Amiodarone is a uniquely effective antiarrhythmic drug, but it is also dangerously rich in iodine. Amiodarone-induced thyrotoxicosis develops in 3% of amiodarone-treated patients in the United States and in 10% of those living in iodine-deficient areas of the world. We review amiodarone's effects on thyroid function and how best to diagnose and treat amiodarone-induced thyrotoxicosis.

The uses and high iodine content of amiodarone

Amiodarone is useful in the treatment of:
• Recurrent severe ventricular arrhythmias (for which it is approved by the US Food and Drug Administration [FDA])
• Paroxysmal atrial tachycardia
• Atrial fibrillation
• Maintenance of sinus rhythm after cardioversion of atrial fibrillation

But 37% of amiodarone's mass is organic iodine; each 200-mg tablet contains about 75 mg, 10% of which is released as free iodide. With typical daily doses of 1 to 3 tablets a day, the patient is exposed to 7 to 21 mg of free iodide—over 50 times the optimal intake.

A spectrum of long-lived effects

Amiodarone can cause a spectrum of effects on the thyroid (Table 1), which can begin as early as a few weeks after starting treatment or up to 4 years after its continuous use. In fact, because amiodarone accumulates in liver and adipose tissue, it can continue to affect the thyroid many months after it is discontinued: total body iodine stores remain increased for up to 9
months after stopping. Amiodarone’s estimated elimination half-life is 50 to 100 days.\textsuperscript{1}

**Euthyroid patients and nonthyroidal illness**

Over half of patients treated with amiodarone have “innocent” changes in thyroid hormone levels, including:

\begin{itemize}
  \item Slightly elevated serum free thyroxine (T\textsubscript{4}) levels
  \item Normal or low total triiodothyronine (T\textsubscript{3}) levels
  \item Elevated reverse T\textsubscript{3}
  \item Transiently increased or decreased thyrotropin (TSH) concentrations.\textsuperscript{12}
\end{itemize}

However, most of these patients remain clinically euthyroid, ie, they do not manifest overt hypothyroidism or hyperthyroidism and require no intervention other than monitoring their TSH levels.

This phenomenon is partly explained by amiodarone’s effects on thyroid hormone synthesis and metabolism. Amiodarone inhibits type 1 5’-deiodinase enzyme activity, thereby decreasing the peripheral conversion of T\textsubscript{4} to T\textsubscript{3}. In addition, amiodarone decreases the clearance of both T\textsubscript{4} and of reverse T\textsubscript{3}, and can act as a competitive antagonist of T\textsubscript{3}.

**High T\textsubscript{3} indicates thyrotoxicosis**

Thus, low serum TSH levels in a patient who is apparently euthyroid presents a special problem: although indicative of hyperthyroidism, low TSH is not by itself diagnostic and can also be a manifestation of the sick euthyroid syndrome. In a patient with suspected amiodarone-induced thyrotoxicosis who has low TSH but no clinical signs of hyperthyroidism, high free T\textsubscript{3} levels confirm the presence of amiodarone-induced thyrotoxicosis.\textsuperscript{13}

**Amiodarone also causes hypothyroidism**

Amiodarone can also cause hypothyroidism, indicated by persistently elevated TSH. In fact, in the United States the prevalence of amiodarone-induced thyrotoxicosis is much lower (3%) than that of amiodarone-induced hypothyroidism (22%). However, in iodine-deficient areas such as Tuscany, Italy,\textsuperscript{11} amiodarone-induced thyrotoxicosis predominates (10%) over hypothyroidism (5%).

<table>
<thead>
<tr>
<th><strong>TABLE 1</strong></th>
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<tbody>
<tr>
<td><strong>Signs of amiodarone-induced thyrotoxicosis</strong></td>
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<tr>
<td><strong>Cardiac signs (may be absent)</strong></td>
</tr>
<tr>
<td>Sinus tachycardia</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
</tr>
<tr>
<td>Ventricular tachycardia</td>
</tr>
<tr>
<td>Angina</td>
</tr>
<tr>
<td>Heart failure</td>
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<tr>
<td><strong>Noncardiac signs</strong></td>
</tr>
<tr>
<td>Unexplained weight loss</td>
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<tr>
<td>Tremor</td>
</tr>
<tr>
<td>Muscle weakness</td>
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<tr>
<td>Low-grade fever</td>
</tr>
<tr>
<td>Restlessness</td>
</tr>
<tr>
<td>Enlarging goiter</td>
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<tr>
<td><strong>Laboratory signs</strong></td>
</tr>
<tr>
<td>Total and free T\textsubscript{4} levels: increased</td>
</tr>
<tr>
<td>Total and free T\textsubscript{3} levels: increased</td>
</tr>
<tr>
<td>TSH: dramatically decreased</td>
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</tbody>
</table>

The clinical presentation of amiodarone-induced hypothyroidism is usually subtle, while that of amiodarone-induced thyrotoxicosis can be dramatic, with life-threatening cardiac manifestations.\textsuperscript{1-4,7-14}

**SIGNS AND SYMPTOMS**

Amiodarone-induced thyrotoxicosis should be suspected in a patient who was previously stable on amiodarone but starts showing signs of cardiac decompensation, sinus tachycardia, atrial fibrillation, ventricular tachycardia, or angina (**TABLE 1**).\textsuperscript{1-4}

However, patients may lack cardiac manifestations of thyrotoxicosis because of amiodarone’s intrinsic inhibitory effects on the heart (similar to the actions of beta-adrenergic blockers and calcium channel blockers). Other clinical signs of hypothyroidism may predominate instead, such as weight loss, tremor, muscle weakness, low-grade fever, restlessness, or an enlarging goiter.

Laboratory tests typically demonstrate:

\begin{itemize}
  \item Elevated total and free T\textsubscript{4}
  \item Elevated total and free T\textsubscript{3}
  \item Dramatically decreased TSH.\textsuperscript{1,12}
\end{itemize}
While the combination of clinical and laboratory abnormalities confirms the diagnosis of thyrotoxicosis, knowing which type of amiodarone-induced thyrotoxicosis is present is essential to selecting the most appropriate treatment. There are two major types:

**Type 1** affects patients with latent or pre-existing thyroid disorders (such as nodular goiter, diffuse goiter, or Graves disease) and is more common in areas of low iodine intake. It is caused by excessive, uncontrolled synthesis of thyroid hormone by autonomously functioning thyroid tissue in response to iodine (iodobasedow phenomenon).

**Type 2** occurs in patients with previously normal thyroid glands and is caused by a destructive inflammatory thyroiditis, induced by amiodarone or its iodine. The drug exerts direct cytotoxic effects on thyroid follicles and triggers inflammation through mechanisms that are poorly understood. As a result of follicular disruption, preformed thyroid hormones are released.

Until recently it was nearly impossible to distinguish the two types confidently, and the distinction is still often difficult. Furthermore, mixed forms also occur, further complicating the diagnosis.

But the distinction is important, as specific treatments exist for both types, and choos-
ing the wrong therapy results in ineffective or
delayed responses and exposes patients to
unjustifiable drug side effects.

Because of uncertainty, empirical combi-
nations of treatments are too often used, espe-
ially in patients with severe amiodarone-
induced thyrotoxicosis, in an effort to achieve
prompt control.

**STRATEGIES TO DISTINGUISH
TYPE 1 FROM TYPE 2**

More reliable diagnostic tools are clearly
needed. Until then, we propose establishing a
diagnosis by assigning a relative weight to all
available information (Table 2).

First, clinicians should try to determine
whether there is preexisting thyroid disease,
which would indicate type 1:

- **Physical examination** may reveal a goiter
  or exophthalmos.

- **Ultrasonography** of the thyroid with
  abnormal patterns (hypoechoic, nodular goi-
ter) or increased gland size should also raise
  suspicion of type 1.1–4

- **Antibody tests** can also be used to iden-
tify latent autoimmune thyroid disease (sub-
clinical Graves disease). These include thy-
roid peroxidase (“microsomal”) antibodies,
thyroglobulin antibodies, and thyroid-stimu-
lating immunoglobulin. When positive, they
lend support to the diagnosis of type 1 ami-
odarone-induced thyrotoxicosis. But negative
tests do not rule out this diagnosis; this is usu-
ally the case in multinodular goiter and in up
to 30% of patients with typical Graves dis-
 ease.

- **Radioactive iodine uptake (RAIU)** stud-
ies are unreliable in the United States. Normal
or elevated values indicate type 1 ami-
odarone-induced thyrotoxicosis,16 but this is
rarely seen here.2

Conversely, values that approach 0% are
typical of type 2 amiodarone-induced thyro-
toxicosis,4 as expected in a condition func-
tionally similar to subacute thyroiditis. But negative
tests do not rule out this diagnosis; this is usu-
ally the case in multinodular goiter and in up
to 30% of patients with typical Graves dis-
 ease.

- **Interleukin-6 (IL-6)** appears to be a bet-
ter marker of thyroid gland destruction. IL-6
has been reported as markedly elevated in
patients with type 2 amiodarone-induced thy-
rotoxicosis, and normal or minimally
increased in type 1.17

However, exceptions to this rule are very
common,2,18 casting doubts on the test’s utili-
ty. Patients with typical type 2 amiodarone-
induced thyrotoxicosis often have unexpect-
edly low IL-6 levels (perhaps due to variable
quality of commercial assays). IL-6 is elevated
in commonly coexisting conditions (eg,
Graves disease, subacute thyroiditis, nonthy-
roidal illness, and heart failure), also limiting
the test’s value for distinguishing the two
types.

The usefulness of IL-6 testing is probably
confined to:

- **Cases in which IL-6 is markedly elevated
  on the initial presentation of thyrotoxicosis
  (consistent with type 2 amiodarone-induced
  thyrotoxicosis), as a way to follow the ther-
aputic response to glucocorticoids. Reversal
of the destructive process (signaled by a decrease
of the IL-6 concentration) should precede the
 correction of the hyperthyroidism.

- **Helping explain exacerbations in patients
  with type 2 amiodarone-induced thyrotho-
 xicosis who are being tapered from glucocorticoids.

- **Cases of apparent type 1 amiodarone-
  induced thyrotoxicosis that recur or fail to
  respond to treatment that actually are mixed
  forms of amiodarone-induced thyrotoxico-
sis.1–4

Low TSH is not
diagnostic and
can indicate
sick euthyroid
syndrome
Color flow Doppler sonography determines the amount of blood flow within the thyroid and provides information about its morphology. Four patterns are recognized:

- Pattern 0: absent vascularity, gland destruction
- Pattern 1: uneven patchy parenchymal flow
- Pattern 2: diffuse, homogeneous distribution of increased flow, similar to Graves disease
- Pattern 3: markedly increased signal and diffuse homogeneous distribution.

Pattern 0 is associated with type 2 and the others with type 1 amiodarone-induced thyrotoxicosis.

Color flow Doppler sonography has shown the most promise as the best tool for the rapid and early diagnosis of type 1 and 2 amiodarone-induced thyrotoxicosis. A recent retrospective review of 37 patients with amiodarone-induced thyrotoxicosis during a 3-year period reported very encouraging results.

TREATMENT IS DIFFICULT

While mild amiodarone-induced thyrotoxicosis subsides spontaneously in up to 20% of cases, treatment is usually a challenge, especially if the type is uncertain.

Whether to stop amiodarone also poses a dilemma because the patient may need it to control his or her arrhythmia. Even if the drug is immediately stopped, the thyrotoxicosis may not reverse for months because of the drug's long elimination half-life and the large total-body iodine stores. Unless amiodarone is ineffective in controlling the arrhythmia, it is usually continued while treating amiodarone-induced thyrotoxicosis.

The two types of amiodarone-induced thyrotoxicosis are treated differently (TABLE 3; FIGURE 1).

Type 1, caused by increased hormonal synthesis, must be treated with a thionamide, eg, methimazole 30 mg/day or propylthiouracil 200 to 300 mg/day.

In addition, potassium perchlorate competitively inhibits iodine intake by the thyroid and minimizes the intrathyroidal iodine content.

Perchlorate use has enjoyed a resurgence in recent years because it can control hyperthyroidism in states of high iodine loads. Its use had virtually ceased in the early 1960s (except for single-dose use in the perchlorate discharge test or as an adjunct to pertechnetate scanning), after seven cases of fatal aplastic anemia were reported worldwide among patients treated for thyrotoxicosis of various etiologies.

It is now clear that perchlorate is extremely effective in conjunction with thionamides for treating type 1 amiodarone-induced thyrotoxicosis, and that it can be used safely, provided that the daily dose is 1,000 mg or less and that the dosage is tapered or stopped after approximately 30 days. Thereafter the thionamide alone can be continued for as long as it is needed.

Perchlorate is difficult to obtain through regular pharmacy channels, and it is not FDA-approved for treating hyperthyroidism. Pharmacists may need to be instructed to purchase perchlorate directly from Mallinckrodt (888-744-1414; www.Mallinckrodt.com).

Type 2 is treated with a relatively long course of a glucocorticoid for its anti-inflammatory and membrane-stabilizing effects. Prednisone 30 to 40 mg daily, tapered over 2 to 3 months, is recommended. Lithium, which inhibits thyroid hormone secretion, has been tried with good results in a relatively small number of patients with presumptive type 2 amiodarone-induced thyrotoxicosis.

EXACERBATION AFTER CONTROL

Thyrotoxicosis may worsen after initial control. In type 1, one should evaluate for possible overlapped type 2 amiodarone-induced

<table>
<thead>
<tr>
<th>TABLE 3</th>
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<tr>
<td><strong>Type 1</strong></td>
<td>Thionamide (eg, methimazole ~30 mg/day or propylthiouracil ~300 mg/day) for as long as needed</td>
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<tr>
<td></td>
<td>Potassium perchlorate (Perchloracaps 200 mg tablets), no more than 5/day. Stop or taper after 30 days</td>
</tr>
<tr>
<td><strong>Type 2</strong></td>
<td>Prednisone 30–40 mg/day, taper over 2–3 months</td>
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</tbody>
</table>

To treat amiodarone-induced thyrotoxicosis, you must know the type
thyrotoxicosis and add steroid therapy to the current treatment.\textsuperscript{2,21}

In type 2, exacerbation can occur when the corticosteroid treatment is tapered. In such cases, the steroid dose should be increased again.\textsuperscript{1,2}

**THYROIDECTOMY, OTHER TREATMENTS**

Total thyroidectomy controls thyrotoxicosis and permits amiodarone to be safely continued. It must be considered\textsuperscript{22–24} for:

- The most severe cases that fail to respond to combination therapy with thionamides, perchlorate, and corticosteroids
- Very sick patients who must continue amiodarone.

Total thyroidectomy utilizing local anesthesia may be the best option for the critically ill.\textsuperscript{24} The resulting hypothyroidism can be easily treated with thyroid hormone replacement.

Radioactive iodine treatment seldom works in amiodarone-induced thyrotoxicosis, because iodine uptake by the gland is inhibited by the iodine of amiodarone. Nevertheless, it can be used as a definitive treatment in the

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**FIGURE 1.** Mild, moderate, and severe thyrotoxicosis are distinguished by the severity of the clinical picture.
rare patient with evidence of adequate iodine uptake (high RAIU).\textsuperscript{16} Recombinant TSH could theoretically be used to enhance the uptake of an ablative dose, but this approach has not been adequately evaluated. Plasmapheresis has only small or transient beneficial effects.

\section*{REFERENCES}


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