■ **RECOMMENDATION 12**

When hyperthyroidism due to GD persists after 6 months following RAI therapy, retreatment with RAI is suggested. In selected patients with minimal response 3 months after therapy additional RAI may be considered.

Weak recommendation, low-quality evidence.

Technical remarks: Response to RAI therapy can be assessed by monitoring the size of the gland, thyroid function, and clinical signs and symptoms. The goal of retreatment is to control hyperthyroidism with certainty by rendering the patient hypothyroid. Patients who have persistent, suppressed TSH with normal total T_3 and free T_4 may not require immediate retreatment but should be monitored closely for either relapse or development of hypothyroidism. In the small percentage of patients with hyperthyroidism refractory to several applications of RAI, surgery should be considered (108).

[E] If ATDs are chosen as initial management of GD, how should the therapy be managed?

ATDs have been employed for seven decades (109). The goal of the therapy is to render the patient euthyroid as quickly and safely as possible. These medications do not cure Graves' hyperthyroidism; however, when given in adequate doses, they are very effective in controlling the hyperthyroidism. When they fail to achieve euthyroidism, the usual cause is nonadherence (110). The treatment itself might have a beneficial immunosuppressive role, either to primarily decrease thyroid specific autoimmunity, or secondarily, by ameliorating the hyperthyroid state, which may restore the dysregulated immune system back to normal (111). In fact, the rate of remission with ATD therapy is much higher (112) than the historical rates of spontaneous remission (113).

[E1] Initiation of ATD therapy for the treatment of GD

■ **RECOMMENDATION 13**

MMI should be used in virtually every patient who chooses ATD therapy for GD, except during the first trimester of pregnancy when PTU is preferred, in the treatment of thyroid storm, and in patients with minor reactions to MMI who refuse RAI therapy or surgery.

Strong recommendation, moderate-quality evidence.

■ **RECOMMENDATION 14**

Patients should be informed of side effects of ATDs and the necessity of informing the physician promptly if they should develop pruritic rash, jaundice, acolic stools or dark urine, arthralgias, abdominal pain, nausea, fatigue, fever, or pharyngitis. Preferably, this information should be in writing. Before starting ATDs and at each subsequent visit, the patient should be alerted to stop the medication immediately and call their physician if there are symptoms suggestive of agranulocytosis or hepatic injury.

Strong recommendation, low-quality evidence.

■ **RECOMMENDATION 15**

Prior to initiating ATD therapy for GD, we suggest that patients have a baseline complete blood count, including white blood cell (WBC) count with differential, and a liver profile including bilirubin and transaminases.

Weak recommendation, low-quality evidence.

In the United States, MMI and PTU are available, and in some countries, carbimazole, a precursor of MMI, is widely used. Carbimazole is rapidly converted to MMI in the serum (10 mg of carbimazole is metabolized to approximately 6 mg of MMI). They work in an identical fashion and both will be referred to as MMI in this text. Both are effective as a single daily dose. At the start of MMI therapy, initial doses of 10–30 mg daily are used to restore euthyroidism, and the dose can then be titrated down to a maintenance level (generally 5–10 mg daily) (109,114). The dose of MMI should be targeted to the degree of thyroid dysfunction because too low a dose will not restore a euthyroid state in patients with severe disease (115) and an excessive dose can cause iatrogenic hypothyroidism in patients with mild disease (116). In addition, adverse drug reactions are more frequent with higher MMI doses. Thus, it is important to use an MMI dose that will achieve the clinical goal of normalization of thyroid function reasonably rapidly, while minimizing adverse drug effects. The task force suggests the following as a rough guide to initial MMI daily dosing: 5–10 mg if free T_4 is 1–1.5 times the upper limit of normal; 10–20 mg for free T_4 1.5–2 times the upper limit of normal; and 30–40 mg for free T_4 2–3 times the upper limit of normal. These rough guidelines should be tailored to the individual patient, incorporating additional information on symptoms, gland size, and total T_3 levels where relevant. Serum T_3 levels are important to monitor initially because some patients normalize their free T_4 levels with MMI but have persistently elevated serum T_3, indicating continuing thyrotoxicosis (117).

MMI has the benefit of once-a-day administration and a reduced risk of major side effects compared to PTU. PTU has a shorter duration of action and is usually administered two or three times daily, starting with 50–150 mg three times daily, depending on the severity of the hyperthyroidism. As the clinical findings and thyroid function tests return to normal, reduction to a maintenance PTU dose of 50 mg two or three times daily is usually possible. When more rapid biochemical control is needed in patients with severe thyrotoxicosis, an initial split dose of MMI (e.g., 15 or 20 mg twice a day) may be more effective than a single daily dose because the duration of action of MMI may be less than 24 hours (118). Higher doses of antithyroid medication are sometimes administered continuously and combined with L-thyroxine in doses to maintain euthyroid levels (so-called block and replace therapy). However, this approach is not generally recommended because it has been shown to result in a higher rate of ATD side effects (109,119).

The use of potassium iodide (KI) as a beneficial adjunct to ATD therapy for GD has been investigated in previous studies (120). Indeed, a recent randomized controlled trial described the administration of 38 mg of KI together with 15 mg of MMI daily, which resulted in better control of hyperthyroidism and fewer adverse reactions compared to 30 mg of MMI given alone (121).

[E2] Adverse effects of ATDs

In general, adverse effects of ATDs can be divided into common, minor allergic side effects and rare but serious allergic/toxic events such as agranulocytosis, vasculitis, or hepatic damage. In a recent systematic review of eight studies that included 667 GD patients receiving MMI or PTU, 13% of patients experienced adverse events (122). The minor allergic reactions included pruritus or a limited, minor rash in 6% of patients taking MMI and 3% of patients taking PTU (122). Hepatocellular injury occurred in 2.7% of patients taking PTU and 0.4% of patients taking MMI. In a separate study of 449 GD patients receiving MMI or PTU, 24% developed a cutaneous reaction, 3.8% developed transaminase elevations more than 3-fold above normal, and 0.7% developed agranulocytosis (absolute neutrophil count <500) (123). Cutaneous reactions were more common with PTU or higher dose MMI (30 mg/d) compared with lower dose MMI (15 mg/d). Hepatotoxicity was more common with PTU. Cutaneous reactions appeared after a median of 18–22 days of treatment, significantly earlier than transaminase elevations (median 28 days). The percentage of patients discontinuing ATD therapy was 17% in the low-dose MMI group, 29% in the high-dose MMI group, and 34% in the PTU group (123).

[E3] Agranulocytosis

Although ATD-associated agranulocytosis is uncommon, it is life-threatening. PTU at any dose appears to be more likely to cause agranulocytosis compared with low doses of MMI (124–126). Three recent reports of large numbers of ATD-treated patients who developed hematologic complications provide information on risk factors, treatment, and outcomes (127–129). Two studies were from Japan and one was from Denmark. In both countries the majority of patients are treated with MMI, so data are more limited for PTU-associated agranulocytosis. In the first study, a retrospective cohort analysis of over 50,000 GD patients, 55 developed agranulocytosis, of whom five had pancytopenia, for an estimated cumulative incidence of 0.3% in 100 days (127), with a median interval to onset of 69 days. All 50 patients with agranulocytosis alone were successfully treated with granulocyte colony stimulating factor, steroids, or supportive care, but one of five patients with pancytopenia died. No predictive risk factors for the development of agranulocytosis could be identified. The second study was based on a national database for adverse drug reactions, which may have included some patients reported in the first study (128). A total of 754 GD patients who developed ATD-induced hematologic complications were reported, for an estimated incidence of 0.1%–0.15%. Of them, 725 patients received MMI, 28 received PTU, and one received both drugs. Eighty-nine percent developed agranulocytosis, and 11% developed pancytopenia or aplastic anemia. At the onset of agranulocytosis, the average MMI dose was 25 mg/d and the average PTU dose was 217 mg/d. The average age of patients developing agranulocytosis was slightly older (45 vs. 40 years), an observation that has been made by others. Seventy-two percent developed agranulocytosis within 60 days of starting ATD, and 85% within 90 days. In 7% of patients, agranulocytosis occurred later than 4 months after starting ATD, but some of these patients had discontinued the medication for long periods of time and developed agranulocytosis after a second or subsequent exposure. Thirty of the events (4%) were fatal. In the third study from Denmark, the frequency of agranulocytosis was 0.27% with PTU and 0.11% with MMI (129). As in prior studies, the median duration of therapy prior to the development of agranulocytosis was 36 and 38 days for MMI and PTU, respectively.

[E4] Hepatotoxicity

Hepatotoxicity is another major adverse effect of ATD therapy. MMI hepatotoxicity has been described as typically cholestatic, but hepatocellular disease may be seen (130,131). In contrast, PTU can cause fulminant hepatic necrosis that may be fatal; liver transplantation has been necessary in some patients taking PTU (132). It is for this reason that the Food and Drug Administration (FDA) issued a safety alert in 2010 regarding the use of PTU, and an analysis of FDA Medwatch data (133) concluded that children are more susceptible to hepatotoxic reactions from PTU than are adults.

A recent pharmacoepidemiologic study from Taiwan challenges the concept that MMI hepatotoxicity is usually cholestatic, while PTU hepatotoxicity is most often hepatocellular (134). Among 71,379 new users of ATDs with a median follow-up of 196 days, MMI was associated with a higher rate of a diagnosis of noninfectious hepatitis than PTU (0.25% vs. 0.08%, respectively), whereas cholestasis was not different (0.019% vs. 0.016%). A diagnosis of liver failure was more common after PTU (0.048% vs. 0.026% in MMI-treated patients). Similar findings were also recently reported from China (135). These surprising results from Asia, which are in contrast to other data from the United States (133,136), suggest that prior data on MMI-related hepatotoxicity from small case series may need to be reconsidered. In the study from Denmark (129), hepatotoxic reactions were not classified as cholestatic or hepatocellular, but the frequency of ''liver failure'' was similar for MMI (0.03%) and PTU (0.03%).

[E5] Vasculitis

Aside from hematologic and hepatic adverse effects, other rare side effects are associated with ATDs. PTU and rarely MMI can cause antineutrophil cytoplasmic antibody (pANCA)-positive small vessel vasculitis (137,138) as well as drug-induced lupus (139). The risk appears to increase with duration of therapy as opposed to other adverse effects seen with ATDs that typically occur early in the course of treatment (140,141). Typically, granulocyte myeloperoxidase is the targeted antigen of the ANCA, but antibodies to many other proteins are seen as well (142). ANCA-positive vasculitis is more common in patients of Asian ethnicity, and the majority of reports come from Asia (143). While up to 40% of patients taking PTU develop ANCA positivity, the vast majority of such individuals do not develop clinical vasculitis (144). When the drug is discontinued, the ANCA slowly disappear in most individuals (144). Children seem to be more likely to develop PTU-related ANCA-positive vasculitis (133). In most cases, the vasculitis resolves with drug discontinuation, although immunosuppressive therapy may be necessary (145).

Rare cases of insulin autoimmune syndrome with symptomatic hypoglycemia have been reported in patients treated with MMI (146,147).

Technical remarks: Baseline blood tests to aid in the interpretation of future laboratory values should be considered before initiating ATD therapy. This suggestion is made in part because low WBC counts are common in patients with GD and in African Americans [10% of whom have a neutrophil count under 2000 (148)], and abnormal liver enzymes are frequently seen in patients with thyrotoxicosis (149). While there is no evidence that neutropenia or liver disease increases the risk of complications from ATDs, the opinion of the task force is that a baseline absolute neutrophil count $<1000/mm^3$ or liver transaminase enzyme levels elevated more than 5-fold above the upper limit of normal should prompt serious reconsideration of initiating ATD therapy. It is advisable to provide information concerning side effects of ATDs to the patient both verbally and in writing to ensure their comprehension, and document that it has been done. This information can be found online (150,151).

[E6] Monitoring of patients taking ATDs

Periodic clinical and biochemical evaluation of thyroid status in patients taking ATDs is necessary, and it is essential that patients understand its importance. An assessment of serum free T_4 and total T_3 should be obtained about 2–6 weeks after initiation of therapy, depending on the severity of the thyrotoxicosis, and the dose of medication should be adjusted accordingly. Serum T_3 should be monitored because the serum free T_4 levels may normalize despite persistent elevation of serum total T_3. Serum TSH may remain suppressed for several months after starting therapy, and it is therefore not a good parameter for monitoring therapy early in the course.

Once the patient is euthyroid, the dose of MMI can usually be decreased by 30%–50%, and biochemical testing repeated in 4–6 weeks. Once euthyroid levels are achieved with the minimal dose of medication, clinical and laboratory evaluation can be undertaken at intervals of 2–3 months. If a patient is receiving long-term MMI (>18 months), this interval can be increased to 6 months (see below).

■ **RECOMMENDATION 16**

A differential WBC count should be obtained during febrile illness and at the onset of pharyngitis in all patients taking antithyroid medication.

Strong recommendation, low-quality evidence.

■ **RECOMMENDATION 17**

There is insufficient evidence to recommend for or against routine monitoring of WBC counts in patients taking ATDs.

No recommendation; insufficient evidence to assess benefits and risks.

No consensus exists concerning the utility of periodic monitoring of WBC counts and liver function tests in predicting early onset of adverse reaction to the medication (152). Although routine monitoring of WBC counts may detect early agranulocytosis, this practice is not likely to identify cases because the frequency is quite low (0.2%–0.5%) and the condition is usually sudden in onset. In a recent analysis of 211 patients with ATD-induced agranulocytosis who had at least one prior granulocyte count measured, 21% had a normal WBC count within a week and 53% within 2 weeks before developing agranulocytosis (128). However, other patients did display a gradual decline in WBC count prior to developing agranulocytosis, suggesting that monitoring might have been useful in some affected patients (152). Because patients are typically symptomatic, measuring WBC counts during febrile illnesses and at the onset of pharyngitis has been the standard approach to monitoring. If monitoring is employed, the maximum benefit would be for the first 90 days of therapy, when the vast majority of agranulocytosis occurs. In a patient developing agranulocytosis or other serious side effects while taking either MMI or PTU, use of the other medication is contraindicated owing to risk of cross-reactivity between the two medications (153). The contraindication to use PTU might be reconsidered in life-threatening thyrotoxicosis (i.e., thyroid storm) in a MMI-treated patient who has developed agranulocytosis, especially if the duration of therapy is brief (154).

■ **RECOMMENDATION 18**

Liver function and hepatocellular integrity should be assessed in patients taking MMI or PTU who experience pruritic rash, jaundice, light-colored stool or dark urine, joint pain, abdominal pain or bloating, anorexia, nausea, or fatigue.

Strong recommendation, low-quality evidence.

Hyperthyroidism can itself cause mildly abnormal liver function tests in up to 30% of patients (149). PTU may cause transient elevations of serum transaminases in up to one-third of patients. Significant elevations to 3-fold above the upper limit of normal are seen in up to 4% of patients taking PTU (155), a prevalence higher than with MMI. As previously noted, PTU can also cause fatal hepatic necrosis, leading to the suggestion by some that patients taking this ATD have routine monitoring of their liver function, especially during the first 6 months of therapy. A 2009 review of the literature (136) found that PTU hepatotoxicity occurred after a median of 120 days after initiation of therapy. Distinguishing these abnormalities from the effect of persistent thyrotoxicosis is difficult unless they are followed prospectively. In patients with improving thyrotoxicosis, a rising alkaline phosphatase with normalization of other liver function does not indicate worsening hepatic toxicity (156) because the origin of the alkaline phosphatase is from bone, not liver. The onset of PTU-induced hepatotoxicity may be acute, difficult to appreciate clinically, and rapidly progressive. If not recognized, it can lead to liver failure and death (115,157–159). Routine monitoring of liver function in all patients taking ATDs has not been found to prevent severe hepatotoxicity. If monitoring is employed, the maximum benefit would be for the first 120 days of therapy, when the vast majority of instances of hepatotoxicity occur.

Technical remarks: PTU should be discontinued if transaminase levels (found incidentally or measured as clinically indicated) reach >3 times the upper limit of normal or if levels elevated at the onset of therapy increase further. After discontinuing the drug, liver function tests should be monitored weekly until there is evidence of resolution. If resolution is not evident, prompt referral to a gastroenterologist or hepatologist for specialty care is warranted. Except in cases

of severe PTU-induced hepatotoxicity, MMI can be used to control the thyrotoxicosis without ill effect (160,161).

■ **RECOMMENDATION 19**

There is insufficient information to recommend for or against routine monitoring of liver function tests in patients taking ATDs.

No recommendation; insufficient evidence to assess benefits and risks.

[E7] Management of allergic reactions

■ **RECOMMENDATION 20**

Minor cutaneous reactions may be managed with concurrent antihistamine therapy without stopping the ATD. Persistent symptomatic minor side effects of antithyroid medication should be managed by cessation of the medication and changing to RAI or surgery, or switching to the other ATD when RAI or surgery are not options. In the case of a serious allergic reaction, prescribing the alternative drug is not recommended.

Strong recommendation, low-quality evidence.

A recent study provided evidence that switching from one ATD to the other is safe in the case of minor side effects, although patients may develop similar side effects with the second ATD (123). In this study, 71 patients with an adverse event from either MMI or PTU switched to the other ATD, with doses individually determined. Median dose of the second ATD was 15 mg/d for MMI (range 10–30) and 300 mg/d for PTU (range 150–450). Thirty-four percent of patients switched to PTU and 30% of patients switched to MMI developed side effects, generally the same type as occurred on the original ATD, while the remaining patients tolerated the second ATD without complications (123). One recent case report described a more severe reaction to MMI consisting of rash, pruritis, and tongue and throat swelling that was successfully managed with antihistamine therapy, but this is not generally recommended because of the risk of anaphylaxis (162).

[E8] Duration of ATD therapy for GD

■ **RECOMMENDATION 21**

Measurement of TRAb levels prior to stopping ATD therapy is suggested because it aids in predicting which patients can be weaned from the medication, with normal levels indicating greater chance for remission.

Strong recommendation, moderate-quality evidence.

■ **RECOMMENDATION 22**

If MMI is chosen as the primary therapy for GD, the medication should be continued for approximately 12–18 months, then discontinued if the TSH and TRAb levels are normal at that time.

Strong recommendation, high-quality evidence.

■ **RECOMMENDATION 23**

If a patient with GD becomes hyperthyroid after completing a course of MMI, consideration should be given to treatment with RAI or thyroidectomy. Continued low-dose MMI treatment for longer than 12–18 months may be considered in patients not in remission who prefer this approach.

Weak recommendation, low-quality evidence.

A patient is considered to be in remission if they have had a normal serum TSH, free T_4, and total T_3 for 1 year after discontinuation of ATD therapy. The remission rate varies considerably between geographical areas. In earlier studies in the United States, about 20%–30% of patients were reported to have a lasting remission after 12–18 months of medication (59), but more recent data are not available. The remission rate may be higher in Europe and Japan; a long-term European study indicated a 50%–60% remission rate after 5–6 years of treatment (163), and a study in Japan reported a 68% remission rate after 2 years of treatment (164). A meta-analysis shows the remission rate in adults is not improved by a course of ATDs longer than 18 months (119). A lower remission rate has been described in men, smokers (especially men), and those with large goiters (≥80 g) (165–169). Higher initial doses of MMI (60–80 mg/d) do not improve remission rates; they increase the risk of side effects and are not recommended (170).

TRAb assessment at the end of the course of ATD therapy is a useful method of dividing patients into two groups: one with persistent elevations who are unlikely to be in remission, and another group with low or undetectable TRAb, who have a higher probability of permanent remission (171,172). In the group with elevated TRAb, relapse rates approach 80%–100%, while in the latter group, relapse rates are in the 20%–30% range (171,172).

[E9] Persistently elevated TRAb

Patients with persistently high TRAb could continue ATD therapy (and repeat TRAb after an additional 12–18 months) or opt for alternate definitive therapy with RAI or surgery. In selected patients (i.e., younger patients with mild stable disease on a low dose of MMI), long-term MMI is a reasonable alternative approach (65,173). Another study reported that MMI doses of 2.5–10 mg/d for a mean of 14 years were safe and effective for the control of GD in 59 patients (174). A recent retrospective analysis compared long-term outcomes (mean follow-up period of 6–7 years) of patients who had relapsed after a course of ATDs, who were treated with either RAI and levothyroxine or long-term ATD therapy (175). Those patients treated with RAI ($n = 114$) more often had persistent thyroid eye disease, continuing thyroid dysfunction, and experienced more weight gain compared with patients receiving long-term ATD treatment ($n = 124$).

If continued MMI therapy is chosen, TRAb levels might be monitored every 1–2 years, with consideration of MMI discontinuation if TRAb levels become negative over long-term follow-up. For patients choosing long-term MMI therapy, monitoring of thyroid function every 4–6 months is reasonable, and patients can be seen for follow-up visits every 6–12 months.

[E10] Negative TRAb

If TRAb is negative and thyroid function is normal at the end of 12–18 months of MMI therapy, it is reasonable to

discontinue the drug. If a patient experiences a relapse in follow-up, RAI therapy or surgery can be considered.

Technical remarks: In patients with negative TRAb, relapses tend to occur relatively later than those that develop in patients whose MMI is stopped when TRAb is still positive (171,176), although 5% occurred within the first 2 months in one study (167). Therefore, in this population, thyroid function testing should be monitored at 2- to 3-month intervals for the first 6 months, then at 4- to 6-month intervals for the next 6 months, and then every 6–12 months in order to detect relapses as early as possible. The patient should be counseled to contact the treating physician if symptoms of hyperthyroidism are recognized. Should a relapse occur, patients should be counseled about alternatives for therapy, which would include another course of MMI, RAI, or surgery. If ATD therapy is chosen, patients should be aware that agranulocytosis can occur with a second exposure to a drug, even many years later, despite an earlier uneventful course of therapy (177,178). If the patient remains euthyroid for more than 1 year (i.e., they are in remission), thyroid function should be monitored at least annually because relapses can occur years later (171), and some patients eventually become hypothyroid (179).

[F] If thyroidectomy is chosen for treatment of GD, how should it be accomplished?

[F1] Preparation of patients with GD for thyroidectomy

■ **RECOMMENDATION 24**

If surgery is chosen as treatment for GD, patients should be rendered euthyroid prior to the procedure with ATD pretreatment, with or without β-adrenergic blockade. A KI-containing preparation should be given in the immediate preoperative period.

Strong recommendation, low-quality evidence.

■ **RECOMMENDATION 25**

Calcium and 25-hydroxy vitamin D should be assessed preoperatively and repleted if necessary, or given prophylactically. Calcitriol supplementation should be considered preoperatively in patients at increased risk for transient or permanent hypoparathyroidism.

Strong recommendation, low-quality evidence.

■ **RECOMMENDATION 26**

In exceptional circumstances, when it is not possible to render a patient with GD euthyroid prior to thyroidectomy, the need for thyroidectomy is urgent, or when the patient is allergic to ATDs, the patient should be adequately treated with β-adrenergic blockade, KI, glucocorticoids, and potentially cholestyramine in the immediate preoperative period. The surgeon and anesthesiologist should have experience in this situation.

Strong recommendation, low-quality evidence.

Thyroid storm may be precipitated by the stress of surgery, anesthesia, or thyroid manipulation and may be prevented by pretreatment with ATDs. Whenever possible, thyrotoxic patients who are undergoing thyroidectomy should be rendered euthyroid by MMI before undergoing surgery (180). Preoperative KI, SSKI, or Lugol's solution should be used before surgery in most patients with GD. This treatment is beneficial because it decreases thyroid blood flow, vascularity, and intraoperative blood loss during thyroidectomy (181,182). In a recent series of 162 patients with GD and 102 patients with TMNG, none of whom received SSKI preoperatively, no significant differences were observed in operative times, blood loss, or postoperative complications between the two groups; the authors concluded that omitting preoperative SSKI for GD patients does not impair patient outcomes (183). Given that this study was performed at a single high-volume institution, its findings may not be generalizable; comparison was made between two different pathologies, and there was no comparison group of patients with GD who received SSKI. It is also unclear whether it was adequately powered to detect a significant difference, if one existed. However, this study mitigates concern when thyroidectomy is scheduled and SSKI is not given because of shortages, scheduling issues, patient allergy, or patient intolerance. In addition, rapid preparation for emergent surgery can be facilitated by the use of corticosteroids (184) and potentially cholestyramine (185–187).

Technical remarks: KI can be given as 5–7 drops (0.25–0.35 mL) of Lugol's solution (8 mg iodide/drop) or 1–2 drops (0.05–0.1 mL) of SSKI (50 mg iodide/drop) three times daily mixed in water or juice for 10 days before surgery.

Recent data suggest that supplementing oral calcium, vitamin D, or both preoperatively may reduce the risk of postoperative hypocalcemia due to parathyroid injury or increased bone turnover (188). Oltmann *et al.* (189) compared 45 Graves' patients treated with 1 g oral calcium carbonate three times a day for 2 weeks prior to surgery to 38 Graves' patients who underwent thyroidectomy without treatment as well as to 38 euthyroid controls; rates of biochemical and symptomatic hypocalcemia were significantly higher in nontreated Graves' patients compared to the two other treatment groups. Another study that focused on postoperative hypocalcemia after thyroid surgery for thyroid cancer, not hyperthyroidism, identified a reduction in postoperative symptomatic hypocalcemia when patients have preoperative serum 25-hydroxy vitamin D levels >20 ng/mL (> 8 nmol/L) prior to the operating room (190). A meta-analysis of risk factors for postoperative hypocalcemia identified preoperative vitamin D deficiency as a risk factor for postoperative hypocalcemia, as well as GD itself (188). In two studies included in another meta-analysis, supplementing calcitriol for a brief period preoperatively helped reduce transient post-thyroidectomy hypocalcemia (191–193).

[F2] The surgical procedure and choice of surgeon

■ **RECOMMENDATION 27**

If surgery is chosen as the primary therapy for GD, near-total or total thyroidectomy is the procedure of choice.

Strong recommendation, moderate-quality evidence.

Thyroidectomy has a high cure rate for the hyperthyroidism of GD. Total thyroidectomy has a nearly 0% risk of recurrence, whereas subtotal thyroidectomy may have an 8% chance of persistence or recurrence of hyperthyroidism at 5 years (194–197). The most common complications following

near-total or total thyroidectomy are hypocalcemia due to hypoparathyroidism (which can be transient or permanent), recurrent or superior laryngeal nerve injury (which can be temporary or permanent), postoperative bleeding, and complications related to general anesthesia.

■ **RECOMMENDATION 28**

If surgery is chosen as the primary therapy for GD, the patient should be referred to a high-volume thyroid surgeon.

Strong recommendation, moderate-quality evidence.

Improved patient outcome has been shown to be independently associated with high thyroidectomy surgeon volume; specifically, average complication rates, length of hospital stay, and cost are reduced when the operation is performed by a surgeon who conducts many thyroidectomies. A significant association is seen between increasing thyroidectomy volume and improved patient outcome; the association is robust and is more pronounced with an increasing number of thyroidectomies (198,199). Data show that surgeons who perform more than 25 thyroid surgeries per year have superior patient clinical and economic outcomes compared to those who perform fewer; complication rates are 51% higher on average when surgery is performed by low-volume surgeons (62,199,200).

The surgeon should be thoroughly trained in the procedure, have an active practice in thyroid surgery, and have conducted a significant number of thyroidectomies with a low frequency of complications. Following thyroidectomy for GD in the hands of high-volume thyroid surgeons, the rate of permanent hypoparathyroidism has been determined to be <2%, and permanent RLN injury occurs in <1% (201). The frequency of bleeding necessitating reoperation is 0.3%–0.7% (202). Mortality following thyroidectomy is between 1 in 10,000 and 5 in 1,000,000 (203).

[F3] Postoperative care

■ **RECOMMENDATION 29**

Following thyroidectomy for GD, alternative strategies may be undertaken for management of calcium levels: serum calcium with or without intact parathyroid hormone (iPTH) levels can be measured, and oral calcium and calcitriol supplementation administered based on these results, or prophylactic calcium with or without calcitriol prescribed empirically.

Weak recommendation, low-quality evidence.

Successful prediction of calcium status after total thyroidectomy can be achieved using the slope of 6- and 12-hour postoperative calcium levels (204–210). Postoperative routine supplementation with oral calcium and calcitriol decreases development of hypocalcemic symptoms and intravenous calcium requirement, allowing for safer early discharge (211). Low iPTH levels (<10–15 pg/mL) in the immediate postoperative setting appear to predict symptomatic hypocalcemia and need for calcium and calcitriol (1,25 vitamin D) supplementation (212,213). However, normal levels of serum iPTH may not predict eucalcemia for GD patients (214). Vitamin D insufficiency may serve as an underlying cause.

Patients can be discharged if they are asymptomatic and their serum calcium levels corrected for albumin are 8.0 mg/dL (2.0 mmol/L) or above and are not falling over a 24-hour period. The use of ionized calcium measurements are preferred by some and are helpful if the patient has abnormal levels of serum proteins. Intravenous calcium gluconate should be readily available and may be administered if patients have worsening hypocalcemic symptoms despite oral supplementation and/or their concomitant serum calcium levels are falling despite oral repletion. In patients with severe hypocalcemia, teriparatide administration has yielded encouraging preliminary results (elimination of symptoms and earlier hospital discharge), but more data are needed before it can be considered for clinical practice (215). Persistent hypocalcemia in the postoperative period should prompt measurement of serum magnesium and possible magnesium repletion (216,217). In addition to reduced serum calcium levels, reduced serum phosphate and increased serum potassium levels may be observed in hungry bone syndrome. Following discharge, serum iPTH levels should be measured in the setting of persistent hypocalcemia to determine if permanent hypoparathyroidism is truly present or whether ''bone hunger'' is ongoing. As the patient reaches eucalcemia, calcium and calcitriol therapy can be tapered.

Technical remarks: Calcium supplementation can be accomplished with oral calcium (usually calcium carbonate, 1250–2500 mg, equivalent to 500–1000 mg of elemental calcium) four times daily, tapered by 500 mg of elemental calcium every 2 days, or 1000 mg every 4 days as tolerated. In addition, calcitriol may be started at a dose of 0.5 μg daily and continued for 1–2 weeks (218) and increased or tapered according to the calcium and/or iPTH level. Patients can be discharged if they are asymptomatic and have stable serum calcium levels. Postoperative evaluation is generally conducted 1–2 weeks following discharge with continuation of supplementation based on clinical parameters.

■ **RECOMMENDATION 30**

ATD should be stopped at the time of thyroidectomy for GD, and β-adrenergic blockers should be weaned following surgery.

Strong recommendation, low-quality evidence.

■ **RECOMMENDATION 31**

Following thyroidectomy for GD, L-thyroxine should be started at a daily dose appropriate for the patient's weight (0.8 μg/lb or 1.6 μg/kg), with elderly patients needing somewhat less, and serum TSH measured 6–8 weeks postoperatively.

Strong recommendation, low-quality evidence.

Technical remarks: If TSH was suppressed preoperatively, free T_4 and TSH should be measured 6–8 weeks postoperatively, since recovery of the pituitary–thyroid axis is occasionally delayed. The appropriate dosing of L-thyroxine will vary with patient body mass index (219), and the percentage of levothyroxine absorbed from the gut. Once stable and normal, TSH should be measured annually or more frequently if clinically indicated.

■ **RECOMMENDATION 32**

Communication among different members of the multidisciplinary team is essential, particularly during transitions of care in the pre- and postoperative settings.

Strong recommendation, low-quality evidence.

It is important to ensure that adequate communication occurs between the medical team and the treating surgeon to ensure that euthyroidism is achievable prior to surgical intervention; in addition, if the patient is noted to have significant vitamin D deficiency, preoperative vitamin D repletion could be performed and surgery scheduled to permit it. Important intraoperative findings and details of postoperative care, including calcium supplementation needs and management of surgical hypothyroidism, should be communicated by the surgeon to the patient and the other physicians who will be important in the patient's postoperative care (220).

[G] How should thyroid nodules be managed in patients with GD?

■ **RECOMMENDATION 33**

If a thyroid nodule is discovered in a patient with GD, the nodule should be evaluated and managed according to recently published guidelines regarding thyroid nodules in euthyroid individuals.

Strong recommendation, moderate-quality evidence.

Thyroid cancer occurs in GD with a frequency of 2% or less (221). Thyroid nodules larger than 1–1.5 cm should be evaluated before RAI therapy. If a RAI scan is performed, any nonfunctioning or hypofunctioning nodules should be considered for fine-needle aspiration because they may have a higher probability of being malignant (62). If the cytopathology is suspicious or diagnostic of malignancy, surgery is advised after normalization of thyroid function with ATDs. Surgery should also be considered for indeterminate cytology. Disease-free survival at 20 years is reported to be 99% after thyroidectomy for GD in patients with small (≤1 cm) coexisting thyroid cancers (222).

The use of thyroid ultrasonography in all patients with GD has been shown to identify more nodules and cancer than does palpation and ^{123}I scintigraphy. However, since most of these cancers are papillary microcarcinomas with minimal clinical impact, further study is required before routine ultrasound (which may lead to surgery) can be recommended (223,224).

Technical remarks: The ATA recently published updated management guidelines for patients with thyroid nodules and differentiated thyroid cancer (225).

[H] How should thyroid storm be managed?

■ **RECOMMENDATION 34**

The diagnosis of thyroid storm should be made clinically in a severely thyrotoxic patient with evidence of systemic decompensation. Adjunctive use of a sensitive diagnostic system should be considered. Patients with a Burch–Wartofsky Point Scale (BWPS) of ≥45 or Japanese Thyroid Association (JTA) categories of thyroid storm 1 (TS1) or thyroid storm 2 (TS2) with evidence of systemic decompensation require aggressive therapy. The decision to use aggressive therapy in patients with a BWPS of 25–44 should be based on clinical judgment.

Strong recommendation, moderate-quality evidence.

■ **RECOMMENDATION 35**

A multimodality treatment approach to patients with thyroid storm should be used, including β-adrenergic blockade, ATD therapy, inorganic iodide, corticosteroid therapy, cooling with acetaminophen and cooling blankets, volume resuscitation, nutritional support, and respiratory care and monitoring in an intensive care unit, as appropriate for an individual patient.

Strong recommendation, low-quality evidence.

Life-threatening thyrotoxicosis or thyroid storm is a rare disorder characterized by multisystem involvement and mortality rates in the range of 8%–25% in modern series (25,72,226,227). A high index of suspicion for thyroid storm should be maintained in patients with thyrotoxicosis associated with any evidence of systemic decompensation. Diagnostic criteria for thyroid storm in patients with severe thyrotoxicosis were first proposed in 1993 and subsequently widely adopted as the BWPS for thyroid storm (26,72,186, 226,228). These criteria (Table 6) include hyperpyrexia, tachycardia, arrhythmias, congestive heart failure, agitation, delirium, psychosis, stupor, and coma, as well as nausea, vomiting, diarrhea, hepatic failure, and the presence of an identified precipitant (26). Points in the BWPS system are based on the severity of individual manifestations, with a point total of ≥45 consistent with thyroid storm, 25–44 points classified as impending thyroid storm, and <25 points making thyroid storm unlikely. Recently, an additional empirically defined diagnostic system has been proposed by the JTA (72). The JTA system uses combinations of similar clinical features to assign patients to the diagnostic categories TS1 or TS2.

Data comparing these two diagnostic systems suggest an overall agreement, but a tendency toward underdiagnosis using the JTA categories of TS1 and TS2, compared to a BWPS ≥45 (72,186,226,227). In a recent study including 25 patients with a clinical diagnosis of thyroid storm, the BWPS was ≥45 in 20 patients and 25–44 in the remaining five, but these latter five patients (20%) were not identified using the JTA system (226).

Importantly, in the same series, among 125 patients hospitalized with a clinical diagnosis of compensated thyrotoxicosis but not in thyroid storm, 27 (21.6%) had a BWPS ≥45, and 21 (16.8%) had a diagnosis category of either TS1 or TS2, suggesting similar rates of overdiagnosis with these two systems. However, an additional 50 patients (40%) hospitalized with a clinical diagnosis of thyrotoxicosis without thyroid storm would have been diagnosed as having impending thyroid storm by the BWPS, which reinforces that a BWPS in the 25–44 range does not supplant clinical judgment in the selection of patients for aggressive therapy.

In summary, the diagnosis of thyroid storm remains a clinical one that is augmented by current diagnostic systems. A BWPS ≥45 appears more sensitive than a JTA classification of TS1 or TS2 in detecting patients with a clinical

Table 6. Point Scale for the Diagnosis of Thyroid Storm[a]

Criteria	*Points*	*Criteria*	*Points*
Thermoregulatory dysfunction		Gastrointestinal–hepatic dysfunction	
Temperature (°F)[b]		Manifestation	
99.0–99.9	5	Absent	0
100.0–100.9	10	Moderate (diarrhea, abdominal pain, nausea/vomiting)	10
101.0–101.9	15	Severe (jaundice)	20
102.0–102.9	20		
103.0–103.9	25		
≥104.0	30		
Cardiovascular		Central nervous system disturbance	
Tachycardia (beats per minute)		Manifestation	
100–109	5	Absent	0
110–119	10	Mild (agitation)	10
120–129	15	Moderate (delirium, psychosis, extreme lethargy)	20
130–139	20	Severe (seizure, coma)	30
≥140	25		
Atrial fibrillation			
Absent	0		
Present	10		
Congestive heart failure		Precipitant history	
Absent	0	Status	
Mild	5	Positive	0
Moderate	10	Negative	10
Severe	20		

Scores totaled	
>45	Thyroid storm
	Impending storm
<25	Storm unlikely

[a]Source: Burch and Wartofsky (26). Printed with permission.
[b]Celsius 37.2–37.7 (5), 37.8–38.3 (10), 38.3–38.8 (15), 38.9–39.4 (20), 39.4–39.9 (25), ≥40 (30 points).

diagnosis of thyroid storm, but patients with a BWPS of 25–44 represent a group in whom the decision to use aggressive therapy should be based on sound clinical judgment and not based solely on diagnostic category in order to avoid overtreatment and the resultant risk of drug toxicity. At a minimum, patients in this intermediate category should be observed closely for deterioration. Care should be taken with either system to avoid inappropriate application to patients without severe thyrotoxicosis because each of the manifestations of thyroid storm, with the possible exception of severe hyperpyrexia, may also be seen in the presence of any major illness, many of which are also known precipitants of thyroid storm (186).

Precipitants of thyroid storm in a patient with previously compensated thyrotoxicosis include abrupt cessation of ATDs, thyroidectomy, or nonthyroidal surgery in a patient with unrecognized or inadequately treated thyrotoxicosis, and a number of acute illnesses unrelated to thyroid disease (72,186,228). Thyroid storm occasionally occurs following RAI therapy.

Aggressive treatment for thyroid storm involves the early targeting of each pharmacologically accessible step in thyroid hormone production and action (Table 7). The treatment strategy for thyroid storm can be broadly divided into (i) therapy directed against thyroid hormone secretion and synthesis; (ii) measures directed against the peripheral action of thyroid hormone at the tissue level; (iii) reversal of systemic decompensation; (iv) treatment of the precipitating event or intercurrent illness; and (v) definitive therapy (26). A number of therapeutic measures are specifically intended to decrease T_4-to-T_3 conversion, such as the preferential use of PTU over MMI (229,230), glucocorticoid therapy (231), and the use of β-adrenergic blocking agents such as propranolol, with selective ability to inhibit type 1 deiodinase (232). For example, an early article comparing acute changes in thyroid hormone level after initiation of PTU or MMI found that T_3 levels dropped by approximately 45% in the first 24 hours of PTU therapy compared to an approximately 10%–15% decrease after starting MMI (229). Both plasmapheresis/plasma exchange and emergency surgery have been used to treat thyroid storm in patients who respond poorly to traditional therapeutic measures (233,234).

Prevention of thyroid storm involves recognizing and actively avoiding common precipitants, educating patients about avoiding abrupt discontinuation of ATD therapy, and ensuring that patients are euthyroid prior to elective surgery, labor and delivery, or other acute stressors.

Technical remarks: Treatment with inorganic iodine (SSKI/Lugol's solution) or oral cholecystographic agents (235) leads to rapid decreases in both T_4 and T_3 levels. Combined with ATDs in patients with severe thyrotoxicosis, these agents result in rapid clinical improvement

Table 7. Thyroid Storm: Drugs and Doses

Drug	*Dosing*	*Comment*
Propylthiouracil[a]	500–1000 mg load, then 250 mg every 4 hours	Blocks new hormone synthesis Blocks T_4-to-T_3 conversion
Methimazole	60–80 mg/d	Blocks new hormone synthesis
Propranolol	60–80 mg every 4 hours	Consider invasive monitoring in congestive heart failure patients Blocks T_4-to-T_3 conversion in high doses Alternate drug: esmolol infusion
Iodine (saturated solution of potassium iodide)	5 drops (0.25 mL or 250 mg) orally every 6 hours	Do not start until 1 hour after antithyroid drugs Blocks new hormone synthesis Blocks thyroid hormone release Alternative drug: Lugol's solution
Hydrocortisone	300 mg intravenous load, then 100 mg every 8 hours	May block T_4-to-T_3 conversion Prophylaxis against relative adrenal insufficiency Alternative drug: dexamethasone

[a]May be given intravenously.

(120). Unfortunately, the oral radiographic contrast agents ipodate and iopanoic acid are not currently available in many countries.

[I] Is there a role for iodine as primary therapy in the treatment of GD?

Prior to the introduction of ATDs, iodine was commonly reported to ameliorate the hyperthyroidism associated with GD (236,237). Iodine acutely lowers thyroid hormone concentrations by reducing hormone secretion (238,239), and inhibits its own organification (the Wolff–Chaikoff effect) (240). However, reports of escape from these beneficial effects of iodine (241) as well as reports of iodine-induced hyperthyroidism in patients with nodular goiter (242) discouraged the use of iodine in GD. Recent studies have suggested a potential role for iodine in patients who have had adverse reactions to ATD and who also have a contraindication or aversion to RAI or surgery (243,244).

■ **RECOMMENDATION 36**

Potassium iodide may be of benefit in select patients with hyperthyroidism due to GD, those who have adverse reactions to ATDs, and those who have a contraindication or aversion to RAI therapy (or aversion to repeat RAI therapy) or surgery. Treatment may be more suitable for patients with mild hyperthyroidism or a prior history of RAI therapy.

No recommendation; insufficient evidence to assess benefits or risks.

Among 44 Japanese patients who had adverse reactions to ATD and who were treated with KI alone, 66% were well controlled for an average of 18 years (range 9–28 years), and 39% achieved a remission after 7 years (range 2–23 years) (243). Among the responders, the doses used were between 13 and 100 mg and were adjusted depending upon biochemical response. Among 15 nonresponders, 11 (25% of all patients) escaped the inhibitory effects of iodine and four patients did not respond at all to KI. None of the patients had side effects. Initial free T_4 concentration and goiter size did not predict a response to therapy. Among 20 Japanese patients with mild hyperthyroidism initially treated with KI alone and matched using propensity score analysis with patients treated with MMI alone, 85% of the patients treated with KI alone had normal thyroid function at 6 months and 1 year, comparable to that of the matched controls treated with MMI (244). Most patients were treated with 50 mg KI daily.

The inhibitory effects of iodine are greater in patients with a prior history of RAI exposure (245) suggesting a role for KI in patients who remain hyperthyroid after one dose of RAI and prefer to avoid a second dose. The use of KI prior to thyroidectomy for GD is discussed in Section [F1], the use of KI as adjunctive therapy following RAI is discussed in Section [D1], the use of KI in combination with MMI for treating GD is discussed in Section [E1], and the use of KI in hyperthyroidism complicating pregnancy is discussed in Section [T].

[J] How should overt hyperthyroidism due to TMNG or TA be managed?

■ **RECOMMENDATION 37**

We suggest that patients with overtly TMNG or TA be treated with RAI therapy or thyroidectomy. On occasion, long-term, low-dose treatment with MMI may be appropriate.

Weak recommendation, moderate-quality evidence.

Two effective and relatively safe definitive treatment options exist for TMNG and TA: RAI therapy and thyroid surgery. The decision regarding treatment should take into consideration several clinical and demographic factors as well as patient preference. The goal of therapy is the rapid and durable elimination of the hyperthyroid state.

For patients with TMNG, the risk of treatment failure or need for repeat treatment is <1% following near-total and/total thyroidectomy (246,247), compared with a 20% risk of the need for retreatment following RAI therapy (246,248). Euthyroidism is achieved within days after surgery (246,247). However, the risk of hypothyroidism and the requirement for exogenous thyroid hormone therapy is 100% after near-total/total thyroidectomy. For patients with TMNG who receive RAI therapy, the response is 50%–60% by 3 months and 80% by 6 months (246,248,249). In a large study of patients with TMNG treated with RAI, the prevalence of hypothyroidism was 3% at 1 year and 64% at 24 years (250). Hypothyroidism was more common among patients under 50 years of age, compared with those over 70 years (61% vs. 36% after 16 years). In a more recent study, the prevalence of hypothyroidism was 4% at 1 year and 16% at 5 years (251).

In a large retrospective series of patients with TMNG presenting with compressive symptoms, all patients undergoing total thyroidectomy had resolution of these symptoms after treatment, whereas only 46% of patients undergoing RAI had improvement in such symptoms (252). This outcome may be due in part to the fact that very large goiters treated with high-activity RAI only decrease in size by 30%–50% (253).

For patients with TA, the risk of treatment failure is <1% after surgical resection (ipsilateral thyroid lobectomy or isthmusectomy) (254). Typically, euthyroidism is achieved within days after surgery. The prevalence of hypothyroidism varies from 2% to 3% following lobectomy for TA, although rates of hypothyroidism after lobectomy for nontoxic nodules have been reported to be as high as 20% (254–256), and lower after isthmusectomy in the unique circumstance in which the TA is confined to the thyroid isthmus. For patients with TA who receive RAI therapy there is a 6%–18% risk of persistent hyperthyroidism and a 3%– 5.5% risk of recurrent hyperthyroidism (254,257). There is a 75% response rate by 3 months and 89% rate by 1 year following RAI therapy for TA (225,257,258). The prevalence of hypothyroidism after RAI is progressive and hastened by the presence of antithyroid antibodies or a nonsuppressed TSH at the time of treatment (257,259,260). A study following 684 patients with TA treated with RAI reported a progressive increase in overt and subclinical hypothyroidism (259). At 1 year, the investigators noted a 7.6% prevalence, with 28% at 5 years, 46% at 10 years, and 60% at 20 years. They observed a faster progression to hypothyroidism among patients who were older and who had incomplete TSH suppression (correlating with only partial extranodular parenchymal suppression) due to prior therapy with ATDs. The nodule is rarely eradicated in patients with TA undergoing RAI therapy, which can lead to the need for continued surveillance (225,257,260).

Potential complications following near-total/total thyroidectomy include the risk of permanent hypoparathyroidism (<2.0%) or RLN injury (<2.0%) (261,262). A small risk of permanent RLN injury exists with surgery for TA (254). Following RAI therapy, there have been reports of new-onset GD (up to 4% prevalence) (263) as well as concern for thyroid malignancy (254,264,265) and a very minimal increase in late nonthyroid malignancy (265). Overall, the success rate of RAI (definitive hypothyroidism or euthyroidism) is high: 93.7% in TA and 81.1% in TMNG patients (266).

Technical remarks: Once the diagnosis has been made, the treating physician and patient should discuss each of the treatment options, including the logistics, benefits, expected speed of recovery, drawbacks, side effects, and costs. This discussion sets the stage for the physician to make a recommendation based upon best clinical judgment and for the final decision to incorporate the personal values and preferences of the patient. TMNG and TA are an uncommon cause of hyperthyroidism in pregnancy and there is a lack of studies in this setting. However, considering the theoretical risks associated with surgery or ATD therapy (has to be used throughout pregnancy and there is a tendency to overtreat the fetus), the optimal therapy might be definitive therapy with RAI or surgery in advance of a planned pregnancy. Most experts prefer to avoid the use of RAI within 6 months of a pregnancy; it should be used with caution if at all.

The panel agreed that TMNG and TA with high nodular RAIU and widely suppressed RAIU in the perinodular thyroid tissue are especially suitable for RAI therapy. However, there are insufficient data to make a recommendation based on these findings.

Factors that favor a particular modality as treatment for TMNG or TA (Table 8):

a. RAI therapy: Advanced patient age, significant comorbidity, prior surgery or scarring in the anterior neck,

Table 8. Clinical Situations That Favor a Particular Modality as Treatment for Toxic Multinodular Goiter or Toxic Adenoma

Clinical situations	*RAI*	*ATD*	*Surgery*
TMNG			
Pregnancy[a]	x	√√ / !	√ / !
Advanced age, comorbidities with increased surgical risk and/or limited life expectancy	√√	√	x
Patients with previously operated or externally irradiated necks	√√	√	!
Lack of access to a high-volume thyroid surgeon	√√	√	!
Symptoms or signs of compression within the neck	√	-	√√
Thyroid malignancy confirmed or suspected	x	-	√√
Large goiter/nodule	√	-	√√
Goiter/nodule with substernal or retrosternal extension	√	-	√√
Coexisting hyperparathyroidism requiring surgery	-	-	√√

√√ = preferred therapy; √ = acceptable therapy; ! = cautious use; - = not usually first line therapy but may be acceptable depending on the clinical circumstances; X = contraindication.

[a]For women considering a pregnancy within 6 months, see discussion in Section [T2].

small goiter size, RAIU sufficient to allow therapy, and lack of access to a high-volume thyroid surgeon (the latter factor is more important for TMNG than for TA).
b. Surgery: Presence of symptoms or signs of compression within the neck, concern for coexisting thyroid cancer, coexisting hyperparathyroidism requiring surgery, large goiter size (>80 g), substernal or retrosternal extension, RAIU insufficient for therapy, or need for rapid correction of the thyrotoxic state (252).
c. ATDs: Advanced age, comorbidities with increased surgical risk or associated with decreased life-expectancy, and poor candidates for ablative therapy.

Contraindications to a particular modality as treatment for TMNG or TA:

a. RAI therapy: Definite contraindications to the use of RAI include pregnancy, lactation, coexisting thyroid cancer, individuals unable to comply with radiation safety guidelines and used with caution in women planning a pregnancy within 4–6 months.
b. Surgery: Factors weighing against the choice of surgery include significant comorbidity, such as cardiopulmonary disease, end-stage cancer, or other debilitating disorders, or lack of access to a high-volume thyroid surgeon. Pregnancy is a relative contraindication, and surgery should only be used in this circumstance when rapid control of hyperthyroidism is required and ATDs cannot be used. Thyroidectomy is best avoided in the first and third trimesters of pregnancy because of teratogenic effects associated with anesthetic agents and increased risk of fetal loss in the first trimester and preterm labor in the third. Optimally, thyroidectomy should be performed in the latter portion of the second trimester. Although it is the safest time, it is not without risk (4.5%–5.5% risk of preterm labor) (67,68).
c. ATDs: Definite contraindications to ATD therapy include previous known major adverse reactions to ATDs.

Factors that may impact patient preference:

a. RAI therapy: Patients with either TMNG or TA choosing RAI therapy would likely place relatively higher value on the avoidance of surgery and attendant hospitalization or complications arising from either surgery or anesthesia; also, patients with TMNG would place greater value on the possibility of remaining euthyroid after RAI treatment.
b. Surgery: Patients choosing surgery would likely place a relatively higher value on definitive control of hyperthyroid symptoms, avoidance of exposure to radioactivity and a lower value on potential surgical and anesthetic risks; patients with TMNG choosing surgery would place a lower value on the certain need for lifelong thyroid hormone replacement, whereas patients with TA who choose surgery would place greater value on the possibility of achieving euthyroidism without hormone replacement.
c. ATDs: Patients choosing ATDs would likely place a relatively higher value on avoidance of exposure to radioactivity and on potential surgical and anesthetic risks and a lower value on the certain need for lifelong thyroid ATD therapy.

[K] If RAI therapy is chosen as treatment for TMNG or TA, how should it be accomplished?

[K1] Preparation of patients with TMNG or TA for RAI therapy

■ **RECOMMENDATION 38**

Because RAI treatment of TMNG or TA can cause a transient exacerbation of hyperthyroidism, β-adrenergic blockade should be considered even in asymptomatic patients who are at increased risk for complications due to worsening of hyperthyroidism (i.e., elderly patients and patients with comorbidities).

Weak recommendation, low-quality evidence.

Medical management before RAI therapy should be tailored to the patient's risk for complications if hyperthyroidism worsens, based on the severity of the hyperthyroidism, patient age, and comorbid conditions. Worsened chemical hyperthyroidism with increased heart rate and rare cases of supraventricular tachycardia, including atrial fibrillation and atrial flutter, have been observed in patients treated with RAI for either TMNG or nontoxic multinodular goiter (MNG) (267–269). In susceptible patients with pre-existing cardiac disease or in the elderly, RAI treatment may produce significant clinical worsening (268). Therefore, the use of β-blockers to prevent posttreatment tachyarrhythmias should be considered in all patients with TMNG or TA who are older than 60 years of age and those with cardiovascular disease or severe hyperthyroidism (31). The decision regarding the use of MMI pretreatment is more complex and is discussed below.

■ **RECOMMENDATION 39**

In addition to β-adrenergic blockade (see Recommendations 2 and 38) pretreatment with MMI prior to RAI therapy for TMNG or TA should be considered in patients who are at increased risk for complications due to worsening of hyperthyroidism, including the elderly and those with cardiovascular disease or severe hyperthyroidism.

Weak recommendation, low-quality evidence.

■ **RECOMMENDATION 40**

In patients who are at increased risk for complications due to worsening of hyperthyroidism, resuming ATDs 3–7 days after RAI administration should be considered.

Weak recommendation, low-quality evidence.

Young and middle-aged patients with TMNG or TA generally do not require pretreatment with ATDs (MMI) before receiving RAI, but may benefit from β-blockade if symptoms warrant and contraindications do not exist.

Technical remarks: If an ATD is used in preparation for RAI therapy in patients with TMNG or TA, caution should be taken to avoid RAI therapy when the TSH is normal or elevated to prevent direct RAI treatment of perinodular and contralateral normal thyroid tissue, which increases the risk of developing hypothyroidism. However, if volume reduction is a goal, at the expense of an increased risk of hypothyroidism, pretreatment with MMI, allowing the TSH to rise slightly prior to RAI administration, results in greater volume

reduction after fixed doses of RAI (270). Similarly, a recent meta-analysis indicated that the application of recombinant human TSH (rhTSH) before RAI therapy in nontoxic MNG or TMNG results in greater thyroid volume reduction but higher hypothyroidism rates than RAI therapy alone (271). Unless volume reduction is an important goal, rhTSH administration before RAI therapy of TMNG is not generally recommended as it could possibly exacerbate hyperthyroidism (272), it represents an off-label use, and mainly stimulates RAIU in TSH-sensitive perinodular tissues (273).

[K2] Evaluation of thyroid nodules before RAI therapy

■ **RECOMMENDATION 41**

Nonfunctioning nodules on radionuclide scintigraphy or nodules with suspicious ultrasound characteristics should be managed according to published guidelines regarding thyroid nodules in euthyroid individuals.

Strong recommendation, moderate-quality evidence.

Thorough assessment of suspicious nodules within a TMNG, according to the published guidelines (225,274), should be completed before selection of RAI as the treatment of choice. The prevalence of thyroid cancer in TMNG historically has been estimated to be about 3% (247). More recently, it has been estimated to be as high as 9%, which is similar to the 10.6% prevalence noted in nontoxic MNG (275).

Technical remarks: Both the ATA and AACE, the latter in conjunction with the European Thyroid Association and Associazione Medici Endocrinologi, and the Latin American Thyroid Society have published management guidelines for patients with thyroid nodules (225,274,276,277).

[K3] Administration of RAI in the treatment of TMNG or TA

■ **RECOMMENDATION 42**

Sufficient activity of RAI should be administered in a single application to alleviate hyperthyroidism in patients with TMNG.

Strong recommendation, moderate-quality evidence.

The goal of RAI therapy, especially in older patients, is the elimination of the hyperthyroid state. Higher activities of RAI, even when appropriately calculated for the specific volume or mass of hyperthyroid tissue, result in more rapid resolution of hyperthyroidism and less need for retreatment, but a higher risk for early hypothyroidism. One study showed a 64% prevalence of hypothyroidism 24 years after RAI therapy for TMNG, with a higher prevalence among patients who required more than one treatment (250). The prevalence of hypothyroidism following RAI therapy is increased by normalization or elevation of TSH at the time of treatment resulting from ATD pretreatment or use of rhTSH and by the presence of antithyroid antibodies (278).

The activity of RAI used to treat TMNG, calculated on the basis of goiter size to deliver 150–200 μCi (5.55–7.4 MBq) per gram of tissue corrected for 24-hour RAIU, is usually higher than that needed to treat GD. In addition, the RAIU values for TMNG may be lower, necessitating an increase in the applied activity of RAI. Radiation safety precautions may be onerous if high activities of RAI are needed for large goiters. Both pretreatment with MMI allowing the TSH to rise slightly (270) and the off-label use of rhTSH (271) may reduce the total activity of RAI needed, but they increase the risk of hypothyroidism (see prior discussion Section [K1]).

Technical remarks: Enlargement of the thyroid is very rare after RAI treatment. However, patients should be advised to immediately report any tightening of the neck, difficulty breathing, or stridor following the administration of RAI. Any compressive symptoms, such as discomfort, swelling, dysphagia, or hoarseness, which develop following RAI therapy, should be carefully assessed and monitored, and if clinically necessary, corticosteroids can be administered. Respiratory compromise in this setting is extremely rare and requires management as any other cause of acute tracheal compression.

■ **RECOMMENDATION 43**

Sufficient activity of RAI should be administered in a single application to alleviate hyperthyroidism in patients with TA.

Strong recommendation, moderate-quality evidence.

RAI administered to treat TA can be given either as a fixed activity of approximately 10–20 mCi (370–740 MBq) or an activity calculated on the basis of nodule size using 150–200 μCi (5.5–7.4 MBq) RAI per gram corrected for 24-hour RAIU (278). A long-term follow-up study of patients with TA, in which patients with nodules <4 cm were administered an average of 13 mCi (481 MBq) and those with larger nodules an average of 17 mCi (629 MBq), showed a progressive increase in hypothyroidism over time in both groups, suggesting that hypothyroidism develops over time regardless of activity adjustment for nodule size (259). A randomized trial of 97 patients with TA compared the effects of high (22.5 mCi or 833 MBq) or low (13 mCi or 481 MBq) fixed activity RAI, with a calculated activity that was either high (180–200 μCi/g or 6.7–7.4 Bq) or low (90–100 μCi/g or 3.3–3.7 Bq) and corrected for 24-hour RAIU (279). This study confirmed previous reports showing an earlier disappearance of hyperthyroidism and earlier appearance of hypothyroidism with higher RAI activity. Use of a calculated activity allowed for a lower RAI activity to be administered for a similar efficacy in the cure of hyperthyroidism.

[K4] Patient follow-up after RAI therapy for TMNG or TA

■ **RECOMMENDATION 44**

Follow-up within the first 1–2 months after RAI therapy for TMNG or TA should include an assessment of free T_4, total T_3, and TSH. Biochemical monitoring should be continued at 4- to 6-week intervals for 6 months, or until the patient becomes hypothyroid and is stable on thyroid hormone replacement.

Strong recommendation, low-quality evidence.

RAI therapy for TMNG results in resolution of hyperthyroidism in approximately 55% of patients at 3 months and 80% of patients at 6 months, with an average failure rate of 15% (246–248). Goiter volume is decreased by 3 months, with further reduction observed over 24 months, for a total

size reduction of 40% (248). For TA, 75% of patients were no longer hyperthyroid at 3 months, with nodule volume decreased by 35% at 3 months and by 45% at 2 years (257). Risk of persistent or recurrent hyperthyroidism ranged from 0% to 30%, depending on the series (246–248,257). Long-term follow-up studies show a progressive risk of clinical or subclinical hypothyroidism of about 8% by 1 year and 60% by 20 years for TA (259), and an average of 3% by 1 year and 64% by 24 years for TMNG (250).

GD might develop after RAI for TMNG in up to 4% of patients (280). Such patients develop worsening hyperthyroidism within a few months of RAI therapy. Treatment with additional RAI is effective.

Technical remarks: If thyroid hormone therapy is necessary, the dose required may be less than full replacement because of underlying persistent autonomous thyroid function.

[K5] Treatment of persistent or recurrent hyperthyroidism following RAI therapy for TMNG or TA

■ **RECOMMENDATION 45**

If hyperthyroidism persists beyond 6 months following RAI therapy for TMNG or TA, retreatment with RAI is suggested. In selected patients with minimal response 3 months after therapy additional RAI may be considered.

Weak recommendation, low-quality evidence.

Technical remarks: In severe or refractory cases of persistent hyperthyroidism due to TMNG or TA, following treatment with RAI, surgery may be considered. Because some patients with mild hyperthyroidism following RAI administration will continue to improve over time, use of MMI with close monitoring may be considered to allow control of the hyperthyroidism until the RAI is effective.

[L] If surgery is chosen, how should it be accomplished?

[L1] Preparation of patients with TMNG or TA for surgery

■ **RECOMMENDATION 46**

If surgery is chosen as treatment for TMNG or TA, patients with overt hyperthyroidism should be rendered euthyroid prior to the procedure with MMI pretreatment, with or without β-adrenergic blockade. Preoperative iodine should not be used in this setting.

Strong recommendation, low-quality evidence.

Risks of surgery are increased in the presence of thyrotoxicosis. Thyrotoxic crisis during or after the operation, can result in extreme hypermetabolism, hyperthermia, tachycardia, hypertension, coma, or death. Therefore, prevention with careful preparation of the patient is of paramount importance (281,282). The literature reports a very low risk of anesthesia-related mortality associated with thyroidectomy (254,283). Preoperative iodine therapy is not indicated because of the risk of exacerbating the hyperthyroidism (284). Usually hyperthyroidism is less severe in patients with TMNG, so that in most cases, patients with allergy to ATDs can be prepared for surgery, when necessary, with β-blockers alone.

[L2] The surgical procedure and choice of surgeon

■ **RECOMMENDATION 47**

If surgery is chosen as treatment for TMNG, near-total or total thyroidectomy should be performed.

Strong recommendation, moderate-quality evidence.

Recurrence can be avoided in TMNG if a near-total or total thyroidectomy is performed initially (285). This procedure can be performed with the same low rate of complications as a subtotal thyroidectomy (286–289). Reoperation for recurrent or persistent goiter results in a 3- to 10-fold increase in the risk of permanent vocal cord paralysis or hypoparathyroidism (290,291).

■ **RECOMMENDATION 48**

Surgery for TMNG should be performed by a high-volume thyroid surgeon.

Strong recommendation, moderate-quality evidence.

TMNG is more common in older patients. Data regarding outcomes following thyroidectomy in elderly patients have shown conflicting results. Overall, however, studies conducted at the population level have demonstrated significantly higher rates of postoperative complications, longer length of hospital stay, and higher costs among elderly patients (198). Data showing equivalent outcomes among the elderly usually have come from high-volume centers (292). Robust data demonstrate that surgeon volume of thyroidectomies is an independent predictor of patient clinical and economic outcomes (i.e., in-hospital complications, length of stay, and total hospital charges) following thyroid surgery (198,199,293). The recommendation for referral to a high-volume surgeon is essentially the same as that described in Section [F2] for the choice of surgeon in GD.

■ **RECOMMENDATION 49**

If surgery is chosen as the treatment for TA, a thyroid ultrasound should be done to evaluate the entire thyroid gland. An ipsilateral thyroid lobectomy, or isthmusectomy if the adenoma is in the thyroid isthmus, should be performed for isolated TAs.

Strong recommendation, moderate-quality evidence.

A preoperative thyroid ultrasound is useful because it will detect the presence of contralateral nodularity that is suspicious in appearance or that will necessitate future surveillance, both circumstances in which a total thyroidectomy may be more appropriate. Lobectomy removes the TA while leaving normal thyroid tissue, allowing residual normal thyroid function in the majority of patients. One large clinical series for TA demonstrated no surgical deaths and low complication rates (254). In patients who wish to avoid general anesthesia or who have significant comorbidities, the risk of anesthesia can be lowered further when cervical block analgesia with sedation is employed by thyroid surgeons and anesthesiologists experienced in this approach (294). Patients with positive antithyroid antibodies preoperatively have a higher risk of postoperative hypothyroidism (256,278).

■ **RECOMMENDATION 50**
We suggest that surgery for TA be performed by a high-volume surgeon.

Weak recommendation, moderate-quality evidence.

While surgeon experience in the setting of TA is of somewhat less importance than in TMNG, it remains a factor to consider in deciding between surgery and RAI therapy. High-volume thyroid surgeons tend to have better outcomes following lobectomy than low-volume surgeons, but the differences are not statistically significant (198). High-volume surgeons may be more comfortable with performing the thyroid lobectomy under cervical block analgesia with sedation.

[L3] Postoperative care

■ **RECOMMENDATION 51**
Following thyroidectomy for TMNG, serum calcium with or without iPTH levels should be measured, and oral calcium and calcitriol supplementation administered based on the results.

Weak recommendation, low-quality evidence.

Technical remarks: The management of hypocalcemia following thyroidectomy for TMNG is essentially the same as that described in Section [F3] for postoperative management in GD. Severe or prolonged preoperative hyperthyroidism and larger size and greater vascularity of the goiter (more typically seen in GD) increase the risk of postoperative hypocalcemia.

■ **RECOMMENDATION 52**
MMI should be stopped at the time of surgery for TMNG or TA. Beta-adrenergic blockade should be slowly discontinued following surgery.

Strong recommendation, low-quality evidence.

Technical remarks: The duration over which β-adrenergic blockade should be tapered should take into account the preoperative free T_4 concentration, the heart rate, and the week-long half-life of T_4. Additionally, patients taking higher doses of β-blockers will require a longer taper.

■ **RECOMMENDATION 53**
Following thyroidectomy for TMNG, thyroid hormone replacement should be started at a dose appropriate for the patient's weight (0.8 μg/lb or 1.6 μg/kg) and age, with elderly patients needing somewhat less. TSH should be measured every 1–2 months until stable, and then annually.

Strong recommendation, low-quality evidence.

Technical remarks: The appropriate dosing of L-thyroxine will vary with patient body mass index (219). If a significant thyroid remnant, which may demonstrate autonomous production of thyroid hormone, remains following thyroidectomy, immediate postoperative doses of thyroid hormone should be initiated at somewhat less than full replacement doses and subsequently adjusted based on thyroid function testing.

■ **RECOMMENDATION 54**
Following lobectomy for TA, TSH and estimated free T_4 levels should be obtained 4–6 weeks after surgery and thyroid hormone supplementation started if there is a persistent rise in TSH above the reference range.

Strong recommendation, low-quality evidence.

Technical remarks: After lobectomy for TA, serum calcium levels do not need to be obtained, and calcium and calcitriol supplements do not need to be administered. Thyroid hormone replacement is required in about 15%–20% of patients following thyroid lobectomy (295). Serum TSH levels may have been suppressed or normal prior to lobectomy, depending on the degree of preoperative preparation with ATDs. TSH levels may remain in the high normal range for 3–6 months following lobectomy; therefore, continued monitoring in an asymptomatic patient for 4–6 months postoperatively is reasonable, since there may be eventual recovery of normal thyroid function (296).

[L4] Treatment of persistent or recurrent disease following surgery for TMNG or TA

■ **RECOMMENDATION 55**
RAI therapy should be used for retreatment of persistent or recurrent hyperthyroidism following inadequate surgery for TMNG or TA.

Strong recommendation, low-quality evidence.

Persistent or recurrent hyperthyroidism following surgery is indicative of inadequate surgery. As remedial thyroid surgery comes at significantly increased risk of hypoparathyroidism and RLN injury, it should be avoided, if possible, in favor of RAI therapy (290,291). If this is not an option, it is essential that the surgery be performed by a high-volume thyroid surgeon.

[M] If ATDs are chosen as treatment of TMNG or TA, how should the therapy be managed?

ATDs do not induce remission in patients with nodular thyroid disease. Therefore, discontinuation of treatment results in relapse (262,297). However, prolonged (lifelong) ATD therapy may be the best choice for some individuals with limited life expectancy and increased surgical risk, including residents of nursing homes or other care facilities where compliance with radiation safety regulations may be difficult.

■ **RECOMMENDATION 56**
Long-term MMI treatment of TMNG or TA might be indicated in some elderly or otherwise ill patients with limited life expectancy, in patients who are not good candidates for surgery or ablative therapy, and in patients who prefer this option.

Weak recommendation, low-quality evidence.

Technical remarks: The required dose of MMI to restore the euthyroid state in TMNG or TA patients is usually low (5–10 mg/d). Because long-term, low-dose ATD treatment in nodular hyperthyroidism can be difficult to regulate, frequent (every 3 months) monitoring is recommended initially,

especially in the elderly (298), until stability has been documented, after which testing frequency can be decreased.

[N] Is there a role for ethanol or radiofrequency ablation in the management of TA or TMNG?

■ **RECOMMENDATION 57**

Alternative therapies such as ethanol or radiofrequency ablation of TA and TMNG can be considered in select patients in whom RAI, surgery, and long-term ATD are inappropriate, contraindicated, or refused, and expertise in these procedures is available.

No recommendation; insufficient evidence to assess benefits and risks.

[N1] Ethanol ablation

Reports that support the efficacy of percutaneous ethanol injection under sonographic guidance to treat TA and TMNG come largely from Europe (299–301). Experience in the United States is limited. A typical protocol involves the injection of ethanol (average dose 10 mL, depending on size of the area to be ablated) into the TA or autonomous area of a TMNG. In one study, the average patient required four sessions at 2-week intervals (299). One hundred twenty-five patients with TA were followed for an average of 5 years; 2.4% refused further treatment because of pain, and 3.2% had complications including transient RLN palsy, abscess, or hematoma (299). Ninety-three percent of patients achieved a functional cure (no uptake on RAI scintigraphy), and 92% had a >50% reduction in nodule size (299). In another study of both TA and TMNG, 78% of cases achieved a functional cure, all nodules regressed, and there was no recurrent hyperthyroidism during 5 years of follow-up (300). Ethanol ablation also has been used following RAI to reduce nodule size (301). However, its use has been limited due to pain associated with extravasation of the ethanol to extranodular locations, and other adverse effects, which have included transient thyrotoxicosis, permanent ipsilateral facial dysesthesia, paranodular fibrosis interfering with subsequent surgery (302), and toxic necrosis of the larynx and adjacent skin (303).

[N2] Radiofrequency ablation

Both radiofrequency ablation (RFA) and laser therapy have been used to treat thyroid nodules. A meta-analysis demonstrated that RFA resulted in larger reductions in nodule size with fewer sessions than laser therapy (304). A retrospective multicenter report of RFA for TA in 44 patients utilized an 18-gauge electrode under ultrasound guidance with a mean follow-up of 20 months (305). An 82% reduction in nodule volume was achieved, but 20% of nodules remained autonomous on scintigraphy, and 18% of patients remained hyperthyroid. All patients complained of pain during the procedure, but there were no complications (305). A Korean study compared the use of RFA to surgery for nontoxic nodules (306). RFA was associated with an 85% reduction in nodule size, the cost was similar to surgery, there were fewer complications (RLN injury or hypoparathyroidism: 6% for surgery and 1% for RFA), and no patient who received RFA became hypothyroid (306). Advocates of RFA argue that it preserves normal thyroid function compared to surgery or RAI (307). However, additional data are needed to determine the success at correcting hyperthyroidism in patients with TA and TMNG. The use of RFA should be limited to centers where clinicians have received adequate training in the technique.

[O] How should GD be managed in children and adolescents?

[O1] General approach

■ **RECOMMENDATION 58**

Children with GD should be treated with MMI, RAI therapy, or thyroidectomy. RAI therapy should be avoided in very young children (<5 years). RAI therapy in children is acceptable if the activity is >150 μCi/g (5.55 MBq/g) of thyroid tissue, and for children between 5 and 10 years of age if the calculated RAI administered activity is <10 mCi (<370 MBq). Thyroidectomy should be chosen when definitive therapy is required, the child is too young for RAI, and surgery can be performed by a high-volume thyroid surgeon.

Strong recommendation, moderate-quality evidence.

The treatment of pediatric patients with GD varies considerably among institutions and practitioners. It is important to recognize that lasting remission after ATD therapy occurs in only a minority of pediatric patients with GD, including children treated with ATDs for many years. In determining the initial treatment approach, the patient's age, clinical status, and likelihood of remission should be considered. Patient and parent values and preferences should also be strongly considered when choosing one of the three treatment modalities.

Because some children will go into remission, MMI therapy for 1 year is still considered first-line treatment for most children. However, the majority of pediatric patients with GD will eventually require either RAI or surgery. When ATDs are used in children, only MMI should be used, except in exceptional circumstances. If clinical characteristics suggest a low chance of remission at initial presentation (see Section [P6] below), MMI, RAI, or surgery may be considered initially. If remission is not achieved after a course of therapy with ATDs, RAI or surgery should be considered. Alternatively, MMI therapy may be continued long term or until the child is considered old enough for surgery or RAI.

Properly administered, RAI is an effective treatment for GD in the pediatric population (308–310). RAI is widely used in children but still viewed as controversial by some practitioners owing primarily to concern over cancer risks (311,312). Although there are sparse clinical data relating to RAI use in children with GD and subsequent thyroid cancer (313), it is known that risks of thyroid cancer after external irradiation are highest in children <5 years of age, and they decline with advancing age (314,315); see discussion of RAI therapy and cancer risk in Section [P3] below. In comparison, activities of RAI used with contemporary therapy are not known to be associated with an increased risk of thyroid neoplasm in children.

Thyroidectomy is an effective treatment for GD, but it is associated with a higher complication rate in children than in adults (316–318). Thyroidectomy should be performed in those children who are too young for RAI, provided that surgery can be performed by a high-volume thyroid surgeon, preferably with experience in conducting thyroidectomies in children.

Technical remarks: There may be circumstances in which RAI therapy is indicated in young children, such as when a child has developed a reaction to ATDs, proper surgical expertise is not available, or the patient is not a suitable surgical candidate.

[P] If ATDs are chosen as initial management of GD in children, how should the therapy be managed?

[P1] Initiation of ATD therapy for the treatment of GD in children

■ **RECOMMENDATION 59**

MMI should be used in children who are treated with ATD therapy.

Strong recommendation, moderate-quality evidence.

Technical remarks: MMI comes in 5- or 10-mg tablets and can be given once daily, even in patients with severe hyperthyroidism. Although many practitioners give MMI in divided doses, data in adults do not support a need for such and show that compliance with once-daily MMI therapy is superior to multiple daily doses of PTU (83% vs. 53%) (319). The MMI dose typically used is 0.2–0.5 mg/kg daily, with a range from 0.1–1.0 mg/kg daily (320–322). One approach is to prescribe the following whole tablet or quarter to half-tablet doses: infants, 1.25 mg/d; 1–5 years, 2.5–5.0 mg/d; 5–10 years, 5–10 mg/d; and 10–18 years, 10–20 mg/d. With severe clinical or biochemical hyperthyroidism, doses that are 50%–100% higher than the above can be used.

Although there may be a tendency to use higher rather than lower doses of MMI at treatment onset, data in adults show only modest benefit of higher doses and only in severe thyrotoxicosis (free T_4 > 7 ng/dL [0.554 pmol/L]) (115). Because most side effects of MMI are dose-related and occur within the first 3 months of treatment (128), high doses of MMI (e.g., >30 mg for an adolescent or adult) should rarely be used initially.

When thyroid hormone levels normalize, MMI doses can be reduced by 50% or more to maintain a euthyroid state (112). Alternatively, some physicians elect not to reduce the MMI dose and add levothyroxine to make the patient euthyroid, a practice referred to as ''block and replace.'' However, because meta-analyses suggest a higher prevalence of adverse events using block-and-replace regimens than dose titration (119,323), likely due to higher doses of MMI and the dose-related complications associated with MMI (324), we suggest that this practice be avoided. However, it may have utility in rare patients, after addressing compliance, who are inadequately controlled on one dose of MMI, then become hypothyroid after a minimal dose increase.

Practitioners should also monitor the weight of children treated with ATDs. Excessive weight gain within 6 months of treatment is seen in children treated for GD, and the gain in weight can persist (325). Parents and patients should be counseled about this possibility and nutrition consultation considered if excessive weight gain occurs.

■ **RECOMMENDATION 60**

Pediatric patients and their caretakers should be informed of side effects of ATD preferably in writing, and the necessity of stopping the medication immediately and informing their physician if they develop pruritic rash, jaundice, acolic stools or dark urine, arthralgias, abdominal pain, nausea, fatigue, fever, or pharyngitis.

Strong recommendation, low-quality evidence.

■ **RECOMMENDATION 61**

Prior to initiating ATD therapy, we suggest that pediatric patients have, as a baseline, complete blood cell count, including WBC count with differential, and a liver profile including bilirubin, transaminases, and alkaline phosphatase.

Weak recommendation, low-quality evidence.

PTU is associated with an unacceptable risk of hepatotoxicity in children, with a risk of liver failure of 1 in 2000–4000 children taking the medication (326,327). PTU can cause fulminant hepatic necrosis that may be fatal; liver transplantation has been necessary in some patients taking PTU (326). For this reason, the FDA issued a black box warning regarding the use of PTU (328), noting that 32 (22 adult and 10 pediatric) cases of serious liver injury have been associated with PTU use (326,328). Furthermore, since the recommendation to avoid PTU use in children was issued, we are unaware of any published cases of PTU-related liver failure (327).

Because PTU-induced liver injury is of rapid onset and can be rapidly progressive, biochemical monitoring of liver function tests and transaminase levels has not been shown to be useful in surveillance for PTU-related liver injury. When neither prompt surgery nor RAI therapy are options, and ATD therapy is necessary in a patient who has developed a minor toxic reaction to MMI, a short course of PTU use can be considered. When surgery is the planned therapy and MMI cannot be administered, if the patient is not too thyrotoxic (and the hyperthyroidism is due to GD), the hyperthyroid state can be controlled before surgery with β-blockade and SSKI (50 mg iodide/drop) 3–7 drops (0.15–0.35 mL) by mouth, given three times a day for 10 days before surgery. Prior to surgery it is desirable to have the free T_4 level or total T_4 and total T_3 levels in the normal or subnormal range. Alternatively, if the surgery cannot be performed within a few weeks, a short course of PTU may be administered with the child closely monitored clinically for signs of hepatic dysfunction including nausea, anorexia, malaise, and abdominal pain.

MMI may also be associated with hepatotoxicity in children, but this tends to be milder and is typically cholestatic rather than hepatocellular (326). At least one case of cholestatic jaundice has been reported in a child (326). However, there have been reports of hepatocellular toxicity with MMI in adults (134).

MMI may also be associated with ANCA-positive vasculitis (329), although this occurs far less frequently than with PTU. Patients of Asian origin seem to be more susceptible to

this adverse reaction, and it can develop after months to years of therapy. Many PTU-treated patients also develop ANCA positivity on treatment but remain asymptomatic (330). Typical manifestations of ANCA-positive vasculitis are polyarthritis, purpuric skin lesions, and occasionally pulmonary and/or renal involvement. Discontinuation of the drug generally results in resolution of the symptoms, but in more severe cases, glucocorticoids or other immunosuppressive therapy may be needed.

Technical remarks: It is advisable to provide information concerning side effects of ATDs to the patient or caretaker in writing. See Recommendation 14 *Technical remarks* for a discussion regarding the utility of obtaining complete blood count and liver profile before initiating MMI therapy.

[P2] Symptomatic management of Graves' hyperthyroidism in children

■ **RECOMMENDATION 62**

Beta-adrenergic blockade is recommended for children experiencing symptoms of hyperthyroidism, especially those with heart rates in excess of 100 beats per minute.

Strong recommendation, low-quality evidence.

In children in whom the diagnosis of Graves' hyperthyroidism is strongly suspected or confirmed, and who are showing significant symptoms, including, but not limited to, tachycardia, muscle weakness, tremor, or neuropsychological changes, treatment with atenolol, propranolol, metoprolol, or other β-blockers leads to a decrease in heart rate and symptoms of GD. In those with reactive airway disease, cardio-selective β-blockers such as atenolol or metoprolol can be used cautiously (331), with the patient monitored for exacerbation of asthma.

[P3] Monitoring of children taking MMI

After initiation of MMI therapy, thyroid function tests (free T_4, total T_3, TSH) are obtained at 2–6 weeks, the dose is adjusted if indicated, and thyroid function tests are measured again at 4–6 weeks, and then every 2–3 months once the dose is stabilized. Depending on the severity of hyperthyroidism and the MMI dose, it can take several months for elevated thyroid hormone levels to fall into the normal range. Serum TSH may remain suppressed for several months after starting therapy and is therefore not a good parameter for monitoring therapy early in the course.

■ **RECOMMENDATION 63**

ATDs should be stopped immediately and WBC counts measured in children who develop fever, arthralgias, mouth sores, pharyngitis, or malaise.

Strong recommendation, low-quality evidence.

Although MMI has a better overall safety profile than PTU, MMI is associated with minor adverse events that may affect up to 20% of children (332). MMI-related adverse events include allergic reactions, rashes, myalgias, and arthralgias (333,334), as well as hypothyroidism from overtreatment. Side effects from MMI usually occur within the first 3 months of starting therapy, but adverse events can occur later. In children, the risks of MMI-related cholestasis and hepatocellular injury appear to be much less than those observed in adults (326).

Agranulocytosis has been reported in about 0.3% of adult patients taking MMI or PTU (128,324,335). Data on the prevalence of agranulocytosis in children are unavailable, but it is estimated to be very low. In adults, agranulocytosis is dose dependent with MMI and rarely occurs at low doses (e.g., 5–10 mg/d) (128,324,335). When agranulocytosis develops, 95% of the time it occurs in the first 100 days of therapy (128,324,335). The overall rate of side effects from ATDs (both major and minor) in children has been reported to be 6%–35% (332,334,336,337).

Technical remarks: While routine monitoring of WBC counts may occasionally detect early agranulocytosis, it is not recommended because of the rarity of the condition and its sudden onset, which is generally symptomatic. For this reason, measuring WBC counts during febrile illnesses and at the onset of pharyngitis has become the standard approach for monitoring.

[P4] Monitoring of children taking PTU

■ **RECOMMENDATION 64**

In general, PTU should not be used in children. But if it is used, the medication should be stopped immediately and liver function and hepatocellular integrity assessed in children who experience anorexia, pruritus, rash, jaundice, light-colored stool or dark urine, joint pain, right upper quadrant pain or abdominal bloating, nausea, or malaise.

Strong recommendation, low-quality evidence.

Technical remarks: PTU should be discontinued if transaminase levels (obtained in symptomatic patients or found incidentally) reach 2–3 times the upper limit of normal. After discontinuing the drug, liver function tests (i.e., bilirubin, alkaline phosphatase, and transaminases) should be monitored weekly until there is evidence of resolution. If there is no evidence of resolution, referral to a gastroenterologist or hepatologist is warranted.

[P5] Management of allergic reactions in children taking MMI

■ **RECOMMENDATION 65**

Persistent minor cutaneous reactions to MMI therapy in children should be managed by concurrent antihistamine treatment or cessation of the medication and changing to therapy with RAI or surgery. In the case of a serious adverse reaction to an ATD, prescribing the other ATD is not recommended.

Strong recommendation, low-quality evidence.

If children develop serious adverse reactions to MMI, RAI or surgery should be considered because the risks of PTU are considered greater than the risks of RAI or surgery. In special circumstances, in which the patient appears to be at risk for thyroid storm and ATD therapy is needed in a child with a serious adverse reaction to MMI, PTU may be considered for short-term therapy to control hyperthyroidism. In this setting, families should be informed of the risks of PTU.

[P6] Duration of MMI therapy in children with GD

■ **RECOMMENDATION 66**

If MMI is chosen as the first-line treatment for GD in children, it may be tapered in those children requiring low doses after 1–2 years to determine if a spontaneous remission has occurred, or it may be continued until the child and caretakers are ready to consider definitive therapy, if needed.

Strong recommendation, moderate-quality evidence.

The issue of how long ATDs should be used in children before considering either RAI or surgery is a topic of controversy and warrants further study. Prospective studies in adults show that if remission does not occur after 12–18 months of therapy, there is a lower chance of remission occurring with prolonged therapy (338). In children, when ATDs are used for 1–2 years, remission rates are generally 20%–30%, with remission defined as being euthyroid for 1 year after cessation of therapy (333,339,340). Retrospective studies have suggested that the chance of remission after 2 years of ATDs is low if the thyroid gland is large (more than 2.5 times normal size for age), the child is young (<12 years) or not Caucasian, serum TRAb levels are above normal on therapy, or free T_4 levels are substantially elevated at diagnosis (>4 ng/dL, 50 pmol/L) (339). One prospective study suggested that likelihood of remission could best be predicted by the initial response to ATDs, with achievement of euthyroid state within 3 months, suggesting higher likelihood. Younger children and those with high initial thyroid hormone levels were also found to be less likely to achieve remission within 2 years in the prospective studies (334,337).

Remission rates in children treated with ATDs for longer than 2 years have been reported. Although two decades ago it was suggested that 25% of children with GD go into remission with every 2 years of continued treatment (341), other studies of larger cohorts of pediatric patients with GD treated with ATDs for extended periods have not revealed similar remission rates (333,339,342). Of 120 pediatric patients treated with ATDs at one center, after 1 year of therapy with ATDs, 25% were in remission; after 2 years, 26%; after 4 years, 37%; and after 4–10 years, 15%. Importantly, 30% of the children who went into remission eventually relapsed (333). In another large cohort of 184 medically treated children, after 1 year of therapy with ATDs, 10% were in remission; after 2 years, 14%; after 3 years, 20%; and after 4 years, 23% (339,342).

More recently, in a retrospective analysis from Japan of 1138 children, 723 were continued on long-term ATD treatment, 271 underwent surgery or RAI, and 144 dropped out. Of the 639 patients of the 723 who discontinued ATD treatment after a mean of 3.8 years (range 0.3 to 24.8 years), 46.2% achieved remission, and 34.2% relapsed. The prevalence of adverse events associated with MMI and PTU were 21.4% and 18.8%, respectively (343).

In comparison, other recent studies of long-term remission rates of pediatric GD treated with ATDs are very low (<20%), especially with longer follow-up, in cohorts from Germany (344) and Denmark (345).

Data also suggest that age-related differences exist in responsiveness to ATDs. In one study that compared outcomes of 32 prepubertal and 68 pubertal children, remission occurred in only 17% of prepubertal children treated 5.9 ± 2.8 years, compared with 30% of pubertal individuals treated 2.8 ± 1.1 years (340). In another report, the course of GD was compared in 7 prepubertal, 21 pubertal, and 12 postpubertal children (336). Remission was achieved in 10 patients (28%) with similar rates among the three groups, whereas the time to remission tended to be longer in the small proportion of prepubertal children (median age, 6 years) (336).

Persistence of GD in children is correlated with the persistence of TRAb. A recent study found that TRAb levels normalized after 24 months in only 18% of pediatric patients on ATDs (346). There were no data showing that there was normalization of TRAb levels when patients were on ATDs for a longer time. Therefore, it appears that TRAb levels persist longer in children than in adults (346). Whereas monitoring of TRAb levels while on ATDs has been shown to be useful in adult patients for predicting the likelihood of remission or relapse of GD after stopping the medication (172), this approach has yet to be validated in children.

Whereas most studies, including recent large database reports (343), show that the vast majority of patients treated for GD with ATDs do not go into remission, a recent prospective report from France shows that with prolonged ATD use, remission rates of up to 49% could be achieved. This study reported remission rates of 20%, 37%, 45%, and 49% after 4, 6, 8, and 10 years follow-up of 154 children treated with ATDs (337). The use of MMI in this group of children was associated with a very low rate of medication side effects (337). Thus, whereas many practitioners will treat for 1–2 years with MMI, these data suggest that treatment for longer periods is also reasonable, as long as side effects to medication do not occur.

■ **RECOMMENDATION 67**

Pediatric patients with GD who are not in remission following at least 1–2 years of MMI therapy should be considered for treatment with RAI or thyroidectomy. Alternatively, if children are tolerating ATD therapy, ATDs may be used for extended periods. This approach may be especially useful for the child not considered to be a candidate for either surgery or RAI. Individuals on prolonged ATD therapy (>2 years) should be reevaluated every 6–12 months and when transitioning to adulthood.

Strong recommendation, low-quality evidence.

If remission is not achieved upon stopping MMI after at least 1 or 2 years of therapy, RAI or surgery should be considered, depending on the age of the child. Alternatively, practitioners can continue MMI for extended periods, as long as adverse drug effects do not occur and the hyperthyroid state is controlled. As already noted, adverse reactions typically occur within the first few months of therapy.

[Q] If RAI is chosen as treatment for GD in children, how should it be accomplished?

[Q1] Preparation of pediatric patients with GD for RAI therapy

■ **RECOMMENDATION 68**

We suggest that children with GD having total T_4 levels of >20 μg/dL (260 nmol/L) or free T_4 >5 ng/dL (60 pmol/L)

who are to receive RAI therapy be pretreated with MMI and β-adrenergic blockade until total T_4 and/or free T_4 normalize before proceeding with RAI treatment.

Weak recommendation, low-quality evidence.

Although the frequency of short-term worsening of hyperthyroidism following pretreatment with ATD therapy is not known, there are rare reports of pediatric patients with severe hyperthyroidism who have developed thyroid storm after receiving RAI (347,348).

Technical remarks: When children receiving MMI are to be treated with RAI, the medication should be stopped 2–3 days before treatment (349). At that time patients should be placed on β-blockers (if not already taking) until total T_4 and/or free T_4 levels normalize following RAI therapy, which generally takes 2–4 months. Although some physicians restart ATDs after treatment with RAI (80), this practice is seldom required in children (309,310,350). Thyroid hormone levels in children begin to fall within the first week following RAI therapy. ATDs can complicate assessment of posttreatment hypothyroidism since it could be the result of the MMI rather than the RAI therapy.

[Q2] Administration of RAI in the treatment of GD in children

■ **RECOMMENDATION 69**

If RAI therapy is chosen as treatment for GD in children, sufficient RAI should be administered in a single dose to render the patient hypothyroid.

Strong recommendation, moderate-quality evidence.

The goal of RAI therapy for GD is to induce hypothyroidism, rather than euthyroidism, because lower administered activities of RAI result in residual, partially irradiated thyroid tissue that is at increased risk for thyroid neoplasm development (351). Because of an increased risk of thyroid nodules and cancer associated with low-level thyroid irradiation in children (314,352–354) and poor remission rates with low-administered activities of RAI (88–90), it is important that RAI activities >150 μCi (>5.55 MBq/g) rather than smaller activities of RAI be administered to achieve hypothyroidism (312). With large glands (50–80 g), RAI activities of ^{131}I 200–300 μCi/g (7.4–11.1 MBq/g) may be needed (349). The administered activity of RAI to patients with very large goiters is high, and a tendency exists to underestimate the size of the gland (and thereby administer insufficient RAI activities to these patients) (90). Therefore, surgery may be preferable to RAI in children with goiters larger than 80 g.

Physicians at some centers administer a fixed dose of about 15 mCi RAI to all children (350), whereas others calculate the activity from estimation or direct measurement of gland size and ^{123}I uptake (349). To assess thyroid size, particularly in the setting of a large gland, ultrasonography is recommended (355). There are no data comparing outcomes of fixed versus calculated activities in children; in adults, similar outcomes have been reported with the two approaches (356). One potential advantage of calculated versus fixed dosing is that it may be possible to use lower administered activities of RAI, especially when uptake is high and the thyroid is small. Calculated dosing also will help assure that an adequate administered activity is given.

When RAI activities >150 μCi/g (>5.55 MBq/g) are administered, hypothyroidism rates are about 95% (88,339, 349). While there are reports that hyperthyroidism can relapse in pediatric patients rendered hypothyroid with RAI, this is very infrequent.

Technical remarks: RAI is excreted by saliva, urine, perspiration, tears, and stool. Significant radioactivity is retained within the thyroid for several days. It is therefore important that patients and families be informed of and adhere to local radiation safety recommendations following RAI therapy. After RAI therapy, T_3, T_4, and/or free T_4 levels should be obtained every month. Because TSH levels may remain suppressed for several months after correction of the hyperthyroid state, TSH determinations may not be useful in this setting for assessing hypothyroidism. Hypothyroidism typically develops by 2–3 months posttreatment (333,349,350), at which time levothyroxine should be prescribed.

[Q3] Side effects of RAI therapy in children

Side effects of RAI therapy in children are uncommon apart from the lifelong hypothyroidism that is the goal of therapy. Fewer than 10% of children complain of mild tenderness over the thyroid in the first week after therapy; it can be treated effectively with acetaminophen or nonsteroidal anti-inflammatory agents for 24–48 hours (310,349).

If residual thyroid tissue remains in young children after RAI treatment, a theoretical risk of development of thyroid cancer exists. Detractors of the use of RAI therapy in children point to the increased rates of thyroid cancer and thyroid nodules observed in young children exposed to radiation from nuclear fallout at Hiroshima or after the Chernobyl nuclear reactor explosion. However, these data do not apply directly when assessing risks of RAI therapy. The risk of thyroid neoplasia is greatest with exposure to low-level external radiation (0.1–25 Gy; $\sim$0.09–30 μCi/g or 3.33–1110 Bq/g) (314,315,352,354,357), not with the higher administered activities used to treat GD. It is also important to note that iodine deficiency and exposure to radionuclides other than RAI may have contributed to the increased risk of thyroid cancer in young children after the Chernobyl reactor explosion (315). Notably, thyroid cancer rates were not increased among 3000 children exposed to RAI from the Hanford nuclear reactor site in an iodine-replete region (358). Increased thyroid cancer rates also were not seen in 6000 children who received RAI for the purpose of diagnostic scanning (359).

No evidence suggests that children or adults treated for GD with more than 150 μCi/g (5.55 MBq/g) of RAI have an increased risk of thyroid cancer directly attributable to RAI. While there are several studies of this issue in adults treated with RAI for GD (see Section [D2]), few studies have focused on populations exposed to RAI for the treatment of GD in childhood or adolescence.

In one study, an analysis was carried out of 602 individuals exposed to RAI below 20 years of age in Swedish and U.S. populations (360). The average follow-up period was 10 years, and the mean administered activity of RAI to the thyroid was 88 Gy (approximately 80 μCi/g or 2.96 MBq/g equivalent), an activity known to be associated with thyroid neoplasia and below that recommended for treatment of GD.

Two cases of thyroid cancer were reported compared to 0.1 cases expected over that period of time. Effects on the development of nonthyroid cancers were not examined.

The pediatric study with the longest follow-up reported 36-year outcomes of 116 patients, treated with RAI between 1953 and 1973 (100). The patients ranged in age at treatment from 3 to 19 years. No patient developed thyroid cancer or leukemia. There was no increase in the rate of spontaneous abortion or in the number of congenital anomalies in offspring. It is important to note that the sample size was small; thus, the statistical power was inadequate to address this issue fully.

Total-body radiation dose after RAI varies with age, and the same absolute activities of RAI will result in more radiation exposure to a young child than to an adolescent or adult (361). At present, we do not have dosimetry information regarding RAI use in children with GD to assess total body exposure in children. Using phantom modeling, it has been estimated that at 0, 1, 5, 10, and 15 years of age, and adulthood, respective total-body radiation activities are 11.1, 4.6, 2.4, 1.45, 0.90, and 0.85 rem (1 rem = 0.1 Sv) per millicurie of RAI administered (361). Based on the Biological Effects of Ionizing Radiation Committee VII analysis of acute, low-level radiation exposure (362), the theoretical lifetime attributable risk of all-cancer incidence and all-cancer mortality for a large population of treated children can be estimated (Table 9).

To date, long-term studies of children treated with RAI for GD have not revealed an increased risk of nonthyroid malignancies. If a small risk exists, a sample size of more than 10,000 children who were treated at <10 years of age would be needed to identify the risk, likely exceeding the number of such treated children. Based on cancer risk projections from estimated whole-body, low-level radiation exposure as related to age, it is theoretically possible that there may be a low risk of malignancies in very young children treated with RAI. Thus, we recommend that RAI therapy be avoided in very young children (<5 years) and that RAI be considered in those children between 5 and 10 years of age when the required activity for treatment is <10 mCi (<370 MBq). It is important to emphasize that these recommendations are based on theoretical concerns and further direct study of this issue is needed. The theoretical risks of RAI use must therefore be weighed against the known risks inherent in thyroidectomy or prolonged ATD use when choosing among the three different treatment options for GD in the pediatric age group.

The activity of RAI administered should be based on thyroid size and uptake and not arbitrarily reduced because of age in young individuals. Attempts to minimize the RAI activity will result in undertreatment and the possible need for additional RAI therapy and radiation exposure.

[R] If thyroidectomy is chosen as treatment for GD in children, how should it be accomplished?

[R1] Preparation of children with GD for thyroidectomy

■ **RECOMMENDATION 70**

Children with GD undergoing thyroidectomy should be rendered euthyroid with the use of MMI. A KI-containing preparation should be given in the immediate preoperative period.

Strong recommendation, low-quality evidence.

Surgery is an acceptable form of therapy for GD in children. Thyroidectomy is the preferred treatment for GD in young children (<5 years) when definitive therapy is required, and the surgery can be performed by a high-volume thyroid surgeon. In individuals with large thyroid glands (>80 g), the response to RAI may be poor (88,90) and surgery also may be preferable for these patients. When performed, near-total or total thyroidectomy is the recommended procedure (363).

Technical remarks: MMI is typically given for 1–2 months in preparation for thyroidectomy. KI (50 mg iodide/drop) can be given as 1–2 drops (i.e., 0.05–0.1 mL) three times daily for 10 days before surgery. SSKI can be mixed in juice or milk.

■ **RECOMMENDATION 71**

If surgery is chosen as therapy for GD in children, total or near-total thyroidectomy should be performed.

Strong recommendation, moderate-quality evidence.

Table 9. Theoretical Projections of Cancer Incidence or Cancer Mortality Related to ^{131}I Therapy for Hyperthyroidism as Related to Age

			Lifetime attributable risk of cancer mortality								
Age at exposure (year)	*Total-body ^{131}I dose (rem or rad)*		*Per 100,000 per 0.1 Gy or Sv*			*Per 100,000 per rad or rem*			*Lifetime cancer risk for 15 mCi ^{131}I*		*Relative lifetime cancer risk for 15 mCi ^{131}I*[a]
	Per mCi	*Per 15 mCi*	*Males*	*Females*	*Average*	*Males*	*Females*	*Average*	*Cases per 100,000*	*%*	
0	11.1	167	1099	1770	1435	110	177	143	23,884	23.9	1.96
1	4.6	69.0	1099	1770	1435	110	177	143	9898	9.9	1.40
5	2.4	36.0	852	1347	1100	85	135	110	3958	3.96	1.16
10	1.45	21.8	712	1104	908	71	110	91	1975	1.97	1.08
15	0.9	13.5	603	914	759	60	91	76	1024	1.02	1.04
20	0.85	12.8	511	762	637	51	76	64	812	0.81	1.03
40	0.85	12.8	377	507	442	38	51	44	564	0.56	1.02
60	0.85	12.8	319	409	364	32	41	36	464	0.46	1.02

[a]Using a gross average of dying from a spontaneous cancer of 25% data analysis by Dr. Patrick Zanzonico, Memorial Sloan Kettering Cancer Center (New York, NY).

■ **RECOMMENDATION 72**

Thyroidectomy in children should be performed by high-volume thyroid surgeons.

Strong recommendation, moderate-quality evidence.

Surgical complication rates are higher in children than in adults, with higher rates in younger than in older children (316,318). Postoperatively, younger children also appear to be at higher risk for transient hypoparathyroidism than adolescents or adults (316,318).

Postoperative hypocalcemia requiring intravenous calcium infusions appears to occur more frequently than in in adults. Data from one center suggest that if calcitriol is started 3 days before surgery (0.25 or 0.5 μg, twice daily), the need for postoperative calcium infusions is markedly reduced, leading to reduction in the length of stay (318). The calcitriol is then weaned over the first two postoperative weeks (318).

In addition, complication rates are 2-fold higher when thyroidectomy is performed by pediatric or general surgeons who do not have extensive current experience in this procedure than when performed by high-volume thyroid surgeons (316). Further support for the notion that thyroidectomy for GD in children should be performed by experienced thyroid surgeons comes from reports of institutional experience showing low complication rates at high-volume centers (318,364). In circumstances in which local pediatric thyroid surgery expertise is not available, referral of a child with GD to a high-volume thyroid surgery center that also has pediatric experience is indicated, especially for young children. A multidisciplinary health-care team that includes pediatric endocrinologists and experienced thyroid surgeons and anesthesiologists is optimal.

[S] How should subclinical hyperthyroidism be managed?

[S1] Prevalence and causes of SH

The prevalence of subclinical hyperthyroidism (SH) in an adult population depends on age, sex, and iodine intake. In a representative sample of U.S. subjects without known thyroid disease, 0.7% had suppressed TSH levels (<0.1 mU/L), and 1.8% had low TSH levels (<0.4 mU/L) (365). Similar rates have been reported in studies from Europe, with higher levels in women and older subjects (366,367). The differential diagnosis of an isolated low or suppressed TSH level includes exogenous thyroid hormone use, nonthyroidal illness, drug effects, and pituitary/hypothalamic disease, all of which need to be ruled out before the diagnosis of SH can be established in a patient with an isolated low or suppressed TSH level. In addition, mean serum TSH levels are lower in black non-Hispanic Americans, some of whom may have slightly low TSH levels without thyroid disease (365). Finally, some otherwise healthy older persons may have low serum TSH levels, low-normal serum levels of free T_4 and total T_3, and no evidence of thyroid or pituitary disease, suggesting an altered set point of the pituitary–thyroid axis (368,369).

The natural history of SH is variable (367,370–377), with annualized rates of 0.5%–7% progression to overt hyperthyroidism and 5%–12% reversion to normal TSH levels. In one study (372), 51.2% of patients had spontaneously developed a normal TSH when first checked at some time within 5 years (mean time to repeat TSH, 13 months). Progression from SH to overt hyperthyroidism appears more likely if the TSH is suppressed (<0.01 mU/L), rather than low but detectable (0.01–0.4 mU/L) (375–377). Patients with GD rather than a TMNG as the cause of SH may be more likely to spontaneously remit (367,378). In patients at high risk of complications from SH, TSH and free T_4 should be repeated within 2–6 weeks. For all other patients, it is important to document that SH is a persistent problem by repeating the serum TSH at 3–6 months, prior to initiating therapy. In clinical series, TMNG is the most common cause of SH, especially in older persons (367,376,377). The second most common cause of SH is GD, which is more prevalent in younger persons and is also common in patients who previously received ATD therapy. Other unusual causes include solitary autonomously functioning nodules and various forms of thyroiditis, the latter of which would be more strictly termed ''subclinical thyrotoxicosis.''

[S2] Clinical significance of SH

Since SH is a mild form of hyperthyroidism, it is not surprising that deleterious effects seen in overt hyperthyroidism might also occur in SH. A large number of recent studies have elucidated these effects.

Overall mortality. Several longitudinal studies have examined correlations between SH and overall mortality, with variable results. Some studies report increased overall mortality rates in SH subjects (374,379–383), especially older subjects, while others indicate no relation (384–387). Limitations of some of these studies include sample sizes, age ranges, length of follow-up, and diagnosis of SH by a single TSH measurement. A recent meta-analysis of individual-level data from 52,674 participants, pooled from 10 cohorts and providing greater power, concluded that SH confers a 24% increased risk of overall mortality (388).

Cardiovascular disease. A recent large study of 26,707 people followed for 12 years reported increased cardiovascular mortality with SH (389). Some other, smaller studies have reached similar conclusions (374,383), although other smaller studies have failed to find a correlation (380,381, 384,386). There have been two recent meta-analyses that examined this question, one of study-level data of 17 cohorts (390) and the other of individual-level data in 52,674 participants (388). Both analyses concluded that SH confers an increased risk of cardiovascular mortality, with hazard ratios of 1.52 (390) and 1.29 (388). In the individual-level meta-analysis, relative risks did not differ based on age, sex, pre-existing cardiovascular disease, or the presence of cardiovascular risk factors. However, the risk was greater in subjects with TSH levels <0.1 mU/L compared to those with TSH levels 0.1–0.4 mU/L.

Some of these studies, including the meta-analyses, have also examined nonfatal cardiovascular events in SH, with similar increased risks (383,388,390,391). The most recent data indicate that SH subjects appear to be at particular risk for the development of heart failure (381,388,392), especially older subjects (381,392) and those with lower TSH levels (392). Mechanistic correlates of these findings include increased left ventricular mass and impaired left ventricular function in SH that improve with treatment (393–396). In addition, two studies have shown impaired glucose tolerance

and decreased insulin sensitivity in SH, suggesting this may contribute to increased cardiovascular risk (397,398).

Arrhythmias are another concern in SH. Sawin *et al.* (399) first reported a 2.8-fold increased risk of atrial fibrillation in SH subjects over age 60 years in 1994, and subsequent studies have confirmed that the risk of arrhythmias, particularly atrial fibrillation, is increased in SH (381,384,388, 391,400,401). In the largest study to date (586,460 people followed for a median of 5.5 years), the highest relative risk for atrial fibrillation occurred in younger subjects, possibly because other causes predominate with age, and in subjects with lower TSH levels (401). However, absolute incidence rates of atrial fibrillation were much lower in younger subjects; for example, women under the age of 65 years had atrial fibrillation incidence rates of 2.3 events per 1000 person-years (relative risk of 1.89 compared to age-matched euthyroid women), while women 65 years and older had incidence rates of 22.7 per 1000 person-years (relative risk of 1.27 compared to age-matched euthyroid women). Similar trends were seen for men. A further population-based study found that SH increased the risk for stroke in subjects over age 50 years with a hazard ratio of 3.39 (402), although a recent meta-analysis of stroke risk in SH found insufficient number of events to draw definitive conclusions (403). Complementing these epidemiologic studies, investigations of smaller numbers of subjects with SH have revealed increased heart rate at rest and during exercise, decreased heart rate variability, and increased frequency of atrial and ventricular premature beats, which improve with treatment of SH (393,394,404,405).

Taken together, these data provide a strong argument for the treatment of SH in older subjects to avoid dysrhythmias and possible subsequent stroke. Whether younger patients should be treated for the same preventive indications is less clear. The most recent data provide evidence that relative risks of cardiovascular mortality and atrial fibrillation are elevated in younger, as well as older, patients with SH. However, the absolute risks of these events are very low in younger patients, so the risk/benefit ratio of treating younger SH patients is not clear. Clinical judgement should be used in these cases, and treatment decisions individualized.

Osteoporosis and fractures. Most studies of endogenous SH show decreased bone mineral density in postmenopausal women, but not in men or premenopausal women (406). However, it is not clear that this finding translates to increased fracture risk. A number of population-based studies have reported that certain groups of subjects with SH have increased fracture rates, including all adults (407), postmenopausal women (408), men (409), or subjects who progress to overt hyperthyroidism over time (391). The most recent and by far the largest individual study to date (231,355 subjects) reported a hazard rate for all major osteoporotic fractures combined (hip, humerus, forearm, spine) of 1.13 [confidence intervals 1.014–1.26]. Risk increased with duration of SH, such that after a median follow-up of 7.5 years, 13.5% of subjects with a low TSH level had experienced at least one major osteoporotic fracture, compared to 6.9% of subjects with a normal TSH level (407). Other studies have not found increased fracture rates in SH subjects (410–412). A recent participant-level meta-analysis of 13 cohorts (70,298 participants, median follow-up of 12.1 years) concluded that SH subjects had significantly elevated hazard ratios of 1.36 for hip fractures (6 vs. 4.9 fractures per 1000 person-years) and 1.28 for any fractures (14.4 vs. 11.2 fractures per 1000 person-years) (413). Risks were further increased if TSH levels were <0.1 mU/L compared to 0.1–0.44 mU/L, and if SH was due to endogenous etiologies, rather than thyroid hormone administration. Risks did not differ when stratified by age, although absolute fracture rates were lower in younger subjects. There are smaller, nonrandomized trials that have shown improvement in bone mineral density with therapy of SH with ATDs or RAI (414–417).

Mood and cognition. A large body of literature has investigated possible correlations between SH and cognitive decline [reviewed by Gan and Pearce (418), with more recent studies by others (419,420)]. Approximately equal numbers of studies report significant associations between SH and measures of cognitive decline and the development of dementia, versus no associations. Therefore, at this time, no conclusions regarding this issue can be reached. There appears to be no correlation between SH and depression (421–423).

Physical functioning. Four studies have investigated whether SH is associated with self-reported functional capacity or objective measures of physical functioning (420, 423–425). Three could find no correlation, while the fourth found a correlation between SH and lower physical performance in men only (425). Another uncontrolled study showed an increase in muscle mass and muscle strength in middle-aged women with SH after treatment with RAI or thyroidectomy (426).

[S3] When to treat SH

■ **RECOMMENDATION 73**

When TSH is persistently <0.1 mU/L, treatment of SH is recommended in all individuals ≥65 years of age; in patients with cardiac risk factors, heart disease or osteoporosis; in postmenopausal women who are not on estrogens or bisphosphonates; and in individuals with hyperthyroid symptoms.

Strong recommendation, moderate-quality evidence.

■ **RECOMMENDATION 74**

When TSH is persistently <0.1 mU/L, treatment of SH should be considered in asymptomatic individuals <65 years of age without the risk factors listed in Recommendation 73.

Weak recommendation, moderate-quality evidence.

Treatment of SH is controversial, since few intervention studies showing benefit have been performed, especially for clinically important endpoints such as cardiovascular events, atrial fibrillation, and fractures. Additionally, none of these studies included a control arm. Thus, the evidence rests only with small uncontrolled studies that have shown improvements in cardiac structure and function, heart rate and the frequency of premature atrial and ventricular beats, bone mineral density, and muscle strength (393–396,405,414–417,426). In 2004, a panel of experts determined that the

evidence for benefit was sufficient to warrant therapy of SH in older individuals whose serum TSH level was <0.1 mU/L (427). This recommendation was based primarily on the studies showing an increased rate of atrial fibrillation and altered skeletal health with a suppressed level of TSH described above. Emerging epidemiologic data since then on risks for overall and cardiovascular-specific mortality, summarized above, have strengthened this argument, even in the absence of interventional data. The European Thyroid Association recently reviewed these data and published guidelines for the treatment of subclinical hyperthyroidism, which are largely concordant with recommendations presented here (428).

There are insufficient data for or against treatment of SH in younger persons or premenopausal women with SH and serum TSH <0.1 mU/L. One uncontrolled study of middle-aged patients showed an improvement in hyperthyroid symptoms with therapy (393). Although this study did not include younger individuals, the task force elected to recommend treatment of SH patients younger than 65 years of age with persistent TSH <0.1 mU/L and hyperthyroid symptoms. In the absence of symptoms or risk factors, treatment decisions must be individualized.

Technical remarks: A TSH level of <0.1 mU/L on repeated measurement over a 3- to 6-month period is considered to be persistent, effectively ruling out transient thyroiditis as a cause. The thyroid disorder underlying SH should be diagnosed, and is most commonly TMNG, GD, or TA.

■ **RECOMMENDATION 75**

When TSH is persistently below the lower limit of normal but ≥0.1 mU/L, treatment of SH should be considered in individuals ≥65 years of age and in patients with cardiac disease, osteoporosis, or symptoms of hyperthyroidism.

Weak recommendation, moderate-quality evidence.

■ **RECOMMENDATION 76**

When TSH is persistently below the lower limit of normal but ≥0.1 mU/L, asymptomatic patients under age 65 without cardiac disease or osteoporosis can be observed without further investigation of the etiology of the subnormal TSH or treatment.

Weak recommendation, low-quality evidence.

A number of the epidemiologic studies listed above performed analyses for SH subjects with low but detectable TSH levels (generally 0.1–0.4 mU/L). Some of these studies reported increased risks of overall mortality in older subjects (380,429), cardiovascular events (391), heart failure (381), and atrial fibrillation in all subjects (401) or in older subjects (384), and vertebral fractures in older women (408). However, there are no interventional data for or against treatment of individuals with serum TSH levels between 0.1 mU/L and the lower limit of the reference range. Therefore, treatment decisions must be individualized, based on the limited epidemiologic evidence and patient risk factors. The task force felt that the limited data are stronger for older subjects, and therefore treatment should be considered for older subjects, but it is not recommended for subjects <65 years of age. However, younger subjects should be monitored at regular 6- to 12-month intervals, and treatment should be considered if the TSH persistently decreases to <0.1 mU/L. In patients with symptoms of hyperthyroidism, a trial of β-adrenergic blockers may be useful to determine whether symptomatic therapy might suffice.

Technical remarks: A TSH level between 0.1 and 0.4 mU/L on repeated measurement over a 3- to 6-month period is considered persistent, effectively ruling out transient thyroiditis as a cause. The thyroid disorder underlying SH with TSH persistently within this range should be diagnosed before considering treatment to avoid treating patients with transient, functional disorders related to acute illness, drugs, and other causes of low TSH. A summary of factors to consider when deciding whether or not to treat a patient with SH is provided (Table 10).

[S4] How to treat SH

■ **RECOMMENDATION 77**

If SH is to be treated, the treatment should be based on the etiology of the thyroid dysfunction and follow the same principles as outlined for the treatment of overt hyperthyroidism.

Strong recommendation, low-quality evidence.

The treatment of SH is similar to the treatment of overt hyperthyroidism. RAI is appropriate for most patients, especially in older patients when TMNG is a frequent cause of SH. There are no data to inform whether elderly patients with SH would benefit from pretreatment with ATDs to normalize thyroid function before RAI therapy. Given the low risk of exacerbation (71), the risks of ATD therapy may outweigh any potential small benefit.

A course of ATD therapy is a reasonable alternative to RAI in patients with GD and SH, especially in younger

Table 10. Subclinical Hyperthyroidism: When to Treat

Factor	*TSH (<0.1 mU/L)*	*TSH (0.1–0.4 mU/L)*[a]
Age >65 years	Yes	Consider treating
Age <65 years with comorbidities		
Heart disease	Yes	Consider treating
Osteoporosis	Yes	Consider treating
Menopausal, not on estrogens or bisphosphonates	Yes	Consider treating
Hyperthyroid symptoms	Yes	Consider treating
Age <65 years, asymptomatic	Consider treating	Observe

[a]Where 0.4 mU/L is the lower limit of the normal range.

patients, since remission rates are highest in persons with mild disease (109).

Some patients with SH due to GD may remit spontaneously without therapy (375–377), so that continued observation without therapy is reasonable for younger patients with SH due to GD. A small subset of elderly patients with persistently low TSH and no evidence of true thyroid dysfunction can be followed without intervention, especially when the serum free T_4 and total T_3 levels are in the lower half of the normal range. Treatment with β-adrenergic blockade may be sufficient to control the cardiovascular-related morbidity from SH, especially that of atrial fibrillation (430).

Technical remarks: Some patients with SH due to mild GD may remit spontaneously and may be followed without therapy with frequent (every 3–6 months) monitoring of thyroid function. In select patients with SH due to TMNG who have compressive symptoms, or in whom there is concern for malignancy, surgery is also an option.

[S5] End points to be assessed to determine effective therapy of SH

The goal of therapy for SH is to render the patient euthyroid with a normal TSH. Since the rationale for therapy of SH is to a large degree preventive, few end points can be used to document that therapy has been successful. Based on the original indication for treatment, it is reasonable to follow hyperthyroid symptoms or bone density (393,414–416); otherwise, the major end point is a TSH level within the age-adjusted reference range.

[T] How should hyperthyroidism in pregnancy be managed?

Normal pregnancy leads to changes in thyroid physiology that are reflected by altered thyroid function testing. In early pregnancy, these changes can mimic biochemical hyperthyroidism that does not require therapy (431). Hyperthyroidism due to GD occurs in 0.5%–1.0% of women in the reproductive age range (432), and 0.1%–0.2% of them are treated with ATD during pregnancy (433,434). Both the thyrotoxicosis and therapy of the disease may seriously complicate the course and outcome of pregnancy. In these guidelines, we will address only the most common issues related to hyperthyroidism in pregnancy, pending full guidelines on thyroid disease and pregnancy that are currently being updated by the ATA.

[T1] Diagnosis of hyperthyroidism in pregnancy

■ **RECOMMENDATION 78**

The diagnosis of hyperthyroidism in pregnancy should be made using serum TSH values, and either total T_4 and T_3 with total T_4 and T_3 reference ranges increasing to 1.5 times above the nonpregnant range by the second and third trimester or free T_4 and total T_3 estimations with trimester-specific normal reference ranges.

Strong recommendation, low-quality evidence.

The diagnosis of hyperthyroidism in pregnancy can be challenging. In the vast majority of patients, the disease is caused by a primary thyroid abnormality, and the principal finding will be a suppressed serum TSH, with serum free T_4 (or total T_4) and/or T_3 levels above the reference range (overt hyperthyroidism), or within the reference range (SH). A key point is that reference ranges for thyroid function tests are different during different stages of pregnancy, and these changes may be assay dependent.

An understanding of pregnancy-related variations in thyroid function tests is important in making the diagnosis of hyperthyroidism in pregnancy. Serum TSH levels may be below the nonpregnant reference range in the first half of a normal-term pregnancy (435,436), and especially so in gestational weeks 9–13, during which a subset of pregnant women may develop a suppressed serum TSH (437–439). The decrease in TSH in early pregnancy is the result of stimulation of the normal thyroid by high levels of serum human chorionic gonadotropin (hCG) (440), and occasionally the biochemical findings that develop may correspond to overt thyrotoxicosis (gestational hyperthyroidism discussed below). However, low serum TSH levels with normal free T_4 (or total T_4) in early pregnancy do not indicate disease in need of therapy. During the second half of pregnancy, the lower limit of normal for TSH in the nonpregnant population can be used (441).

Free T_4 and T_3 measured in an equilibrium dialysate or an ultrafiltrate of serum around week 10 of pregnancy may be slightly higher (5%–10%) than nonpregnancy values, corresponding to the period of high serum hCG and low serum TSH. From normal or slightly elevated levels, a gradual decrease occurs during pregnancy, and late third trimester reference values are 10%–30% below nonpregnancy values (442).

Serum total T_4 and T_3 increase in parallel in early pregnancy, primarily due to increases in TBG. In one longitudinal study, the increase in T_4 and T_3 reference ranges were observed to occur at a rate of 5% of nonpregnant values per week over the 10-week period of gestation weeks 7–16 (443). After this 50% increase, total T_4 and T_3 values remain stable with reference range limits 1.5 times above nonpregnancy ranges over the remaining weeks of pregnancy (442,443). Total T_4 and T_3 values may be combined with a T_3 uptake test or measurements of TBG to adjust for pregnancy-associated variations in TBG. Such ''free T_4 index'' or ''TBG-adjusted T_4'' values may be useful for diagnosing hyperthyroidism in pregnancy; however, trimester-specific normal reference ranges should be established for each individual test and assay used. In the absence of these, consideration should be given to utilizing total T_4 and T_3 levels and multiply the nonpregnancy reference range by 1.5 after week 16, as previously discussed.

Excluding patients with TSH suppression or gestational thyrotoxicosis during the first trimester, GD is the most common cause of hyperthyroidism during pregnancy (431,444); nodular thyroid disease is less common. Hyperthyroidism caused by a hCG-producing molar pregnancy or a choriocarcinoma presents with a diffuse hyperactive thyroid similar to GD, but without eye signs and without TRAb being detectable in serum. In these patients, serum hCG will be higher than expected, and the cause can be identified by obstetrical investigation.

Technical remarks: The reliability of automated analog-based assays for free T_4 and free T_3 has been questioned for more than 25 years (445), but these estimates are currently

widely used because of their suitability for large-scale automatic analyses within short time periods. In many clinics, they are the standard of measurement in pregnancy. Because pregnancy may influence results of these assays from different manufacturers in different ways, and some assays may give spuriously low results (446), method-specific reference ranges for each trimester of pregnancy should be used and provided by the manufacturer (447,448). If trimester-specific references for free T_4 (and free T_3) are not provided, and total T_4 (and T_3) assays are not locally available, samples for thyroid function testing in pregnancy should be sent to a reference laboratory.

[T2] Management of hyperthyroidism in pregnancy

Table 11 provides a summary of the recommendations concerning management of GD during pregnancy.

■ **RECOMMENDATION 79**

Transient hCG-mediated TSH suppression in early pregnancy should not be treated with ATD therapy.

Strong recommendation, low-quality evidence.

Once the diagnosis of hyperthyroidism is made in a pregnant woman, attention should focus on determining the etiology and whether it warrants treatment. Clinical features that indicate the presence of hyperthyroidism include failure to gain weight, heat intolerance, excessive sweating, and tachycardia beyond that normally associated with pregnancy.

The two most common types of biochemical hyperthyroidism that occur during pregnancy are gestational hyperthyroidism (e.g., hCG-mediated transient TSH suppression) and GD. Gestational hyperthyroidism is a generally asymptomatic, mild, and self-limiting biochemical hyperthyroidism that may be observed in the first trimester of normal pregnancy. The disorder lacks the characteristics of GD (431) and is caused by the high serum hCG of early pregnancy (440). It is not associated with adverse pregnancy outcomes (449). More severe degrees of gestational hyperthyroidism are associated with hyperemesis; affected women may develop biochemically overt hyperthyroidism and clinical symptoms and signs of hyperthyroidism. Complicated cases of gestational hyperthyroidism should be referred to medical centers with expertise in treating these patients.

Technical remarks: There is no evidence that treatment of gestational hyperthyroidism with ATDs is beneficial, and use of ATD in early pregnancy has been associated with an increase in risk of birth defects. In these patients, physical examination and repeat thyroid function tests at intervals of 3–4 weeks is recommended. In the case of very symptomatic disease, a trial of β-blocker therapy [propranolol or metroprolol, but not atenolol (450,451)] for this transient disorder may be considered.

Table 11. Summary of Recommendations Concerning Management of Graves' Disease Causing Overt Hyperthyroidism in Pregnancy

Timing of diagnosis	*Specific circumstances*	*Recommendations*
GD diagnosed during pregnancy	Diagnosed during first trimester	Begin PTU[a] Measure TRAb at diagnosis and, if elevated, repeat at 18–22 weeks[b] and again at 30–34 weeks[c] of gestation If thyroidectomy is required, it is optimally performed during the second trimester
	Diagnosed after first trimester	Begin MMI[a] Measure TRAb at diagnosis and, if elevated, repeat at 18–22 weeks[b] and again at 30–34 weeks[c] of gestation (all depending on week of diagnosis). If thyroidectomy is required, it is optimally performed during the second trimester
GD diagnosed and treated prior to pregnancy	Currently taking methimazole	Switch to PTU or withdraw ATD therapy as soon as pregnancy is confirmed with early testing[a] Measure TRAb initially and, if elevated, again at 18–22 weeks[b] and 30–34 weeks[c] of gestation
	In remission after stopping antithyroid medication	Perform thyroid function testing to confirm euthyroidism. TRAb measurement not necessary
	Previous treatment with RAI or surgery	Measure TRAb initially during the first trimester and, if elevated, again at 18–22 weeks of gestation[d]

[a]See remarks under Recommendations 83, 86, and 87 for discussion regarding switching from one ATD to the other during pregnancy or withdrawing from therapy.

[b]If a TRAb-positive woman becomes TRAb-negative during pregnancy, this may indicate a need to reduce or stop ATD therapy to avoid fetal hypothyroidism. See remarks under Recommendations 89 and 93.

[c]If the ATD-treated mother has high TRAb values in late pregnancy, this indicates a risk of delayed neonatal hyperthyroidism (see remarks to Recommendations 87 and 94).

[d]If the mother has undergone some type of thyroid ablation (RAI or surgery) for GD and TRAb is high, evaluate fetus carefully for hyperthyroidism in second half of pregnancy and adjust or begin ATD therapy accordingly. See remarks to Recommendation 92.

■ **RECOMMENDATION 80**

ATD therapy should be used for overt hyperthyroidism due to GD during pregnancy. PTU should be used when ATD therapy is given during the first trimester. MMI should be used when ATD therapy is started after the first trimester.

Strong recommendation, low-quality evidence.

Untreated or insufficiently treated hyperthyroidism may seriously complicate pregnancy (452–454), and patients with this disorder should be treated at centers with specific expertise in this area. GD as the cause of hyperthyroidism in pregnancy may be diagnosed from typical clinical findings, including the presence of GO and/or serum TRAb in a hyperthyroid patient. Approximately 5% of patients with newly diagnosed Graves' hyperthyroidism are TRAb negative in older assays (47,455), and 3% are negative in third-generation assays (57), especially those with milder disease.

A small increase in incidence of GD was found in early pregnancy in one study (456), and this report fits the clinical observation that existing GD may occasionally worsen in early pregnancy (457). On the other hand, the incidence of GD drops dramatically in late pregnancy (456), which is consistent with the notion that thyroid autoimmunity improves in the second half of pregnancy (458).

Women who were treated with ATDs for GD and considered in remission after such previous therapy have a small risk of recurrence when they become pregnant and should have their thyroid function tested in early pregnancy. In contrast, the risk of relapse (as well as the risk of thyrotoxicosis from postpartum destructive thyroiditis) during the postpartum period is relatively high (459), and it remains elevated for more than 1 year (456).

ATDs have much the same effect on thyroid function in pregnant as in nonpregnant women. Both ATDs and TRAb pass through the placenta and can affect the fetal thyroid. However, T_4 and T_3 cross the placenta only in limited amounts because of degradation by high deiodinase type 3 activities in the placenta (460).

PTU generally has been preferred in pregnancy because of concerns about well-documented teratogenicity associated with MMI, first described in 1972 (461). Defects that may be observed in 2%–4% of exposed children (462,463) have included aplasia cutis; choanal atresia, esophageal, and other types of gut atresias; abdominal wall abnormalities including omphalocale; and eye, heart, and urinary tract malformations. Moreover, typical facial features of MMI-exposed children have been described in case reports (464). In a U.S. study, 31% of women who had received MMI around the time of conception had elective termination of pregnancy versus 9% of those who received PTU, and it was hypothesized that fear of MMI-associated birth defects had led to the decision to terminate pregnancy (465).

Recently, an increase in the rate of birth defects (2.3% above the background rate) was also observed after PTU exposure in early pregnancy (463), but these defects tended to be less severe than with MMI and included preauricular sinuses and cysts and urinary tract abnormalities (466). In a large group of children selected because they had major birth defects and had been exposed to some type of medication in early pregnancy, children exposed to PTU had a significantly higher frequency of situs inversus and cardiac outflow abnormalities than children exposed to other drugs (467), but these types of defects have not been observed in excess in studies comparing PTU-exposed children with nonselected control children. Similar to other teratogenic drugs (468) the period of highest risk for birth defects from ATDs is gestational weeks 6–10 (469).

Concerns about rare but potentially fatal PTU-related hepatotoxicity have led the U.S. FDA to recommended that PTU be reserved for patients who are in their first trimester of pregnancy or who are allergic to or intolerant of MMI (157,470)

MMI and PTU both appear in breast milk in only small concentrations, and studies of breastfed infants of mothers taking ATDs have demonstrated normal thyroid function and subsequent normal intellectual development (109). However, because of the potential for hepatic necrosis in either mother or child from maternal PTU use, MMI is the preferred ATD in nursing mothers.

As discussed in other sections of these guidelines, small doses of β-adrenergic blocking agents are in general useful to reduce pulse rate and the hyperadrenergic symptoms of thyrotoxicosis during the time period from the start of ATD therapy until the patient has become euthyroid. These agents have been studied extensively when used for treating hypertension in pregnancy, and no major side effects have been detected, although fetal growth restriction has been associated with the prolonged use of especially atenolol (431,471). Therapy with propranolol (e.g., 10–20 mg every 8 hours) or metoprolol (e.g., 100 mg once daily) are useful and can be considered safe for short periods of time to relieve symptoms in pregnant women suffering from thyrotoxicosis.

■ **RECOMMENDATION 81**

In women who develop hyperthyroidism during their reproductive age range, the possibility and timing of future pregnancy should be discussed. Because of the risks of the hyperthyroid state on pregnancy and fetal outcome, we suggest that women should postpone pregnancy until they have become euthyroid with therapy.

Strong recommendation, low-quality evidence.

Both maternal thyroid dysfunction and therapy of the hyperthyroidism may have negative effects on the pregnancy outcome. These factors should all be considered when determining the choice of therapy for the patient who is currently pregnant or may become pregnant in the future.

A single set of thyroid function tests within the reference range may not guarantee euthyroidism for more than a short period during the early phase of hyperthyroidism therapy. Two sets of tests within the reference range, taken with an interval of at least 1 month and without a change of therapy is preferable to indicate euthyroidism.

■ **RECOMMENDATION 82**

We suggest that women with hyperthyroidism caused by GD who require high doses of ATDs to achieve euthyroidism should be considered for definitive therapy before they become pregnant.

Weak recommendation, low-quality evidence.

Both thyroidectomy and RAI therapy are useful for rendering patients with GD permanently hypothyroid with the

possibility of a stable euthyroid state on thyroid hormone replacement therapy, as discussed in these guidelines. Thyroidectomy is often followed by a decrease or disappearance of TRAb from circulation, whereas RAI is often followed by a transient increase in TRAb. This increase is a potential argument in favor of surgical thyroidectomy in women with high TRAb titers who may become pregnant within the years to come, especially those planning therapy within the next year (172). However, the importance of this difference in autoimmune activity for pregnancy outcome has not been studied, and it should be weighed against the other benefits and harms of surgery and RAI therapy.

To predict reduction in TRAb after surgical thyroidectomy, a recent retrospective Japanese study of 45 (41 female) patients with high TRAb (median 64 IU/L, range 5.6–400, normal for assay <1.9 IU/L) may be useful. Patients were followed for 12 months. Smoking and the presence of orbitopathy predicted slow disappearance of TRAb (half-life 162 days, or 357 days if both factors were present), whereas TRAb levels in serum decreased with a half-life of 94 days in the remaining patients (472).

Medical tradition and experience with different types of therapy for GD varies between countries and clinics, and the risk of relapse of hyperthyroidism after ATD withdrawal may differ considerably, depending on iodine intake, and other factors that are only partly understood (473). Thus, advice given to women with GD on therapy in relation to a possible future pregnancy may differ. However, irrespective of such differences, the physician providing care to a young woman with newly diagnosed GD should include discussion and guidance on GD and pregnancy. The severely hyperthyroid patient may not be in a position to fully comprehend many simultaneous messages, and a more detailed discussion may be appropriate when the patient has become euthyroid.

■ RECOMMENDATION 83

Women with hyperthyroidism caused by GD that is well controlled on MMI and who desire pregnancy have several options:

a. Patients could consider definitive therapy before they become pregnant.
b. Patients could switch to PTU before trying to conceive.
c. Patients could switch to PTU as soon as pregnancy is diagnosed.
d. Appropriately selected patients could withdraw from ATD therapy as soon as pregnancy is diagnosed. If ATD therapy is withdrawn, thyroid function should be assessed weekly throughout the first trimester, then monthly.

Weak recommendation, low-quality evidence.

The evidence is insufficient to give universal guidance on how to choose among these options, and therefore the potential risks and benefits of each option should be discussed with the patient, and patient values and preferences should be taken into account. Each option is presented in depth in the following technical remarks.

Definitive therapy before becoming pregnant. This strategy is discussed in Recommendation 82. It has the advantage of allowing the patient to become pregnant free of worry from the adverse fetal effects of ATDs. The disadvantage is that the patient will require levothyroxine therapy while pregnant and lifelong and will be exposed to either the potential complications of RAI, including worsening or induction of GO, or the potential for undesirable surgical outcomes.

Switching from MMI to PTU before pregnancy. Switching from MMI to PTU before conception would eliminate the risk from early pregnancy exposure to MMI in women in whom pregnancy is not recognized within the first few weeks after conception. MMI-associated birth defects occur in 2%–4% of children exposed in early pregnancy, and abnormalities may be severe. PTU-associated birth defects are less well documented. They may occur in 2%–3% of children but they mostly seem to be less severe. PTU is associated with liver failure with an estimated 1:10,000 risk of severe liver failure in adult patients (136). Thus, mothers must balance the risk of PTU to themselves versus the risk to the child. Switching to PTU before conception may be preferred in younger women with regular menses who are expected to be able to conceive within 1–3 months. In a German prospective study of 340 such women, 68% became pregnant within 3 months (474).

A special variant is women who have hyperthyroidism diagnosed at a time when they hope to become pregnant soon. There are not sufficient data to recommend for or against starting therapy with PTU and thus bypass a phase of MMI therapy in such patients.

Switching from MMI to PTU after conception. Alternatively, the patient may continue MMI therapy but be prepared to detect pregnancy very early and modify therapy immediately as recommended below. Switching to PTU as soon as pregnancy is diagnosed may be preferred in older women and women who have conditions that may be associated with delayed conception. This strategy may prevent prolonged use of PTU prior to conception but has the risk of fetal exposure to MMI if the diagnosis of pregnancy is delayed.

Withdrawing ATD treatment after conception. Women with a stable euthyroid state on 5–10 mg MMI per day achieved within a few months and a falling TRAb level are likely candidates to withdraw from ATD therapy in early pregnancy.

No study has directly addressed the risk of relapse of hyperthyroidism after ATD withdrawal in early pregnancy, and evidence comes from controlled or cohort studies of nonpregnant patients who had been treated with ATD for varying periods before drug withdrawal. Based on the latter studies, the risk of relapse of hyperthyroidism within a 2-month interval after ATD withdrawal in TRAb-negative nonsmoking patients who have already been treated for 12–24 months is <10% (167,475).

However, the risk of early relapse is very high in patients who have received ATD for less than 6 months and/or still have indicators of high disease activity such as low serum TSH, high TRAb level, signs of active GO, or need of MMI dose in excess of 5–10 mg/d to remain euthyroid (473).

If ATD withdrawal is followed by a relapse of hyperthyroidism, it will often develop gradually over some weeks, but

exact information on such time course in early pregnancy is not available. Therefore, frequent thyroid function testing during the remaining first trimester of pregnancy is recommended until more data on safety become available.

A subset of women with GD will experience relapse of hyperthyroidism in pregnancy if ATD therapy is withdrawn according to Recommendation 81. Frequent testing of thyroid function will allow early detection of such relapse and initiation of therapy with PTU (or MMI if relapse occurs in the second trimester) to keep the mother euthyroid. The risk to the mother from such hyperthyroidism is considered negligible.

Considering the fetus, two recent studies performed in Japan suggest that such transient and mild maternal hyperthyroidism will not increase the risk of malformations. One study observed a significantly lower risk of birth defects in mothers who had been shifted from MMI to iodine therapy in early pregnancy, even if some of the mothers in the iodine group had developed biochemical hyperthyroidism and needed retreatment with ATD (476). In another study from the same institution, the presence of a major birth defect was associated with the use of MMI in early pregnancy but not with maternal thyroid dysfunction (462).

A more pertinent risk may be fetal loss caused by maternal hyperthyroidism in pregnancy (477,478). However, the risk from a brief period of mild maternal thyroid hyperfunction in early pregnancy may be low or absent. In a large cohort of pregnant women from the United States, low or suppressed serum TSH in early pregnancy (presumably mostly caused by early pregnancy high hCG levels) was not associated with adverse pregnancy outcomes (449). In a recent retrospective Japanese study of women with GD either treated with MMI in early pregnancy or shifted from MMI to iodine therapy in early pregnancy, no increase in fetal loss occurred in the iodine group despite more cases of maternal hyperthyroidism in this group (476).

■ RECOMMENDATION 84

We suggest that women who are treated with ATD and who may potentially become pregnant should be instructed to perform a pregnancy test within the first days after a missed or unusually light menstrual period.

Weak recommendation, low-quality evidence.

The period of major risk of birth defects caused by intake of medication in pregnancy is gestational weeks 6–10 (468), and a study of time of exposure to ATD and risk of defects suggests that this time span is also the major period of teratogenic effects of ATD (469). Thus, withdrawal of ATD therapy before week 5 of pregnancy may theoretically prevent birth defects caused by ATD exposure.

The week of pregnancy is calculated starting from the first day of the last normal menstrual period, with conception taking place about 2 weeks after this. The first real sign of pregnancy, a missed or unusually light menstrual period, appears 2 weeks later. By this time, blood and urine concentrations of hCG have started to rise and generally available pregnancy tests based on detection of hCG in urine normally become positive early in gestational week 5. Very early testing for pregnancy to allow medication withdrawal before the major period of teratogenicity is recommended for other types of drugs that may be teratogenic (479).

■ RECOMMENDATION 85

We suggest that a woman who tests positive for pregnancy according to recommendation 84 contact the physician responsible for the ATD therapy within 24 hours to discuss future treatment options.

Weak recommendation, low-quality evidence.

The time window that will allow medication withdrawal or change in early pregnancy to prevent birth defects is narrow (468,469), probably confined to gestational week 5. Thus, pregnancy should be detected early and action has to be taken immediately.

■ RECOMMENDATION 86

We suggest that the physician contacted according to Recommendation 85 evaluate whether ATD withdrawal in the first trimester of pregnancy is likely to cause relapse of hyperthyroidism. Evaluation should be based on patient records, especially the severity of GD at time of diagnosis and current disease activity, duration of ATD therapy, current ATD dose requirement, and results of recent thyroid function and TRAb testing. If risk of relapse is considered low, therapy can be withdrawn and followed by weekly thyroid function testing during the first trimester.

Weak recommendation, low-quality evidence.

In the majority of patients with GD, ATD therapy is followed by a gradual remission of disease with a possibility of disappearance of TRAb from circulation (172). When patients have been treated with ATD for 12–18 months a rapid relapse of hyperthyroidism after ATD withdrawal becomes less likely (119), even if the frequency of relapse may be in the order of 50% within 1 year. The risk of relapse after ATD withdrawal varies considerably among individual patients, and it depends on a variety of factors (473), as already discussed in detail.

■ RECOMMENDATION 87

We suggest that women in early pregnancy who have a high risk of recurrent or worsening hyperthyroidism if ATD is withdrawn be shifted from MMI to PTU immediately after diagnosing pregnancy.

Weak recommendation, low-quality evidence.

Even if birth defects may occur after both MMI and PTU exposure in early pregnancy (463), defects after MMI exposure are better documented. The reason seems to be that MMI-associated defects are more severe, whereas PTU-associated defects tend to be less severe and may not be diagnosed immediately after birth (466). Birth defects associated with both PTU and MMI were seen in the neonates from women who shifted drugs during the first trimester (463). Thus, it is critical to diagnose pregnancy and shift from MMI to PTU as early as possible in the first trimester.

Both MMI and PTU are effective therapies of hyperthyroidism in the majority of patients, and the major effect of both drugs is interaction with thyroid peroxidase–catalyzed thyroid hormone production (109). Apart from the differences in side effects discussed previously, it is important to consider differences in potency per milligram of drug and in duration of effect.

A dosage ratio of MMI to PTU of 1:20 is recommended when changing from one drug to another (115,319,480), although only two studies have examined this dosage ratio directly (115,319). Moreover, the difference in duration of effect should be taken into account. For example, 15 mg of MMI would be roughly equivalent to 300 mg of PTU, but because the half-life of PTU is considerably shorter than that of MMI, the dose of PTU should be split over the day (481,482); for example, MMI 15 mg once daily may be substituted with PTU 100 mg three times a day (319).

■ **RECOMMENDATION 88**

Women taking PTU during the first trimester of pregnancy according to Recommendations 80, 83, or 87 may be switched to MMI at the beginning of the second trimester, or they may continue PTU therapy for the remaining part of pregnancy if ATD is needed.

No recommendation; insufficient evidence to assess benefits and risks.

The reason for the FDA black box warning against PTU therapy after the first trimester of pregnancy is the risk of PTU-associated liver failure. However, even if this risk is real, the absolute risk observed in studies of U.S. health databases was low (433,465). Similarly, a recent Danish national registry study observed one case of reversible liver failure among 1103 women treated with PTU in pregnancy (129).

The risk of side effects from PTU should be weighed against the risk of the shift from PTU to MMI inducing a transient thyroid function abnormality in the pregnant woman who is doing well on PTU therapy. Starting from the second trimester of pregnancy, women with GD may start entering gradual remission of the autoimmune abnormality, and full focus should be on the feasibility of ATD dose reduction to protect the fetus against goiter and hypothyroidism, as discussed below. Patients who remain on PTU during the second and third trimesters could have hepatic enzymes measured at the same time that thyroid function is assessed. However, no prospective data show that this type of monitoring is effective in preventing fulminant PTU-related hepatotoxicity. Another aspect to consider is that both agranulocytosis and liver failure developing during MMI and PTU therapy mostly occur during the initial 3 months of therapy (128), but this risk can recur when the drug is reintroduced after a relatively long period of time (177). For example, in a Japanese study (177) of 14 patients who developed agranulocytosis after retreatment with the same ATD, no patient who restarted the drug less than 5 months after stopping the previous course of therapy developed this adverse reaction. There are no data to directly evaluate how shifting from PTU to MMI in the second trimester of pregnancy will affect the risk of these severe, but rare side effects.

Other medical treatments for hyperthyroidism during pregnancy. Other types of medical therapy have been used to treat hyperthyroidism, such as iodine, perchlorate, cholestyramine, cholecystographic agents, and lithium.

Iodine in supraphysiological doses has multiple mostly inhibitory effects on the thyroid, and it has with some success been used to treat hyperthyroid women in pregnancy in Japan. In one study, cord and maternal sera were tested at delivery in 35 patients with GD treated with iodine (6–40 mg/d) initiated at 11–37 weeks of gestation. Similar to ATD therapy, thyroid function at term tended to be lower in the fetus than in the mother, but overall results of therapy were judged satisfactory, with a low risk of inducing hypothyroidism and goiter in the fetus; only 1 of 35 neonates had subclinical hypothyroidism at birth (483). In a recent study, outcomes of pregnancy in 1333 women who had continued ATD in early pregnancy were retrospectively compared with 283 women who had shifted from ATD to iodine (median gestational week of shift was week 6, range 4–12) (476). Overall, shifting has been more common in recent years. The prevalence of major birth defects was lower in the women who had shifted to iodine therapy (1.53% vs. 4.14%, $p < 0.05$). However, according to the authors, some degree of hyperthyroidism was relatively common after shifting, and free T_4 levels were always higher in the group that had shifted to iodine. Despite this, live births were more common in the group that had shifted than in the group that had continued MMI therapy (91.9% vs. 85.1%, $p < 0.05$). In the publication, data on thyroid function in the MMI group are sparse, but the study may indicate that a brief period of mild hyperthyroidism in the mother will not impair pregnancy.

No recent data on iodine therapy for GD in pregnancy are available from outside Japan, but before ATDs became available, experience with iodine therapy for GD in general was extensive (484), and it corresponds to the more recent Japanese studies. The minimal effective dose of iodine was around 6 mg/d, but most patients received higher doses (484). Iodine was effective for therapy of hyperthyroidism in patients with mild GD, but clearly less effective than ATD in patients with more severe disease (484). Additional data are needed before iodine therapy of pregnant women with GD can be generally recommended.

Perchlorate is a competitive inhibitor of iodine uptake by the thyroid, and a few cases have been published in which it was used in pregnancy (485). Apparently, teratogenicity of perchlorate has not been demonstrated (486), but more clinical studies on this are clearly needed. Further, this drug is not available in the United States.

Cholestyramine binds thyroid hormones in the gut during their enterohepatic recirculation and has been used to treat hyperthyroidism, mostly in combination with other drugs (487,488). Cholestyramine is not absorbed from the gut, and it is not expected to affect the fetus directly. However, binding in the gut and excretion of vitamins and other substances of importance for pregnancy are concerns and have led to a note of caution by the FDA. Cholecystographic drugs are not generally available any more. Lithium may be teratogenic (489) and it should not be used to treat hyperthyroidism in pregnancy.

■ **RECOMMENDATION 89**

GD during pregnancy should be treated with the lowest possible dose of ATD needed to keep the mother's thyroid hormone levels at or slightly above the reference range for total T_4 and T_3 values in pregnancy (1.5 times above nonpregnant reference ranges in the second and third trimesters), and the TSH below the reference range for pregnancy. Similarly, free T_4 levels should be kept at or

slightly above the upper limit of the pregnancy trimester reference range for the assay. Thyroid function should be assessed at least monthly, and the ATD dose adjusted, as required.

Strong recommendation, low-quality evidence.

Even if the mother is euthyroid during ATD therapy, a risk of inducing fetal hypothyroidism and goiter during the second and third trimesters exists when the fetal thyroid has begun to function (490,491). Thus, the dose of ATD should be kept as low as possible. Block-replacement therapy consisting of ATD plus levothyroxine should not be used in pregnancy. If a woman receiving such therapy becomes pregnant, and she is still in need of ATD therapy, the regimen should be changed to an ATD alone (444).

Technical remarks: Free T_4 is the parameter that has been most closely correlated with good fetal outcome. Serum TSH may still be suppressed in these patients and should not be used as the sole guide in treatment, although normalization of maternal TSH during ATD therapy may indicate a need to reduce the dose of ATD (444). In Japanese studies, ATD-treated maternal free T_4 values were kept above the nonpregnancy reference range in the last part of pregnancy to avoid cases of elevated TSH in newborn cord blood (458,491). However, with some automated free T_4 assays nonpregnancy free T_4 is much higher than late pregnancy free T_4 (446,492). Thus, maternal free T_4 above the nonpregnancy reference with suppressed TSH may leave the mother overtly hyperthyroid, which is not recommended.

Although many patients with GD may enter remission of the autoimmune abnormality during the second half of pregnancy with a need of ATD dose reduction or withdrawal, this is not a universal phenomenon. A small group of patients experiences severe disease that may even progress during pregnancy, with difficult-to-treat hyperthyroidism, high TRAb levels, and often a considerable goiter with high blood flow. Such patients may show a ''high T_3–low T_4 pattern'' during ATD therapy (444) presumably caused by a high type 1 deiodinase activity in the hyperactive thyroid (493) and preferential T_3 synthesis in the hyperstimulated thyroid made iodine deficient from ATD therapy (494). Maternal thyroid function should be monitored frequently and noninvasive assessment of fetal thyroid function (e.g., fetal heart rate, bone maturity, and fetal goiter on ultrasound), and ATD therapy balanced to keep acceptable thyroid function in both the mother and the fetus (444).

■ RECOMMENDATION 90

Pregnancy is a relative contraindication to thyroidectomy and should only be used when medical management has been unsuccessful or ATDs cannot be used.

Strong recommendation, low-quality evidence.

In a population-based U.S. study, pregnant women had worse clinical and economic outcomes following thyroid (and parathyroid) surgery than nonpregnant women, with disparities in outcomes based on race/ethnicity, insurance, and access to high-volume surgeons (68).

■ RECOMMENDATION 91

When thyroidectomy is necessary for the treatment of hyperthyroidism during pregnancy, the surgery should be performed if possible during the second trimester.

Strong recommendation, low-quality evidence.

Thyroidectomy is best avoided in the first and third trimesters of pregnancy because of teratogenic effects associated with anesthetic agents and increased risk of fetal loss in the first trimester and increased risk of preterm labor in the third. Optimally, thyroidectomy would be performed in the latter portion of the second trimester. Although it is the safest time, it is not without risk (4.5%–5.5% risk of preterm labor) (67,68).

Evaluation by a high-risk obstetrician is advised along with counseling before surgery regarding the risks involved (68). Thyroidectomy cures the hyperthyroidism and is often followed by a gradual reduction in circulating TRAb (495). Until such remission takes place, TRAb produced by the mother may stimulate the thyroid of the fetus or newborn and induce hyperthyroidism. In the setting in which the mother still harbors TRAb after thyroidectomy, close fetal monitoring for both cardiovascular and skeletal changes with fetal ultrasound is essential.

There are no data concerning whether SSKI or iodine should be used to prepare pregnant patients for thyroidectomy. The risk of iodide therapy to the fetus relates to inhibition of iodine organification via the Wolff–Chaikoff effect. The fetal thyroid gland is particularly susceptible to the inhibitory effects of excess iodine in the second half of gestation, and fetal goiter can occur with chronic therapy (496). However, there is no evidence that brief iodine preparation of the mother done preoperatively to reduce thyroid blood flow and control hyperthyroidism is harmful to the fetus.

Technical remarks: In patients with difficult-to-treat hyperthyroidism, preoperative preparation for thyroidectomy during the second trimester of pregnancy includes 10 days of iodine (e.g., SSKI one drop three times a day), along with ATD therapy and β-blockers [propranolol or metroprolol, but not atenolol (450,451)] to control hyperthyroidism (497–499). In euthyroid patients with no signs of high thyroid activity, but who are offered surgical thyroidectomy for other reasons (e.g., intolerance to ATD), the use of iodine for surgical preparation is considered unnecessary.

[T3] The role of TRAb level measurement in pregnancy

■ RECOMMENDATION 92

TRAb levels should be measured when the etiology of hyperthyroidism in pregnancy is uncertain.

Strong recommendation, low-quality evidence.

The two best indicators of the activity of GD during pregnancy are thyroid function in the untreated patient and measurement of TRAb levels in the serum. TRAb measurement is useful in the diagnosis of GD in pregnant women with newly diagnosed hyperthyroidism who do not have clinical signs specific for GD, keeping in mind that the diagnostic sensitivity of good assays is around 95% and the specificity is 99% (47).

■ **RECOMMENDATION 93**

Patients who were treated with RAI or thyroidectomy for GD prior to pregnancy should have TRAb levels measured using a sensitive assay initially during the first trimester thyroid function testing and, if levels are elevated, again at 18–22 weeks of gestation.

Strong recommendation, low-quality evidence.

Measurement of TRAb levels can detect persistent TSH receptor autoimmunity in a pregnant woman previously treated with ablative therapy (RAI or thyroidectomy) for GD who is now euthyroid with or without thyroid hormone replacement (495,500). If the mother still produces TRAb, the antibodies will cross the placenta and may affect fetal thyroid function in the last half of the pregnancy. Because of the slow clearance of maternal immunoglobulin G from the neonatal circulation, thyroid dysfunction in the child may last for several months after birth. To evaluate the risk of such complications, the TRAb level should be measured in the pregnant woman initially during the first trimester and, if it is elevated, again at 18–22 weeks of gestation. If the level is high, a program of fetal and neonatal surveillance for thyroid dysfunction should be initiated (501).

The advantage to initial TRAb measurement during the first trimester is that it allows time to initiate specialty consultation and, if the levels are especially high at that time, intervention may be required by the second trimester. Whereas it has generally been considered that isolated fetal thyrotoxicosis in a previously ablated mother who is still producing TRAb might only start developing around weeks 20–22 of pregnancy, a recent case report described severe fetal thyrotoxicosis that had already developed in gestational week 18 (502). The pregnant woman had previously undergone unsuccessful RAI, and a total thyroidectomy had subsequently been performed, followed by levothyroxine replacement. The mother was euthyroid, but her TRAb values remained extremely elevated.

TRAb measurement is not necessary in a euthyroid pregnant patient previously found to have GD if she has an intact thyroid (i.e., not previously treated with surgery or RAI) and she is not currently taking ATDs (495,503).

■ **RECOMMENDATION 94**

Patients receiving ATD for GD when becoming pregnant or found to have GD during pregnancy should have TRAb levels measured at initial pregnancy visit or at diagnosis using a sensitive assay and, if they are elevated, again at 18–22 weeks of gestation.

Strong recommendation, low-quality evidence.

TRAb (TBII or TSI) measurement may be useful to assist in the evaluation of disease activity in a woman being treated with ATDs for GD during pregnancy (444,495). In many patients, GD gradually remits during pregnancy. Disappearance of TRAb is an indication that ATD therapy may no longer be necessary and its continuation may put the fetus at risk for hypothyroidism, even if the mother is euthyroid on the medication.

■ **RECOMMENDATION 95**

Patients with elevated TRAb levels at 18–22 weeks of gestation should have TRAb remeasured in late pregnancy (weeks 30–34) to guide decisions regarding neonatal monitoring. An exception to this recommendation is a woman with an intact thyroid who is no longer in need of ATD therapy.

Strong recommendation, low-quality evidence.

TRAb measurement in late pregnancy can be used to assess the risk of delayed neonatal hyperthyroidism, when the mother continues to need ATD to control hyperthyroidism up to term. After delivery, ATD delivered to the fetus via placental passage is rapidly metabolized by the neonate, whereas the maternal TRAb disappears more slowly, with a half-life of around 3 weeks. Thus, a high level of TRAb in the mother in late pregnancy is an indicator that the neonate may need to be monitored for the onset of neonatal hyperthyroidism starting a few days after birth. In a recent study of 47 newborns to mothers who were TRAb positive in pregnancy, nine of the children had neonatal biochemical hyperthyroidism, and five of these (9% of all) needed ATD therapy. All hyperthyroid neonates were born to mothers with TRAb levels ≥5 IU/L (>3 times upper reference for the assay) in the second trimester (sensitivity 100%, specificity 43%). All mothers who gave birth to hyperthyroid newborns required ATD therapy in late pregnancy (504).

[T4] Postpartum thyroiditis

■ **RECOMMENDATION 96**

In women developing thyrotoxicosis after delivery, selective diagnostic studies should be performed to distinguish postpartum destructive thyroiditis from postpartum GD.

Strong recommendation, low-quality evidence.

Postpartum thyroid dysfunction occurs in up to 10% of pregnancies in the United States. Postpartum thyroiditis is an autoimmune disorder unmasked in predisposed women as immune surveillance rebounds after pregnancy. The classic triphasic pattern is thyrotoxicosis at 1–6 months postpartum, followed by hypothyroidism and return to euthyroidism at 9–12 months postpartum (505,506). However, this sequence is not observed in every patient. Among 371 cases in 13 studies, 25% of patients were found to have a triphasic pattern, 43% had hypothyroidism without preceding thyrotoxicosis, and 32% had thyrotoxicosis without subsequent hypothyroidism (506). In a prospective study of pregnant women, those with positive anti–thyroid peroxidase antibodies in the first trimester were 27 times more likely to develop postpartum thyroiditis than were those with negative serology (507). In this study, tobacco smoking and bottle-feeding increased the risk of developing thyroiditis.

Postpartum thyroiditis must be distinguished from GD to recommend proper therapy. The postpartum surge in thyroid autoimmunity leading to postpartum thyroiditis is also associated with a 3- to 4-fold increase in the incidence of GD that peaks 3–12 months after delivery (456). In a Japanese hospital study, thyrotoxicosis caused by thyroiditis developed earlier after delivery than GD, although some overlap existed. All patients who developed overt thyrotoxicosis within the first 3 months after delivery suffered from destructive thyroiditis, whereas GD developed after this

3-month period (508). Goiter is generally more pronounced in GD, and thyroid bruit or GO strongly suggest GD as well. TRAb may occasionally be measurable in patients with postpartum thyroiditis, suggesting that some patients may experience a combination of GD and destructive thyroiditis (509), but higher TRAb values are suggestive of GD. When *in vivo* testing is required to make this distinction in women who are nursing, the gamma-emitters ^{123}I (half-life 13 hours) or ^{99m}Tc pertechnetate (half-life 6 hours) should be used rather than the β-emitter ^{131}I (half-life 8 days). The shorter half-lives of these agents (510) will allow breast milk to be pumped and discarded for 10 half-lives (5 or 3 days, respectively) and nursing resumed, whereas breastfeeding should ideally be discontinued 3 months prior to ^{131}I administration to avoid radiation exposure to the breast and not be resumed if ^{131}I is given as treatment for GD (511).

Most often, the use of radioactive substances can be avoided and the diagnosis can be based on a combination of clinical presentation, TRAb measurement, and evaluation of serum T_4 and T_3. Thyroidal production of T_3 compared with T_4 is relatively high in GD, but not in destructive thyroiditis, and T_3 tends to be fractionally more elevated above the upper reference limit compared with T_4 in GD, whereas T_4 is more elevated than T_3 in destructive thyroiditis (50). If needed, thyroid color Doppler ultrasonography may assist in distinguishing between destructive thyroiditis and GD (508,512,513).

■ **RECOMMENDATION 97**

In women with symptomatic thyrotoxicosis from postpartum destructive thyroiditis, the judicious use of β-adrenergic blocking agents is recommended.

Strong recommendation, low-quality evidence.

Treatment for postpartum thyroiditis is generally supportive in nature, with the use of β-adrenergic blockers such as propranolol or metroprolol to control pulse rate and hyperadrenergic symptoms during the thyrotoxic stage (514). The selective β-1 adrenergic receptor-blocking agent atenolol should not be used in breastfeeding mothers because it may lead to symptoms consistent with β-adrenergic blockage in neonates. This adverse effect presumably develops because atenolol is <5% bound to maternal plasma proteins (vs. 93% binding of propranolol), and thus accumulates in milk, and because of low kidney excretion of atenolol in small children with immature renal function (515). Levothyroxine therapy may be beneficial, at least transiently, for women with symptomatic hypothyroidism or those having TSH levels >10 mU/L (506).

Technical remarks: Because propranalol and metoprolol are secreted into breast milk in only very low amounts, no special monitoring is needed for breastfed infants of mothers on these medications (514).

■ **RECOMMENDATION 98**

In pregnant women diagnosed with hyperthyroidism due to multinodular thyroid autonomy or a solitary TA, special care should be taken not to induce fetal hypothyroidism by ATD therapy.

Strong recommendation, low-quality evidence.

Hyperthyroidism caused by thyroid autonomy is very common in people having current (or previous) mild to moderate iodine deficiency (13), but it mostly develops in patients after the age of 50 years. In the uncommon case of this type of hyperthyroidism in a pregnant woman, pathogenic differences from GD should be considered.

Thyroid hormone production in autonomy is dependent on iodine substrate, but no study has addressed the effect of a change in iodine intake on thyroid function in pregnant women with autonomy or on the fetus. It might be beneficial to keep iodine intake on the low side, but care must be taken that the fetus is not iodine deficient, especially in areas where the population is iodine deficient. The degree of maternal hyperthyroidism and assessment of her diet should be considered before deciding whether to administer iodine supplements. Hormone overproduction is often limited in patients with autonomy (50). In mild cases, a theoretical possibility exists that the normal pregnancy-associated increase in thyroid hormone production may catch up with the hormone production in the autonomous areas of the thyroid and alleviate the need for ATD therapy. However, the high hCG levels in early pregnancy may theoretically stimulate the nonfunctioning normal thyroid tissue in these patients and worsen hyperthyroidism. Because there is no TRAb production, the fetal thyroid will not be abnormally stimulated in the second half of pregnancy as it is in GD. Thus, the fetus will not develop hyperthyroidism in parallel with the untreated hyperthyroid mother as it happens during the second half of pregnancy in GD, and neonatal hyperthyroidism is not a risk. However, the tendency to induce fetal hypothyroidism and goiter in the second half of pregnancy from ATDs given to the mother would be even higher in this type of hyperthyroidism than in GD. Based on this theoretical risk, surgical therapy in the second trimester of pregnancy may be considered if the hyperthyroidism turns out to require more than low dose MMI (5–10 mg/d) for control. No firm recommendations are given because no good evidence is available.

[U] How should hyperthyroidism be managed in patients with GO?

GO is an inflammatory eye disease that develops in the orbit in association with autoimmune thyroid disorders (516). In the majority of cases (about 90%), it occurs in patients with current or past GD. Thyroid-associated orbitopathy, thyroid eye disease, and Graves' ophthalmopathy are other names used for GO. Approximately a third of patients with Graves' hyperthyroidism have some signs and/or symptoms of GO, while only 5% have moderate-to-severe disease (517,518). In contrast to GD, for which women are at higher risk, the role of sex in GO is more controversial. More recent studies do not identify a clear sex-related risk for GO (517,518), while some older studies point to a possible slightly increased risk for men (519,520). This variability in results might be related to changes in smoking patterns over the years. The disease peaks in incidence in the fifth and sixth decade of life (517,518,521,522) with a higher prevalence of severe cases in the elderly population (517).

[U1] Assessment of disease activity and severity

The natural history of the disease is one of rapid deterioration followed by gradual improvement toward the baseline. This active phase is best described by the clinical activity score (CAS) (523,524), the elements of which are outlined in

TABLE 12. ASSESSMENT OF GRAVES' ORBITOPATHY: CLINICAL ACTIVITY SCORE ELEMENTS[a]

Elements[b]	*Each visit*	*Comparison with previous visit*	*Score*
Painful feeling behind the globe over last 4 weeks	X		1
Pain with eye movement during last 4 weeks	X		1
Redness of the eyelids	X		1
Redness of the conjunctiva	X		1
Swelling of the eyelids	X		1
Chemosis (edema of the conjunctiva)	X		1
Swollen caruncle (flesh body at medial angle of eye)	X		1
Increase in proptosis ≥2 mm		X	1
Decreased eye movements ≥5° any direction		X	1
Decreased visual acuity ≥1 line on Snellen chart		X	1

[a]Sources: Adapted from Mourits *et al.* (523,524).
[b]A 7-point scale (excluding the last three elements) is used when no previous assessment is available. GO is considered active in patients with a clinical activity score (CAS) ≥3.

Table 12. The score ranges from 0 to 10 and predicts response to anti-inflammatory therapies (523,524). A 7-point scale, lacking the last three elements, is used when no previous assessment is available. GO is considered active in patients with a CAS ≥3. However, some of the eye changes seen in hyperthyroidism, like lid retraction or stare, result from the increased sympathetic state, and when present without associated eye changes, they are not considered to reflect GO (69).

The severity of the disease is best assessed using objective, quantifiable parameters and is a useful tool for directing therapy. The main gradations of disease severity are mild, moderate-to-severe, and sight threatening (525). Table 13 lists the elements as agreed upon in a consensus statement by the European Group on Graves' Orbitopathy (525). Both activity and severity of the disease must be considered in therapeutic decisions regarding treatment of the eye disease itself, as well as treatment of hyperthyroidism, keeping in mind that they do not always correlate, particularly in early and late disease. The overall evaluation and management of GO is best done in a multidisciplinary clinic combining endocrinologists and ophthalmologists with expertise in the condition and other specialties in consultation (e.g., ENT, radiation therapy, plastic surgery, and endocrine surgery).

Quality of life is clearly impaired by GO (526). The FDA has endorsed QoL information as a component of any therapeutic application. The QoL correlation with disease severity has been fair to excellent for two GO specific instruments published to date in North American populations (527,528), though the effect of GO therapy on these QoL scores still needs prospective data. Presently, the only instrument that has such data is the instrument extensively used in Europe (529), which has not yet been tested in a North American population. Overall, this area is in need of more research emphasis because, despite its agreed-upon importance, a significant number of intervention trials in GO are still being reported without associated QoL outcomes (530).

The prevention of GO and the management of hyperthyroidism in patients having established GO is discussed in the remainder of Section [U]. In particular, we focus on recommendations regarding the concurrent use of corticosteroids in patients choosing RAI as treatment for hyperthyroidism (Table 14).

[U2] Prevention of GO

Current therapeutic approaches to GO, including local measures, corticosteroids, orbital radiation, and surgery (525), often fail to significantly improve the QoL of patients with this debilitating condition. Therefore, efforts should be made to prevent the development or progression of GO in patients with Graves' hyperthyroidism. Identified risk factors

TABLE 13. GRAVES' ORBITOPATHY SEVERITY ASSESSMENT[a]

Grade[b]	*Lid retraction*	*Soft tissues*	*Proptosis*[c]	*Diplopia*	*Corneal exposure*	*Optic nerve status*
Mild	<2 mm	Mild involvement	<3 mm	Transient or absent	Absent	Normal
Moderate	≥2 mm	Moderate involvement	≥3 mm	Inconstant	Mild	Normal
Severe	≥2 mm	Severe involvement	≥3 mm	Constant	Mild	Normal
Sight threatening	—	—	—	—	Severe	Compression
Upper limits of normal						
African American		F/M = 23/24 mm				
White		F/M = 19/21 mm				
Asian		F/M = 16/17 mm (Thai) or 18.6 mm (Chinese)				

[a]Sources: Adapted from de Juan *et al.* (676), Sarinnapakorn *et al.* (677), Tsai *et al.* (678), and Bartalena *et al.* (525).
[b]Mild GO: patients whose features of GO have only a minor impact on daily life, generally insufficient to justify immunosuppressive or surgical treatment. Moderate-to-severe GO: patients without sight-threatening GO whose eye disease has sufficient impact on daily life to justify the risks of immunosuppression (if active) or surgical intervention (if inactive). Sight-threatening GO: patients with dysthyroid optic neuropathy and/or corneal breakdown. This category warrants immediate intervention.
[c]Proptosis refers to the variation compared to the upper limit of normal for each race/sex or the patient's baseline, if available.

Table 14. Use of Oral Glucocorticoids for Prevention of Graves' Orbitopathy Development or Progression When Radioactive Iodine Is Used to Treat Graves' Hyperthyroidism[a]

	Recommendation	*RAI without glucocorticoids*	*RAI with oral glucocorticoids*
No GO (nonsmoker)	101	Recommend	Recommend against
No GO (smoker)	103	Insufficient data to recommend for or against	
GO present, active and mild (risk factors absent)	105	Acceptable[b]	Acceptable[b]
GO present, active and mild (risk factors present)	106	Recommend against	Recommend
GO present, active and moderate-to-severe or sight-threatening	107	Recommend against	Recommend against
GO present, inactive	108	Recommend	Recommend against

[a]ATDs or thyroidectomy are also recommended treatment options in each of these scenarios, and they are the preferred choice of therapy in patients with active and moderate-to-severe or sight-threatening GO.
[b]The decision regarding use of concurrent glucocorticoids should be made in light of the risk–benefit ratio relative to the patient's overall health. Risk factors for GO deterioration (high TRAb level, smoking) increase the benefit of glucocorticoids in preventing GO deterioration. Poorly controlled diabetes, osteoporosis, psychiatric illness, and high risk for infections increase the likelihood of complications from glucocorticoids.

for GO are listed in Table 15, and the most pertinent ones to this discussion are RAI therapy for hyperthyroidism (531,532), untreated hyperthyroidism, smoking, high serum pretreatment TRAb levels (normal <1.75 IU/L, high risk for progression if >8.8 IU/L) (533), and any delay in treating hypothyroidism after therapy for hyperthyroidism (106,534). High pretreatment levels of T_3 and T_4 were each reported to have a predictive role in GO, but these conclusions were not validated by subsequent studies (69,106,532,534), suggesting the possibility of higher TRAb values measured on less sensitive assays early-on being partly responsible for this variation.

■ RECOMMENDATION 99

Euthyroidism should be expeditiously achieved and maintained in hyperthyroid patients with GO or risk factors for the development of orbitopathy.

Strong recommendation, moderate-quality evidence.

A number of studies have suggested that development of persistent, untreated hypothyroidism after therapy for hyperthyroidism plays a detrimental role in the progression of GO. An early study noted that patients who were either hypo- or hyperthyroid had more severe GO than euthyroid patients (535). Subsequently, two cohort studies in which patients received levothyroxine therapy early after RAI with the specific intent of preventing hypothyroidism noted that deterioration of GO rarely occurred (0%–2%) (534,536). A randomized study of newly diagnosed GD found that RAI followed by active prevention of hypothyroidism by administration of thyroid hormone 2 weeks later did not increase the risk of worsening GO compared to therapy with MMI (relative risk [RR] of 0.95) (69).

■ RECOMMENDATION 100

We recommend clinicians advise patients with GD to stop smoking and refer them to a structured smoking cessation program. As both firsthand and secondhand smoking increase GO risk, patients exposed to secondhand smoke should be identified and advised of its negative impact.

Strong recommendation, moderate-quality evidence.

Smoking is the most important known risk factor for the development or worsening of GO, unrelated to type of therapy for GO (535), and consistent data from several studies show a detrimental effect of smoking on GO in patients

Table 15. Risk Factors for Graves' Orbitopathy

Risk factor	*Amenable to intervention*	*Comments*
Age	No	Advanced age, risk for more severe GO.
Sex	No	GO is more frequent in women (as GD is); more severe in men.
Genetics/ancestry	No	Highest prevalence of GO in Caucasians, lowest in Asians. Immunomodulatory genes likely involved.
Mechanical factors	No	Noted wider lateral wall orbital angle in GO.
TSH receptor antibody	No[a]	Predicts GO risk and GO therapy response.
Smoking	Yes	Increases GO progression and decreases therapy efficacy. Smoking-cessation clinics favored for intervention.
Thyroid dysfunction	Yes	Need for expeditious control of hyperthyroidism then prevention of hypothyroidism post GD therapy.
RAI therapy	Yes	Risk is additive to smoking; increased with preexistent and active GO; preventable by glucocorticoids 6–12 weeks post RAI.

[a]Decreased TRAb noted with methimazole therapy yet available data are unable to separate that change from the natural history of GO with improving TRAb.

treated with RAI (69,531). The risk is proportional to the number of cigarettes smoked per day, and former smokers have significantly lower risk than current smokers, even after adjusting for lifetime cigarette consumption (537).

Technical remarks: Clinicians should use smoking cessation programs based on effective and evidence-based approaches to aid in smoking cessation and avoidance of secondhand smoke (538,539).

[U3] Treatment of hyperthyroidism in patients with no apparent GO

■ **RECOMMENDATION 101**

In nonsmoking patients with GD without apparent GO, RAI therapy (without concurrent steroids), ATDs, or thyroidectomy should be considered equally acceptable therapeutic options in regard to risk of GO.

Strong recommendation, moderate-quality evidence.

Several randomized trials have identified the risk of GO development or progression after RAI therapy for hyperthyroidism to be between 10% and 39% (69,540). With regard to the risk of new GO development, that risk appears to be lower. Two randomized controlled trials found the risk to be 6/78 (8%) for RAI compared with 1/74 (1%) for ATDs (531) in one study, and 10/32 (32%) for RAI compared with 6/56 (11%) for ATDs and 6/58 (10%) for surgery (532) in the older study. Fortunately, the cases of new or worse GO were usually mild, with only 6/168 patients in this second trial (four in the RAI group, one in the ATD group, and one in the surgical group) requiring specific therapy for GO. In contrast, one prospective but nonrandomized cohort study identified no difference among ATD, surgery, and RAI treatment, with an overall 4.9%–7.1% frequency of GO development (541). The higher risk of GO development after RAI therapy in the majority of studies may be related to the unique increase in TRAb levels observed following this therapy (172). Experimental evidence suggests that these antibodies are directly involved in GO pathogenesis (516,542,543).

There is evidence that corticosteroids given concurrently with RAI may prevent worsening of GO in patients with mild active eye disease (531). However, the evidence is insufficient for recommending prophylactic treatment with corticosteroids in nonsmoking patients who do not have clinically apparent GO. The relatively low absolute risk of nonsmokers developing new-onset severe GO suggests that GO prevention should not be a factor in the selection of therapy for hyperthyroidism in this group of patients (531). Table 14 further details the use of glucocorticoids for various GO clinical scenarios.

■ **RECOMMENDATION 102**

In smoking patients with GD without apparent GO, RAI therapy, ATDs, or thyroidectomy should be considered equally acceptable therapeutic options in regard to risk of GO.

Weak recommendation, low-quality evidence.

■ **RECOMMENDATION 103**

There is insufficient evidence to recommend for or against the use of prophylactic corticosteroids in smokers who receive RAI and have no evidence of GO.

No recommendation, insufficient evidence.

However, in two different studies, active smokers who received RAI represented the group with the highest incidence (23%–40%) of new GO or deterioration of pre-existing GO during 1 year of follow-up (69,531).

[U4] Treatment of hyperthyroidism in patients with active GO of mild severity (see Tables 12 and 13 for definitions of disease activity and severity)

■ **RECOMMENDATION 104**

In patients with Graves' hyperthyroidism who have mild active ophthalmopathy and no risk factors for deterioration of their eye disease, RAI therapy, ATDs, and thyroidectomy should be considered equally acceptable therapeutic options.

Strong recommendation, moderate-quality evidence.

■ **RECOMMENDATION 105**

In the absence of any strong contraindication to GC use we suggest considering them for coverage of GD patients with mild active GO who are treated with RAI, even in the absence of risk factors for GO deterioration.

Weak recommendation, low-quality evidence.

Technical remarks: The decision on whether to administer concurrent glucocorticoids in a particular patient choosing RAI therapy should be made in light of risk–benefit considerations (i.e., their personal risk of worsening GO, balanced against their risk of developing glucocorticoid side effects). Risk factors for side effects of oral corticosteroids include poorly controlled diabetes, hypertension, osteoporosis, psychiatric disease, and predisposition to infections. Smokers in whom the risk–benefit ratio for the concurrent use of corticosteroids is high may be better treated with ATDs or surgery. Besides smoking, the main risk factors for deterioration of GO to be considered in this decision include active and progressive GO over the preceding 3 months and high serum pretreatment TRAb levels (normal <1.75 IU/L, high risk for GO progression if >8.8 IU/L) (see Table 15).

The dose of corticosteroids validated in a randomized clinical trial for GO prophylaxis is the equivalent of prednisone 0.4–0.5 mg/kg per day, started 1–3 days after RAI administration, continued for 1 month, and then tapered over 2 months (525). However, a retrospective cohort study suggested that even lower doses and shorter duration of oral prednisone (about 0.2 mg/kg per day for 6 weeks) may be equally effective for prevention of GO exacerbation in patients with initially mild or absent eye disease, (544). Currently most task force members use a minimum starting dose of 30 mg prednisone daily and tapering off within 6–8 weeks. Table 14 details further the use of glucocorticoids for various GO clinical scenarios.

■ **RECOMMENDATION 106**

In GD patients with mild GO who are treated with RAI we recommend steroid coverage if there are concomitant risk factors for GO deterioration.

Strong recommendation, moderate-quality evidence.

Unfortunately, the initial data regarding the impact of various GD therapies on GO outcome were affected by the

absence of GO activity assessment and lack of stratification on smoking status at randomization as well as by variation in the timing of tackling post-RAI hypothyroidism. Two early nonrandomized studies found no differences between the three GD therapeutic modalities (541,545).

The first randomized study of GD patients (13% with mild preexistent GO) assigned to therapy for hyperthyroidism with ATDs, surgery, or RAI (532) found the relative risk for deterioration of eye disease to be elevated at 3.2 for RAI compared to ATDs. There appeared to be no difference in such risk between ATDs and surgery. A large, more recent randomized controlled trial studying mainly patients with previously treated GD showed RAI therapy to be associated with an increased risk of GO progression (RR of 5.8 in comparison with ATDs) and found the risk to be eliminated with concurrent corticosteroid administration (531). Finally, the most recent randomized controlled trial (69) revealed an increased risk for new or worse GO in RAI-treated patients (38.7% of the group) compared with ATD-treated patients (21.3% of the group), to be mainly related to development of new GO cases, while worsening of preexisting GO occurred at a similar percentage in both groups (45% for RAI and 47% for ATD). Smoking was a strong risk factor for an undesirable GO outcome. In this last trial there was no routine use of prophylactic glucocorticoids. Table 14 further details the use of glucocorticoids for various GO clinical scenarios.

[U5] Treatment of hyperthyroidism in patients with active and moderate-to-severe or sight-threatening GO (see Tables 12 and 13 for definitions of disease activity and severity)

■ **RECOMMENDATION 107**

In patients with active and moderate-to-severe or sight-threatening GO we recommend against RAI therapy. Surgery or ATDs are preferred treatment options for GD in these patients.

Strong recommendation, low-quality evidence.

We are aware of no trials in patients with moderate-to-severe and active eye disease that compare hyperthyroidism therapies for impact on GO. However, a comparison of two different surgical approaches (total thyroidectomy vs. subtotal thyroidectomy) for patients with moderate-to-severe GO showed that the eye disease improved during 3 years of follow-up in all patients (546). In another series of 42 patients with progressive GO treated with total thyroidectomy, exophthalmos was stable in 60% of cases and improved in the remainder (547), suggesting that surgery is not detrimental to GO and may be associated with improvement in some patients. Additionally, a more recent study suggests that surgery might lead to a more rapid improvement in GO than ATDs, and it might thus be a better option for patients that are most concerned about GO changes (548). Other studies suggest that ATDs may not adversely impact mild active GO, but they do not address severe GO (531).

Alternatively, if ATDs are selected for GD therapy, there are reassuring data that long-term use is relatively safe and effective at preserving euthyroidism while waiting for GO to enter remission (66,549).

[U6] Treatment of GD in patients with inactive GO (see Table 12 for definition of disease inactivity)

■ **RECOMMENDATION 108**

In patients with inactive GO we suggest RAI therapy can be administered without steroid coverage. However, in cases of elevated risk for reactivation (high TRAb, CAS ≥1 and smokers) that approach might have to be reconsidered.

Weak recommendation, low-quality evidence.

There is a low rate of GO progression or reactivation following RAI in patients with inactive GO. A series of 72 patients with inactive GO according to the CAS were treated with RAI without concurrent glucocorticoid administration (536). For those in whom hypothyroidism was prevented by early thyroxine therapy, no deterioration in eye disease was reported (536). Smoking history did not impact GO outcome in this cohort. A recent trial from Japan (540) randomized patients without GO or inactive GO (i.e., CAS <3 or T2-weighted imaging T2SIR ≤1) to receive either glucocorticoid prophylaxis with low-dose prednisolone (on average 0.28 mg/kg per day tapered rapidly over 6 weeks) or no prophylaxis at all. The rate of disease progression in the absence of risk factors was low (4.2%) and not impacted by glucocorticoid therapy. The presence of risk factors for GO (high thyroid stimulating antibody, CAS ≥1) increased that risk, again without a benefit from low-dose steroid prophylaxis. Ultimately, most GO cases were mild, and only 7 cases (2.4%) required GO-directed therapy. Whether high-dose glucocorticoid therapy would have made a difference in these patients is not known.

Another study retrospectively examined the effect of concurrent oral or intravenous glucocorticoid therapy on the development or deterioration of preexistent GO after RAI therapy for relapsing GD patients (550). They identified GO development, deterioration, or reactivation in approximately 7% of patients (6/83) considered at low risk who were given no steroid prophylaxis. Only two of these cases had preexistent inactive GO. Despite prophylaxis, 33% of patients considered at high risk who were treated with oral glucocorticoids had worsening of GO. However, because of the lack of clarity of this retrospective study regarding prevalence of active and inactive GO in each group and the lack of prespecified criteria for dose and route of steroid use in those considered at risk, we weighed this evidence less in our deliberations regarding the above recommendation. Table 14 further details the use of glucocorticoids for various GO clinical scenarios.

[V] How should iodine-induced and amiodarone-induced thyrotoxicosis be managed?

[V1] Iodine-induced hyperthyroidism

■ **RECOMMENDATION 109**

Routine administration of ATDs before iodinated contrast media exposure is not recommended **for all patients**.

Weak recommendation, low-quality evidence.

Technical remarks: Patients deemed to be at high risk of developing iodine-induced hyperthyroidism or whose

cardiac status is tenuous at baseline may be considered for prophylactic therapy with ATDs.

Iodine-induced hyperthyroidism (the Jod–Basedow phenomenon) is uncommon in modern series and generally self-limited, but it may occasionally persist for months (551,552) and may be life-threatening (553–556). Individuals who are the most susceptible are elderly patients with autonomously functioning nodular goiters (557) and, less commonly, patients with occult GD (558) or patients with a prior history of GD who are in remission after a course of ATDs (559). Very rarely, iodine excess may trigger thyrotoxicosis in patients with a previously normal thyroid gland (560). Chronic iodine deficiency increases the prevalence of autonomous thyroid nodules, and therefore iodine repletion in this setting has historically been linked to iodine-induced hyperthyroidism (561).

Multiple observational studies have examined changes in thyroid hormone levels following a single exposure to intravenous iodinated contrast in both iodine-sufficient (562–565) and iodine-deficient (566–569) regions. A study of patients living in Boston showed that 5 of 49 (10.2%) developed a suppressed TSH value 1–4 weeks following exposure to a single computed tomography (CT) study with contrast, with only one patient developing overt hyperthyroidism (565). Additional observational studies in the United States and Japan involving 56 and 22 patients, respectively, found no new cases of hyperthyroidism following coronary angiography (564) or hysterosalpingography (563), whereas an Australian study from a region of iodine sufficiency found that 2 of 72 (2.8%) of patients developed overt hyperthyroidism and an additional two patients developed subclinical hyperthyroidism within 8 weeks of iodinated contrast exposure (562). Overall, similar rates of iodine-induced hyperthyroidism have been described in iodine-deficient regions, including a study from Germany in which 2 of 788 (0.25%) patients developed overt hyperthyroidism following coronary angiography (566), a New Zealand study in which subclinical hyperthyroidism developed in 2 of 102 (2%) patients after a CT scan with iodinated contrast (567), a study from Italy that found that 1.9% of 1752 patients undergoing coronary angiography developed a suppressed TSH with normal free T_4 and T_3 levels (568), and finally, a Turkish study identifying new subclinical hyperthyroidism in 5.9% of 101 patients by 8 weeks following coronary angiography (569).

A recent case–control study in the United States found that iodinated contrast exposure in patients without baseline thyroid abnormality resulted in hyperthyroidism (defined only as a suppressed TSH value) with an odds ratio of 1.98 ([95% CI, 1.08–3.60], $p = 0.03$), and that 23 patients would need to be exposed before encountering one case of iodine-induced thyrotoxicosis (570). Interestingly, a recent meta-analysis including nine randomized-controlled trials and eight observational studies involving iodine supplementation of young children and pregnant women in regions of mild to moderate iodine deficiency did not find an increased risk of thyroid dysfunction following iodine supplementation of 200–300 mg/d (571).

In summary, iodine-induced hyperthyroidism is uncommon and generally subclinical, but it can occasionally be severe. For most clinical circumstances, the likelihood of developing overt thyrotoxicosis after iodinated contrast exposure is too low to justify the risk of adverse effects associated with prophylactic ATD therapy.

■ RECOMMENDATION 110

Beta-adrenergic blocking agents alone or in combination with MMI should be used to treat overt iodine-induced hyperthyroidism.

Strong recommendation, low-quality evidence.

Treatment of iodine-induced hyperthyroidism includes avoidance of additional iodine and administration of β-blockers alone or with ATDs, depending on the severity of hyperthyroidism and the clinical status of the patient. RAI is not an option until the iodine load has been cleared and might not be desirable given the reversibility of this condition. Recent data suggest that urinary iodine normalizes more rapidly than previously believed, with a return to baseline urinary iodine excretion within 1–2 months in most patients (565,572).

Technical remarks: Dosing of MMI for iodine-induced thyrotoxicosis is 20–40 mg/d, given either as a daily or twice-daily dosing. There may be relative resistance to ATD in patients with iodine-induced hyperthyroidism. Urinary iodine (a spot urine iodine adjusted for urine creatinine concentration or a 24-hour urine iodine) may be monitored to assess the rate of clearance of the iodine load.

[V2] Amiodarone-induced thyrotoxicosis

■ RECOMMENDATION 111

We suggest monitoring thyroid function tests before and within the first 3 months following the initiation of amiodarone therapy, and at 3- to 6-month intervals thereafter.

Weak recommendation, low-quality evidence.

Amiodarone is a drug that is frequently used in the treatment of refractory atrial or ventricular tachyarrhymias. Amiodarone-induced thyrotoxicosis (AIT) occurs in up to 6% of patients taking this medication in iodine-sufficient areas of the world (573–575) and in up to 10% in iodine-deficient areas, such as parts of Europe (576). Studies evaluating the adequacy of monitoring for adverse effects from amiodarone have shown suboptimal results (577,578).

Two distinct mechanisms have been proposed in the development of AIT, including an iodine-induced form of hyperthyroidism (type 1 AIT) due to the high iodine content of amiodarone (37% by molecular weight) and a destructive thyroiditis (type 2 AIT) due to direct toxicity of amiodarone on follicular cells. Type 1 AIT tends to occur in patients with underlying thyroid autonomy in a nodular goiter, or GD, whereas type 2 AIT occurs as a result of direct damage or induction of apoptosis in thyrocytes by amiodarone (579–582).

■ RECOMMENDATION 112

The decision to stop amiodarone in the setting of thyrotoxicosis should be determined on an individual basis in consultation with the treating cardiologist, depending on the clinical manifestations and presence or absence of effective alternative antiarrhythmic therapy.

Strong recommendation, low-quality evidence.

The need for amiodarone discontinuation is controversial because (i) this drug is frequently the only medication able to

control cardiac arrhythmia, (ii) the effects of this fat-soluble drug may persist for many months, (iii) amiodarone may have T_3-antagonistic properties at the cardiac level and inhibit T_4 to T_3 conversion in the heart (583) such that withdrawal may actually aggravate cardiac manifestations of thyrotoxicosis (573). Deaths from ventricular fibrillation have occurred after stopping amiodarone in patients with AIT (584). In addition, type 2 AIT typically responds to treatment even if amiodarone therapy is continued (585–587), but continuation may lead to a more prolonged time to recovery and a higher rate of future recurrences of AIT (588).

■ **RECOMMENDATION 113**

In clinically stable patients with AIT, we suggest measuring thyroid function tests to identify disorders associated with iodine-induced hyperthyroidism (type 1 AIT), specifically including toxic nodular disease and previously occult GD.

Strong recommendation, low-quality evidence.

■ **RECOMMENDATION 114**

MMI should be used to treat overt thyrotoxicosis in patients with proven underlying autonomous thyroid nodules or GD as the cause of AIT (type 1 disease), and corticosteroids should be used to treat patients with overt amiodarone-induced thyroiditis (type 2 disease).

Strong recommendation, low-quality evidence.

■ **RECOMMENDATION 115**

Combined ATD and corticosteroid therapy should be used to treat patients with overt AIT who are too unstable clinically to allow a trial of monotherapy or who fail to respond to single modality therapy, or patients in whom the etiology of thyrotoxicosis cannot be unequivocally determined.

Strong recommendation, low-quality evidence.

As the pathogenesis of AIT is not fully understood, the classic division of AIT into two subtypes likely represents an oversimplification. First, as discussed further below, many patients cannot be readily classified into one of the two AIT subtypes. Secondly, once classified as having type 1 or type 2 AIT, patients often fail to respond to therapy specifically directed to that subtype (583,589,590). Finally, findings of responsiveness in patients with type 2 AIT to measures not typically useful in destructive thyroiditis, such as perchlorate (586,591) and oral cholecystographic agents (592,593), cannot be adequately explained on the basis of the current classification system, although spontaneous resolution independent of therapy is one possible explanation.

Several methods have been examined to distinguish type 1 from type 2 AIT, but with the possible exception of color flow Doppler study (CFDS), most are considered unreliable (574). For example, the T_3-to-T_4 ratio, which tends to be higher in patients with autonomous thyroid glands than in those with destructive thyroiditis, is not helpful in this instance because of amiodarone-associated inhibition of T_4 monodeiodination (594). Further, features historically used to distinguish the subtypes, such as antibodies against thyroid peroxidase and the presence of thyroid nodules in patients with type 1 AIT, may actually occur with both subtypes, given the prevalence of these abnormalities in the general population. Interleukin-6 levels and RAIU values, once promoted as useful for distinguishing between subtypes (590), actually overlap extensively between the two subtypes and are therefore also not useful (594). Several modern series of patients with AIT make no attempt to classify patients into type 1 or type 2 disease (585,595–598).

Several studies have shown that increased vascularity on CFDS may be seen in patients with type 1, but not type 2 AIT (599–601). Two studies showed a clear separation into type 1 and type 2 AIT, allowing successful application of targeted therapy (599,600). However, CFDS is not universally useful (584,589). In a series of 24 cases of AIT, 12 patients were classified as type 2 due to an absence of vascularity (CFDS 0) and treated with corticosteroids, but only 7 (58%) proved responsive (584). Likewise, the authors found that among 11 patients classified as type 1 AIT based on CFDS scores of I–III, only four (36%) responded to ATD therapy. In another series of 30 patients with AIT requiring therapy, 10 (33%) patients could not be subtyped on the basis of CFDS, including several patients with goiters but normal vascular flow (589). In a series of 55 patients in whom a CFDS qualitative assessment of vascular flow was used to distinguish type 1 from type 2 AIT, 81.3% of patients determined to have type 1 AIT had pattern I vascularity (the lowest level above zero), illustrating the skill and nuance needed to successfully make this distinction (599). Among European thyroidologists surveyed on the use of diagnostic imaging in the differential diagnosis of AIT, approximately 20% preferred RAIU alone, 20% preferred CFDS alone, nearly 40% utilized both methods simultaneously, and 20% thought both techniques were useless (602). Recently, sestamibi uptake by the thyroid, which is diminished with thyroiditis, has been applied for distinguishing AIT subtypes with preliminarily promising results (603,604).

A recent retrospective report including 200 AIT patients found that the onset of thyrotoxicosis was significantly earlier in type 1 (median 3.5 months, range 1–61 months) than type 2 (median 30 months, range 1–95 months; $p < 0.001$) (605). Since 80% of type 1 patients in this study had autonomous thyroid nodules or TMNG, it is not unexpected that iodine-induced thyrotoxicosis occurred early in the course of amiodarone therapy. However, based on these data, a patient with late onset of AIT in whom GD has been excluded is more likely to have type 2 AIT. Another observation reported in this study is the development of AIT following amiodarone discontinuation. Nineteen percent of patients (38/200) developed AIT a mean of 5.5 months after the drug was stopped, 36 of whom had type 2 AIT.

Patients who are clinically stable and have definite evidence supporting a distinct subtype of overt AIT may be tried on appropriate monotherapy. When identified with certainty, type 1 AIT is best treated with MMI to prevent new hormone synthesis and rarely with added potassium perchlorate (250 mg four times daily; not available in the United States) (590). Type 2 AIT is better treated with anti-inflammatory therapy such as prednisone, with improvement occasionally seen as early as 1 week, and usually within a few weeks (590). As noted above, some patients with mild type 2 AIT (approximately 20%) resolve spontaneously without stopping amiodarone or administering corticosteroids (606,607).

Most series of patients with AIT contain cases in which sequential therapy for both subtypes was required before resolution of AIT occurred. These patients are frequently referred to as having ''mixed'' types of AIT. In a study of 20 patients with AIT that included both type 1 and type 2 patients, perchlorate was administered alone for 1 month, resulting in euthyroidism in 12 patients (seven with type 1 AIT and five with type 2 AIT) (591). Corticosteroids were then given to the eight nonresponders (including seven patients with presumed type 1 disease), and euthyroidism was achieved in all after an average of approximately 6 weeks (591). Patients are often reclassified retrospectively from type 1 to type 2 AIT based on a positive response to corticosteroid therapy or after an outcome of permanent hypothyroidism, both of which would be unlikely in iodine-induced thyrotoxicosis (598,606). Patients recovering from apparent type 2 AIT should be monitored for permanent hypothyroidism, which appears to occur more often with AIT than with subacute thyroiditis (608).

Importantly, individuals with moderate thyrotoxicosis and compromised cardiac status should be considered for initial combined therapy rather than sequential empiric therapy. Some centers recommend starting combined therapy with ATDs and corticosteroids at the time of initial AIT diagnosis (594,609), and between 16% and 25% of surveyed thyroidologists prefer combination ATD and corticosteroid therapy for patients with apparent type 2 AIT (610). A rapid response to combined corticosteroid and ATD therapy is believed to favor type 2 AIT (594) and allows a reduction in ATDs, although some patients with type 2 AIT have a prolonged course, particularly those with larger thyroids or worse thyrotoxicosis at the time of diagnosis (611). A suggested approach to the management of AIT is shown in Figure 1.

Technical remarks: The suggested starting dose of MMI in this setting is 40 mg once daily until the patient is euthyroid (generally 3–6 months). If high doses of MMI continue to be required, splitting the dose may be more effective. The

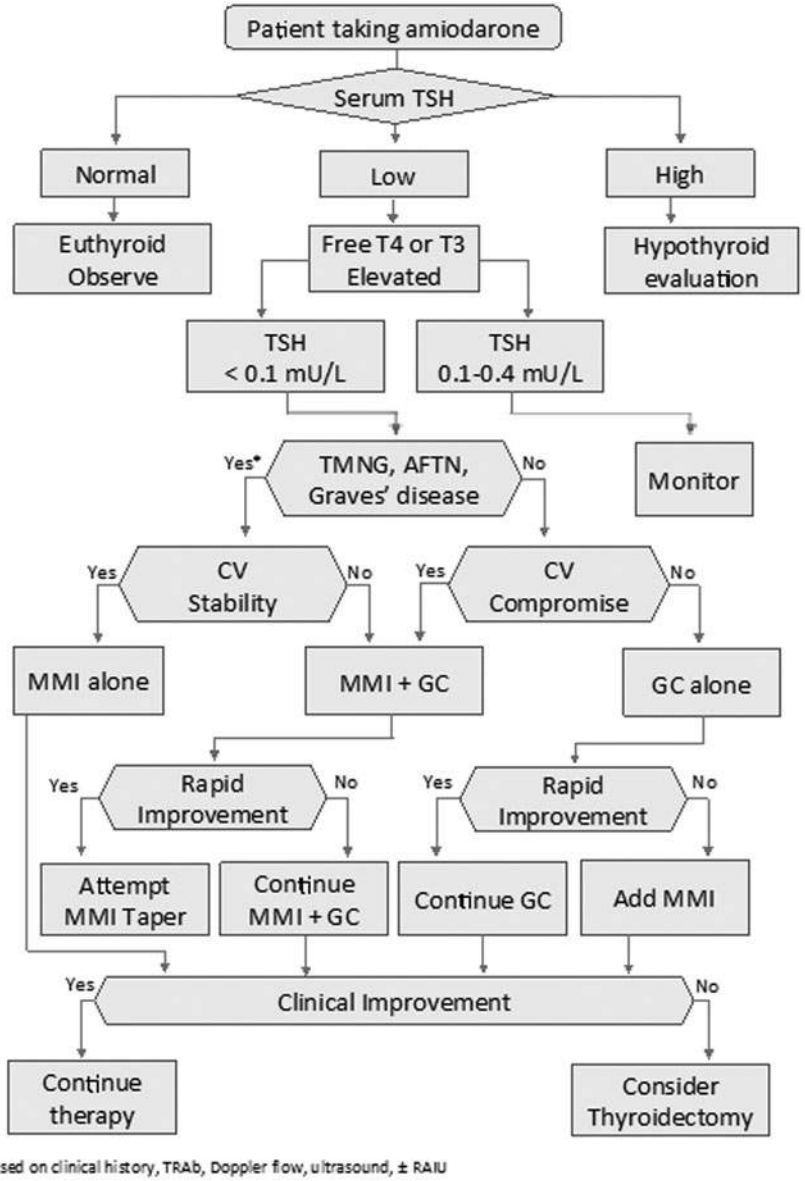

FIG. 1. A suggested approach to the management of amiodarone-induced thyrotoxicosis.

suggested dose of corticosteroids in this setting is equivalent to 40 mg prednisone given once daily for 2–4 weeks, followed by a gradual taper over 2–3 months, based on the patient's clinical response.

■ **RECOMMENDATION 116**

Patients with AIT who are unresponsive to aggressive medical therapy with MMI and corticosteroids should undergo thyroidectomy.

Strong recommendation, low-quality evidence.

Patients with AIT who fail to respond to medical therapy should be offered thyroidectomy before they become excessively debilitated from inadequately controlled thyrotoxicosis. The patient should be counseled that while thyroidectomy in this setting carries with it significant morbidity and a high mortality rate (9%), delay or deferral of surgery imparts an even higher risk of death (612). Thyroidectomy done under regional anesthesia when available may be preferred for very ill patients (613). Several surgical series involving patients with AIT have now been published, with generally favorable results (612,614–616). Patients in whom amiodarone was stopped during an episode of AIT should be considered for definitive therapy with RAI or surgery in order to facilitate reintroduction of amiodarone without concerns about recurrent AIT (617).

[W] How should thyrotoxicosis due to destructive thyroiditis be managed?

Several varieties of thyroiditis can present with temporary thyrotoxicosis as part of a classic triphasic course (thyrotoxicosis, hypothyroidism, recovery), including subacute thyroiditis, painless (silent) thyroiditis, acute (suppurative) thyroiditis, palpation (traumatic) thyroiditis, postpartum thyroiditis, and drug-induced thyroiditis. In general, thyroid dysfunction caused by thyroiditis is less severe than that seen with other forms of endogenous thyrotoxicosis (50); RAIU is universally low during the thyrotoxic stage, owing to leaking of preformed thyroid hormone with suppression of serum TSH concentrations. In this section, subacute, painless, acute, and palpation thyroiditis will be discussed; see Section [T4] for a discussion of postpartum and Section [X] for a discussion of drug-induced thyroiditis.

[W1] Subacute thyroiditis

Subacute thyroiditis, also called subacute granulomatous or de Quervain thyroiditis, is a common cause of thyroid pain (24). The diagnosis of subacute thyroiditis is based on clinical history, physical examination, laboratory data, and RAIU. Subacute thyroiditis presents with moderate-to-severe pain in the thyroid, often radiating to the ears, jaw, or throat. The pain may begin focally and spread from one side to the other of the gland over several weeks. Patients may have a prodrome of malaise, low-grade fever, pharyngitis symptoms, and fatigue. The thyroid may be slightly enlarged and is firm and painful to palpation. Subacute thyroiditis is thought to be due to a sequela of an upper respiratory viral infection that involves the thyroid gland.

About 50% of patients with subacute thyroiditis have an initial thyrotoxic phase due to unregulated release of preformed thyroid hormone from damaged thyroid follicular cells (24). Therefore, early in the course of the disease, patients may have clinical findings of thyrotoxicosis, although this is often mild. The serum TSH level is suppressed, and the free T_4 level may be elevated preferentially compared to the total T_3 level, in contrast to other endogenous forms of thyrotoxicosis, although substantial overlap occurs among the etiologies (618). In addition to laboratory evidence of thyrotoxicosis, the erythrocyte sedimentation rate (ESR) or C-reactive protein is elevated, and mild anemia and elevation of the WBC count are common. Up to 25% of patients have low concentrations of antithyroid antibodies (24,619,620). RAIU is low, as is uptake on a thyroid scintigram. Thyroid ultrasonography shows diffuse heterogeneity, focal hypoechoic areas, and decreased or normal color flow Doppler, rather than the enhanced flow characteristic of GD (621,622). A biopsy of the thyroid gland is usually not necessary in subacute thyroiditis. However, if a biopsy is performed due to uncertainty of the diagnosis, its result shows granulomatous infiltrate and giant cells, consistent with a viral infection (24).

The thyrotoxic phase usually lasts 3–6 weeks, ending when the thyroid stores of preformed hormone are depleted. About 30% of patients subsequently enter a hypothyroid phase that can last up to 6 months. Thyroid pain and the elevated ESR have usually resolved by this time, and the predominant clinical features are those of hypothyroidism with a small nontender goiter. Most patients become euthyroid again within 12 months of disease onset, although 5%–15% have persistent hypothyroidism (24,620,621). In addition, recurrence rates of 1%–4% have been reported (24,620,623).

■ **RECOMMENDATION 117**

Patients with mild symptomatic subacute thyroiditis should be treated initially with β-adrenergic-blocking drugs and nonsteroidal anti-inflammatory agents (NSAIDs). Corticosteroids should be used instead of NSAIDs when patients fail to respond or present initially with moderate to severe pain and/or thyrotoxic symptoms.

Strong recommendation, low-quality evidence.

Subacute thyroiditis is treated with β-blockers and anti-inflammatory therapy. Beta-blockers are used as needed to control thyrotoxic symptoms. NSAIDs provide pain relief in patients with mild symptoms and should be considered first-line therapy. With NSAIDs, the median time for resolution of pain is 5 weeks (range 1–20 weeks) (24). Patients who fail to respond to full doses of NSAIDs over several days should be treated instead with corticosteroid therapy. Standard recommendations are to use prednisone 40 mg daily for 1–2 weeks followed by a gradual taper over 2–4 weeks or longer, depending upon clinical response. A retrospective review found that patients treated with corticosteroids at similar doses had more rapid resolution of pain (mean duration, 8 days) compared with those treated with NSAIDs (mean duration, 35 days). However, symptoms can recur as the dose of corticosteroid is reduced (24). A more recent study reported that a lower initial daily dose of 15 mg of prednisolone, with tapering by 5 mg every 2 weeks, was effective. However, 20% of patients required longer than 8 weeks to discontinue the glucocorticoid (624). Levothyroxine may be employed during the hypothyroid stage but should be withdrawn after 3–6 months, with recovery of normal function verified by thyroid

function testing. ATDs have no role in the treatment of subacute thyroiditis.

[W2] Painless thyroiditis

Painless or silent thyroiditis classically presents with the same triphasic course described for subacute thyroiditis, but with no prodrome, neck pain, or elevated ESR, WBC count, or C-reactive protein (625). The postpartum period is the most common time when painless thyroiditis is seen, but painless thyroiditis can also occur in nonpregnant women and in men. Painless thyroiditis has been described in some types of drug-induced thyroid dysfunction, including that associated with lithium or cytokine therapy. Postpartum and drug-induced thyroiditis are discussed in detail in Sections [T4] and [X], respectively. A small nontender goiter is common in all types of painless thyroiditis.

The thyrotoxic phase occurs in 5%–20% of patients and typically lasts 3–4 months. The hypothyroid phase is more common or at least is recognized more often, lasting up to 6 months. Normal thyroid function is reestablished by 12 months in most patients, but 10%–20% have persistent hypothyroidism. Recurrence rates are about 5%–10%, but may be higher in Japan, with one Japanese study reporting a long-term recurrence rate of 65% (626). Recurrences are managed in the same manner as the initial occurrence, but rare patients with multiple recurrences have opted for surgery or RAI ablation of the gland following recovery from the thyrotoxic phase (626).

Painless thyroiditis is probably an autoimmune disease manifested by positive anti–thyroid peroxidase antibodies in about 50% of patients and findings of lymphocytic infiltration on pathology (626,627). During the thyrotoxic phase, the serum TSH level is suppressed and free T_4 levels are elevated, often out of proportion to T_3 levels. Patients with painless thyroiditis have a low RAIU and low uptake on a thyroid scintigram during the thyrotoxic phase, and ultrasound often shows inhomogeneous hypoechogenic texture with decreased blood flow. These tests and the absence of TRAb antibodies help distinguish painless thyroiditis from GD (628).

■ **RECOMMENDATION 118**

Patients with symptomatic thyrotoxicosis due to painless thyroiditis should be treated with β-adrenergic-blocking drugs to control symptoms.

Strong recommendation, low-quality evidence.

Beta-adrenergic blockers can be used to treat thyrotoxic symptoms in patients with painless thyroiditis, but ATDs have no utility, since new hormone synthesis is already low in these patients. Rarely, corticosteroids have been used to ameliorate the severity and the time course of thyrotoxicosis due to painless thyroiditis (629), but they should be reserved for severe cases only.

[W3] Acute thyroiditis

■ **RECOMMENDATION 119**

Acute thyroiditis should be treated with antibiotics and surgical drainage as determined by clinical judgement. Beta-blockers may be used to treat symptoms of thyrotoxicosis.

Strong recommendation, low-quality evidence.

Patients with acute thyroiditis (also referred to as suppurative thyroiditis or thyroid abscess) are generally euthyroid. However, on occasion, the condition presents as destructive thyroiditis with thyrotoxicosis (630). Ultrasound or CT examinations are usually diagnostic, showing hypoechoic lesions in and around the affected thyroid lobe, destruction of the lobe, and abscess formation. However, early in the process, radiologic examination may be nonspecific, often leading to the erroneous diagnoses of subacute thyroiditis (631). The etiology of acute thyroiditis is most frequently a bacterial infection affecting the thyroid, either through hematogenous spread or direct extension through a fistula from an infected pyriform sinus. Therapy involves systemic antibiotics as well as abscess drainage or removal, and excision or occlusion of the offending pyriform sinus. Thyrotoxicosis should be treated symptomatically with β-blocking agents. As in other forms of destructive thyroiditis, there is no role for ATDs.

[W4] Palpation thyroiditis

In 1975, Carney *et al.* (632) described a nonspecific multifocal granulomatous folliculitis in thyroid glands removed at surgery for thyroid-related or unrelated conditions. They named this pathologic entity ''palpation thyroiditis,'' concluding that it was due to palpation of the thyroid gland at surgery. It was generally thought to be of little clinical importance, except for rare case reports of patients who developed thyrotoxicosis following manipulation of the thyroid gland during surgery (633–636). However, a recent study suggested that the rate of transient overt or subclinical thyrotoxicosis following parathyroid surgery may be as high as 30%, although there was likely ascertainment bias because not all patients had postoperative TSH levels measured (637). There are no data on treatment of palpation thyroiditis, although the use of β-blockers for symptomatic thyrotoxicosis seems reasonable.

[X] How should other causes of thyrotoxicosis be managed?

Tables 16 and 17 summarize drug-associated and unusual causes of thyrotoxicosis.

■ **RECOMMENDATION 120**

Patients taking medications known to cause thyrotoxicosis, including interferon (IFN)-α, interleukin-2, tyrosine kinase inhibitors, and lithium, should be monitored clinically and biochemically at 6-month intervals for the development of thyroid dysfunction. Patients who develop thyrotoxicosis should be evaluated to determine etiology and treated accordingly.

Strong recommendation, low-quality evidence.

[X1] Interferon-α and interleukin-2

Patients treated with IFN-α and interleukin-2 patients are at increased risk for developing thyrotoxicosis, especially those with pre-existing thyroid autoimmunity. A recent study including 1233 patients who were euthyroid at baseline found that 79 (6.4%) patients developed a biphasic thyroiditis and an additional 57 (4.6%) patients developed a suppressed TSH value (638). The latter group included 33 patients with mild TSH suppression and 24 with a TSH value <0.1 mU/L, among whom 11 had free T_4 elevation and five required ATD therapy (638). Thyrotoxicosis in patients treated with IFN-α

Table 16. Causes of Drug-Associated Thyrotoxicosis[a]

Drug	*Mechanism(s)*	*Timing of onset following initiation of the drug*	*Therapy*
Amiodarone	Iodine induced (type 1)	Months to years	Supportive care[b] ATDs; perchlorate[c] Surgery
	Thyroiditis (type 2)	Often >1 year	Supportive care[b] Corticosteroids Surgery
Lithium	Painless thyroiditis GD	Often >1 year	Supportive care[b] ATDs and/or RAI (GD only)
Interferon α	Painless thyroiditis; GD	Months	Supportive care[b] ATDs and/or RAI (GD only)
Interleukin-2	Painless thyroiditis GD	Months	Supportive care[b] ATDs and/or RAI (GD only)
Iodinated contrast	Underlying thyroid autonomy	Weeks to months	Antithyroid drugs
Tyrosine kinase inhibitors	Destruction	3–12 months	Supportive care
Radioactive iodine, early	Destruction	1–4 weeks	Observation; if severe, administer corticosteroids
Radioactive iodine for TMNG, late	GD	3–6 months	Antithyroid drugs Repeat RAI Surgery

[a]Thyroid hormone ingestion, including levothyroxine, liothyronine, thyroid extract, and nonprescription supplements that contain thyroid hormone, may cause thyrotoxicosis—see Section [X7], thyrotoxicosis factitia.
[b]Supportive care may include beta-adrenergic blockers during the thyrotoxic stage and levothyroxine if hypothyroidism develops.
[c]Not available in the United States.

can be due to either painless thyroiditis or GD (639). In a review of published cases from eight series, 69% of 49 patients with IFN-α–associated thyrotoxicosis for whom an etiology was identified were found to have GD, based on either positive TRAb titers or requirement for a prolonged course of ATDs (640). An earlier literature review found that 2.4% of 1664 patients treated with IFN-α therapy for hepatitis C infection developed thyrotoxicosis, although the specific etiology was not consistently identified (641).

[X2] Tyrosine kinase inhibitors

The tyrosine kinase inhibitors sunitinib (642–647), sorafenib (648–650), and nilotinib (651) have each been associated with a transient thyrotoxicosis due to destructive thyroiditis. One study of 69 patients treated with sorafenib for metastatic renal cell carcinoma found that 11 (16%) developed transient thyroiditis followed by hypothyroidism (649). Another study found that 6 of 31 (19.3%) receiving sunitinib therapy for metastatic renal cell carcinoma developed thyrotoxicosis, including one case of thyroid storm (644).

[X3] Lithium

Patients taking lithium for bipolar disorder are at a high risk of developing thyroid dysfunction, including both hypothyroidism and to a lesser extent thyrotoxicosis (652). Two published series have identified the development of thyrotoxicosis in 0.6% and 3.0% of patients, respectively (653,654). An epidemiological study of hyperthyroidism occurring over a 3-year period in Denmark identified lithium-associated thyrotoxicosis as the etiology in 0.7% of all cases (432). A case series of 24 patients with lithium-associated thyrotoxicosis identified GD in 12 (50%), painless thyroiditis in two patients, TMNG in three patients, and no identified etiology in seven patients (655). Another more recent series found that 1.4% of referrals to a thyroid clinic over a 12-year period were for lithium related thyrotoxicosis (656). Patients in this series had been taking lithium for a median duration of 6 years (range 0.6–25 years), and 87% were women. Diagnostic evaluation found that 11 (47.8%) had GD, nine (39%) had painless thyroiditis, two had TMNG, and one patient had subacute thyroiditis (656). A smaller series described three

Table 17. Unusual Causes of Thyrotoxicosis

Disorder	*Diagnosis*	*Primary management*
TSH-producing adenoma	Pituitary MRI, α-subunit to TSH ratio	Surgical removal
Struma ovarii	RAI uptake over pelvis	Surgical removal
Choriocarcinoma	hCG elevation in the absence of pregnancy	Surgical removal
Thyrotoxicosis factitia (surreptitious LT_4 or LT_3)	Absence of goiter; suppressed thyroglobulin	Psychosocial evaluation
Functional thyroid cancer metastases	Whole-body RAI scanning	RAI ablation, embolization and/or surgical removal

hCG, human chorionic gonadotrophin; MRI, magnetic resonance imaging.

cases of GD occurring in patients receiving lithium (657). In a retrospective review of 100 cases of thyroiditis and 400 cases of GD occurring at a single medical center, six cases of painless thyroiditis had a history of recent lithium exposure, representing a nearly 5-fold increase compared to cases of lithium exposure in patients with GD (19).

[X4] TSH-secreting pituitary tumors

■ **RECOMMENDATION 121**

The diagnosis of a TSH-secreting pituitary adenoma should be based on an inappropriately normal or elevated serum TSH level associated with elevated free T_4 and total T_3 concentrations, generally associated with a pituitary tumor on MRI or CT and the absence of a family history or genetic testing consistent with resistance to thyroid hormone.

Strong recommendation, low-quality evidence.

TSH-secreting pituitary adenomas are rare tumors and represent an even rarer cause of hyperthyroidism. Recent data from the Swedish registry reported an incidence of 0.15 per 1 million inhabitants, with a prevalence of 2.8 cases per million (658). After excluding laboratory interference with either the free T_4 or TSH assay, as may occur with T_4 antibodies and heterophilic antibodies, respectively, distinction between a TSH-secreting adenoma and resistance to thyroid hormone is important since thyroid function test results are similar, yet management is quite different for these two disorders. TSH-secreting adenomas are more likely to have a concurrent α-subunit elevation (not useful in postmenopausal women because of concurrent gonadotropin elevation), a blunted TSH response to thyrotropin-releasing hormone (when available), elevated sex hormone–binding globulin and resting energy expenditure, and clinical evidence of thyrotoxicosis, as well as an anatomic abnormality on MRI of the pituitary. Finally, a response to somatostatin analog therapy with clinical improvement lends support to the diagnosis of a TSH-secreting adenoma in cases in which diagnostic uncertainty persists. Although most TSH-secreting pituitary adenomas only secrete TSH, co-secretion of prolactin or growth hormone is possible and should be assessed concurrently along with assessment of the pituitary–adrenal axis and pituitary–gonadal axes.

Technical remarks: Genetic testing for resistance to thyroid hormone is commercially available and may be useful in equivocal cases, especially in patients without family members available for thyroid function testing. Calculation of the molar α-subunit/TSH ratio can be accomplished by dividing the α-subunit concentration (ng/mL) by TSH (mU/L) and multiplying by 10. A ratio greater than 1 favors a TSH-secreting pituitary adenoma.

Pituitary surgery is generally the mainstay of therapy for TSH-producing pituitary tumors. In a recent series of 68 patients undergoing transsphenoidal surgery, 75% normalized thyroid function after surgery, 58% normalized both pituitary imaging and TSH hypersecretion, 9% developed new deficiencies, and 3% experienced tumor recurrence (659). The patient should be made euthyroid preoperatively. Long-term ATD therapy and other measures directed at the thyroid, such as RAI or thyroidectomy, are generally avoided because of theoretical concerns of tumor growth. Preoperative adjunctive therapy with octreotide and dopamine agonist therapy has been examined. Treatment with octreotide results in a >50% reduction in serum TSH values in the majority of patients treated and a concurrent return to euthyroidism in most (43). A reduction in tumor size has been observed in 20%–50% of patients treated with octreotide (43,660), but less impressive results have been obtained with bromocriptine therapy (660). However, presurgical medical treatment did not significantly improve surgical outcome (63% vs. 57% had negative tumor imaging after surgery) (659). In a recent case series of seven patients treated with octreotide without prior surgery, mean free T_4 and T_3 levels were reduced by nearly 50% in the first 3 months of therapy and six of seven patients experienced tumor volume reduction (661).

Sterotactic or conventional radiotherapy has also been used in cases that prove refractory to medical therapy. Radiotherapy controlled thyroid hypersecretion in 37% of patients treated with this modality, but hypopituitarism occurred in 32% of those treated (659). For patients with TSH-producing adenomas who are considered poor surgical candidates, primary medical therapy with octreotide can be considered (661). Patients who fail to respond to pituitary surgery and somatostatin analog therapy or those who have tumor enlargement despite these measures are sometimes treated with radiation therapy.

■ **RECOMMENDATION 122**

Patients with TSH-secreting pituitary adenomas should undergo surgery performed by an experienced pituitary surgeon.

Strong recommendation, low-quality evidence.

Technical remarks: Postoperative adjunctive therapy with octreotide and/or external beam radiation therapy may be useful in managing patients with persistent central hyperthyroidism after a debulking procedure for nonresectable TSH-secreting adenomas (43).

[X5] Struma ovarii

■ **RECOMMENDATION 123**

Patients with struma ovarii should be treated initially with surgical resection following preoperative normalization of thyroid hormones.

Strong recommendation, low-quality evidence.

Struma ovarii, defined as ectopic thyroid tissue existing as a substantial component of an ovarian tumor, is quite rare, representing <1% of all ovarian tumors. Approximately 5%–10% of patients with struma ovarii present with thyrotoxicosis (662) due to either autonomous ectopic thyroid function or the coexistence of GD, and up to 25% of struma ovarii tumors contain elements of papillary thyroid cancer. Patients previously treated for GD may have persistent or recurrent hyperthyroidism due to the action of TRAb on the ectopic thyroid tissue (663). The diagnosis should be considered in any thyrotoxic patient with a very low or absent RAIU over the eutopic thyroid gland. Other conditions that present with this constellation of findings include various forms of thyroiditis, factitious thyrotoxicosis, and iodine-induced hyperthyroidism. In struma ovarii, the RAI is concentrated in

the pelvic region over the teratoma. Cosynchronous primary thyroid cancer occurred in 9% of patients in one series of 68 patients identified in the Surveillance, Epidemiology, and End Results database (664). Treatment of struma ovarii generally involves surgical removal, performed both to cure the hyperthyroidism and to eliminate the risk of untreated ectopic thyroid cancer. Preoperative treatment with β-adrenergic-blocking agents and ATDs is warranted to restore euthyroidism before surgery.

Technical remarks: In cases of suspected metastatic malignant struma ovarii, RAI is generally given following surgical removal of both the ovarian tumor and the patient's thyroid to facilitate delivery of isotope to any potential residual malignant cells.

[X6] Choriocarcinoma

■ **RECOMMENDATION 124**

Treatment of hyperthyroidism due to choriocarcinoma should include both MMI and treatment directed against the primary tumor.

Strong recommendation, low-quality evidence.

Patients with choriocarcinoma, including molar pregnancy and testicular cancer, may present with thyrotoxicosis because of the effect of tumor-derived hCG upon the TSH receptor (665–668). This cross-stimulation only occurs at very high levels of hCG, since hCG is only a weak agonist for the TSH receptor. Therefore, patients with testicular choriocarcinoma presenting with overt thyrotoxicosis may have widely metastatic disease at presentation (667,668). Treatment of hyperthyroidism due to choriocarcinoma involves both treatment directed against the primary tumor and ATDs.

[X7] Thyrotoxicosis factitia

Thyrotoxicosis factitia includes all causes of thyrotoxicosis due to the ingestion of thyroid hormone. This may include intentional ingestion of thyroid hormone either surreptitiously or iatrogenically, as well as unintentional ingestion either accidentally, such as in pediatric poisoning or pharmacy error, or through ingestion of supplements that contain thyroid hormone (669). Historically, accidental thyroid hormone ingestion has occurred as a result of eating meat contaminated with animal thyroid tissue (''hamburger thyrotoxicosis'') (670).

Whereas iatrogenic causes of thyrotoxicosis factitia are easily identified, surreptitious use of thyroid hormone may present a diagnostic quandary. Clues to this diagnosis are an absence of goiter, a suppressed serum thyroglobulin level, and a decreased RAIU. In a patient who has circulating antithyroglobulin antibodies that artifactually render the serum thyroglobulin undetectable in immunometric assays, the distinction between painless thyroiditis and factitious thyrotoxicosis can be difficult. In both situations there will be elevated levels of T_4, a high T_4/T_3 ratio (with exogenous levothyroxine), a small thyroid, and a low thyroidal RAIU. Thyroid ultrasound may be helpful because the thyroid has a heterogeneous echotexture and is normal sized or slightly enlarged in painless thyroiditis, while it is small with a normal echotexture in an otherwise normal individual who is ingesting thyroid hormone surreptitiously. Fecal levothyroxine has been measured as a means of distinguishing surreptitious use of thyroid hormone from painless thyroiditis (54). A disproportionately elevated T_3 level suggests that the patient may be ingesting liothyronine or a combination T_4/T_3 preparation.

Severe thyrotoxicosis and rarely, thyroid storm, have been reported following thyroid hormone overdose or poisoning. Treatment with cholestyramine (671) and charcoal hemoperfusion (672) have been used in this circumstance.

[X8] Functional thyroid cancer metastases

Thyrotoxicosis due to functional metastases in patients with thyroid cancer has been described in a handful of cases. Typically, patients have either a very large primary follicular cancer or widely metastatic follicular thyroid cancer, and they may have coexisting TRAb as the proximate cause of the thyrotoxicosis (673) or activating mutations in the TSH receptor (674). In general, functioning metastases are treated with RAI with the addition of ATDs as needed for persistent hyperthyroidism. Recombinant human TSH should be avoided in these patients. Patients with massive metastatic follicular thyroid cancer may also exhibit T_3 thyrotoxicosis, most likely due to increased conversion of T_4 to T_3 by tumor expressing high type 1 and type 2 deiodinase activities (675). Thus, occasional measurement of serum T_3 in addition to FT_4 and TSH is recommended in patients with a large metastatic tumor burden, particularly if FT_4 decreases on fixed doses of levothyroxine.

ENDORSEMENTS

The final document was officially endorsed by the American Association of Clinical Endocrinologists; American Association of Endocrine Surgeons; Canadian Association of Otolaryngology Head and Neck Surgery; International Association of Endocrine Surgeons; International Federation of Head and Neck Oncologic Societie; Latin American Thyroid Society; The Endocrine Society of Australia.

AUTHOR DISCLOSURE STATEMENT

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ABBREVIATIONS

AACE = American Association of Clinical Endocrinologists
AIT = amiodarone-induced thyrotoxicosis
ANCA = antineutrophil cytoplasmic antibody
ATA = American Thyroid Association
ATD = antithyroid drugs
BWPS = Burch–Wartofsky point scale
CAS = clinical activity score
CFDS = color flow Doppler study
CT = computed tomography
ESR = erythrocyte sedimentation rate
GD = Graves' disease
GO = Graves' orbitopathy
hCG = human chorionic gonadotropin
IFN = interferon
iPTH = intact parathyroid hormone
JTA = Japanese Thyroid Association
KI = potassium iodide
MMI = methimazole
MNG = multinodular goiter
MRI = magnetic resonance imaging
NSAID = nonsteroidal anti-inflammatory agent
pANCA = antineutrophil cytoplasmic antibody
PTU = propylthiouracil
QoL = quality of life
RAI = radioactive iodine
RAIU = radioactive iodine uptake
rhTSH = recombinant human thyrotropin
RLN = recurrent laryngeal nerve
RFA = radiofrequency ablation
SH = subclinical hyperthyroidism
SSKI = saturated solution of potassium iodide
T_3 = triiodothyronine
T_4 = thyroxine
TA = toxic adenoma
TBII = thyrotropin binding inhibition immunoglobulin
TBG = T_4 binding globulin
TcO_4 = technetium
TMNG = toxic multinodular goiter
TRAb = thyrotropin receptor antibodies
TSH = thyrotropin
TSI = thyroid-stimulating immunoglobulin
WBC = white blood cell