Thyroid Artery Embolization for Thyroid Nodules, Goiter, and Graves' Disease

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Abstract

Thyroid nodules, goiter, and Graves' disease currently lack a robust treatment algorithm, as traditional interventions, such as medical therapy and surgery, carry high relapse rates or risks of permanent complications. Thyroid artery embolization (TAE) has emerged as a minimally invasive, nonsurgical alternative for patients with select thyroid pathologies. It is primarily indicated for patients with large symptomatic benign nodules exceeding 30 mL, compressive goiters, hyperthyroidism refractory to medical therapy, or those who are poor surgical candidates or wish to avoid surgery. TAE targets feeding thyroid arteries with embolic spheres, aiming to diminish parenchymal blush. Published studies reported volume reductions between 53% and 69%, high rates of euthyroidism restoration, and decreases in thyrotropin receptor antibody levels for Graves' disease. While rare major complications exist, TAE maintains a favorable safety profile characterized primarily by transient postembolization syndrome. TAE provides a viable, tissue-sparing alternative for appropriately selected patients, though further prospective trials and standardized protocols are required to fully establish its long-term role within the treatment algorithm.

Keywords: thyroid artery embolization, thyroid nodule, thyroid goiter, Graves' disease, transarterial embolization

Introduction

The thyroid gland is a vascularized endocrine organ located below the thyroid cartilage and anterior to the trachea in the lower anterior neck, composed of 2 lobes connected by an isthmus.[1] The superior and inferior thyroid arteries provide the primary blood supply to the gland, with occasional contributions from a thyroidea ima artery originating from the aortic arch or brachiocephalic trunk.[2,3] The thyroid consists of follicles lined by follicular epithelial cells that synthesize and store thyroid hormones responsible for regulating the body's metabolic functions.[4]

Thyroid nodules are focal areas of abnormal growth within the thyroid parenchyma and represent one of the most common clinical findings in endocrinology.[5] Their global prevalence has increased from 22% between 2000 and 2011 to 29% between 2012 and 2022.[6] Thyroid nodules are largely asymptomatic, but may be accompanied by dysphagia, dyspnea, hoarseness, and neck pain. Additionally, the gland's anatomical location creates an aesthetic motivation for nodule removal. Risk factors for thyroid nodules include female sex, older age, higher body mass index, and iodine deficiency.[5] Approximately 10% of those who present with thyroid nodules, especially those who have undergone childhood irradiation, have a family history of thyroid cancer or hereditary syndromes, and rapid nodule growth, are at risk of malignancy.[7]

First-line management for benign, asymptomatic thyroid nodules typically consists of US monitoring to observe changes in gland size. For those with symptomatic, benign nodules, radioactive iodine (RAI) therapy achieves 40-50% volume reduction within 1 year, but it is limited by variable rates of response, high rates of subsequent hypothyroidism, and decreased efficacy in goiters.[8-10] More recently, other minimally invasive techniques such as radiofrequency ablation (RFA) have emerged. RFA has shown lower complication rates than

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surgery, with associated volume reduction rates (VRRs) of 73% at 6 months and 76% at 12 months.[11] However, RFA may require multiple sessions for large nodules, resulting in an extended treatment course.[12,13] For patients with large goiters or nodules refractory to the aforementioned therapies, current surgical interventions include thyroid lobectomy or total thyroidectomy. Despite their high efficacy, surgical procedures require general anesthesia and carry the risk of recurrent laryngeal nerve injury, permanent hypoparathyroidism, and postoperative hemorrhage.[14]

Graves' disease, another common thyroid pathology, is the most common cause of hyperthyroidism with an incidence of around 20-50 cases per 100,000 people.[15] Graves' is an autoimmune disorder in which thyrotropin receptor antibodies (TRAb) bind to and activate thyroid-stimulating hormone (TSH) receptors on thyroid follicular cells. This results in unregulated synthesis and release of thyroid hormones independent of the hypothalamic-pituitary axis, leading to palpitations, tremor, weight loss, anxiety, and diarrhea.[16] Graves' disease can also present with extrathyroidal manifestations, including orbitopathy and dermatopathy, which result from fibroblast activation and glycosaminoglycan deposition in the retro-orbital tissues and skin.[15]

Current treatment options for Graves' disease include antithyroid drugs (ATDs), RAI therapy, and thyroidectomy. ATDs are widely used and effective for short-term resolution of hyperthyroidism, but with relapse rates of around 50%, their long-term efficacy is compromised. ATDs also carry risk of agranulocytosis and hepatotoxicity, which may limit long-term use.[17] RAI therapy is also effective with resolution but carries the risk of hypothyroidism in 50-70% of patients after low-dose and 90-100% after high-dose regimens, with the potential of exacerbating or inducing Graves' orbitopathy.[18,19]

This review examines the potential role of thyroid artery embolization (TAE) in the treatment of thyroid nodules, goiter, and Graves' disease in patients who are not ideal candidates for surgery or prefer nonsurgical treatment.

Patient Selection

Patient selection plays a central role in optimizing outcomes in TAE. This procedure is most effective in patients with symptomatic benign thyroid nodules measuring greater than 30 mL or multinodular goiter producing compressive symptoms such as dysphagia or dyspnea, those with cosmetic concerns, or those with hyperthyroidism refractory to medical therapy.[20] Ideal candidates are those wishing to delay surgery or who are deemed unfit for surgery. TAE may also serve as an adjunct to thermal ablation in hypervascular nodules where the heatsink effect limits ablative efficacy.[21] In the setting of Graves' disease, TAE may be particularly advantageous for patients with active or high-risk Graves' orbitopathy, in whom RAI therapy is relatively contraindicated due to the risk of exacerbating eye disease.[22]

A thorough clinical evaluation is necessary during the initial consultation to assess suitability for the procedure. Thyroid ultrasonography is essential to characterize nodule features, location, relation to critical structures, and volume. Thyroid function tests, including TSH, free T4, and a complete blood count, are also recommended.[23] For patients being evaluated for Graves' disease, TRAb levels should be obtained to confirm autoimmune etiology and establish a baseline to monitor the severity of the disease.[24] The benign nature of the nodule can be confirmed via a US-guided fine-needle aspiration biopsy yielding a Bethesda II cytology result.[25] In addition to US, cross-sectional imaging with CT may be utilized in cases of suspected retrosternal extension to evaluate the extent of intrathoracic disease.

Given the catheter-based nature of the procedure, patients with hypersensitivity to iodinated contrast media or significant renal insufficiency represent relative contraindications for TAE. Patients with marked tracheal compression may not be well suited for the procedure as post-procedural edema may compromise the airway. Confirmed or suspected thyroid malignancy should be excluded as TAE is not yet indicated as a definitive treatment for thyroid cancer.

Procedural Technique

TAE aims to diminish blood flow to the thyroid parenchyma and its nodular components selectively targeting the feeding branches of the superior and/or inferior thyroid artery, thereby inducing ischemia-driven volume reduction.[26]

Access is typically gained through the radial artery, although femoral access may be used with US guidance while utilizing Seldinger's technique. Given the occurrence of vasospasm in the radial artery, a vasodilatory cocktail is often administered to prevent arterial damage or intraprocedural complications. After placement of a 5-French vascular sheath, a catheter is advanced over a hydrophilic guidewire to select the ipsilateral subclavian artery via a radial approach. Contrast is injected and a subclavian arteriogram is performed to confirm hypertrophied thyroid arteries and hyperemic staining of the thyroid nodule/goiter on the ipsilateral side. A 1.7-2.8-French microcatheter is then selectively advanced in either the ipsilateral thyrocervical trunk or external carotid artery to identify the inferior or superior arteries, respectively. Contrast is injected to delineate the arterial anatomy and confirm the feeding vessels to the thyroid parenchyma. A balloon occlusion or pressure-enabled microcatheter is often selected in these cases to prevent reflux of embolic particles.

Embolization can be performed with calibrated, permanent microspheres or polyvinyl alcohol (PVA) particles. Reported particle sizes range from 100 to 700 µm with microspheres and 350-500 µm with PVA particles.[21,27,28] Particles are injected under fluoroscopic guidance until decreased flow to the thyroid

gland is observed. TAE is routinely performed with particles as opposed to other embolic agents as they allow for more controlled delivery and are able to be lodged at the microvascular level, leading to devascularization and necrosis of the thyroid parenchyma. Embolization is typically performed with 300-500-µm-sized particles, but other particle sizes can be used for more proximal or distal occlusion.[20] In TAE, the endpoint is diminished parenchymal blush within the target nodule or gland rather than complete arterial stasis. There have been reports of occlusion of the proximal portion of feeding arteries with coils to ensure durable embolization.[21] Once embolization of one side of the thyroid is complete, the decision to embolize contralateral vessels depends on the extent of the disease and feeding arteries. If necessary, the procedural steps are repeated on the contralateral side beginning with radial access. In patients with bilateral thyroid nodules or goiter, traditional techniques called for preservation of at least one inferior thyroid artery to reduce the risk of hypoparathyroidism resulting from devascularization of the parathyroid glands, which are located on the posterior surface of the thyroid gland.[21] More recent techniques permit bilateral inferior TAE.

In a retrospective cohort study of 22 patients undergoing pressure-enabled TAE, 12 (55%) underwent bilateral embolization, with a 100% technical and clinical success rate, in addition to no neurovascular complications reported across the entire cohort.[29] This revised approach allows for more distal embolization using smaller particles through the utilization of a pressure gradient generated by a pressurized catheter.

Following embolization, the microcatheter is carefully withdrawn to prevent arterial spasm and completion angiography is performed to confirm occlusion of the target vessels and absence of residual nodular blush. A post-procedure thyroid ultrasonography is performed once the patient is stabilized and all catheters and wires are removed.

Patients are observed for 2-6 hours to monitor for potential complications. Neck pain is a common post-procedural discomfort that can be managed with nonsteroidal anti-inflammatory drugs. Follow-up evaluation is completed 1, 3, 6, and 12 months post-procedure to monitor progress.

Case Examples

An adult patient presented with a multinodular goiter with a history of compressive symptoms. Arteriograms of the right and left subclavian arteries were performed demonstrating hypertrophied right and left inferior thyroid arteries, respectively (Figure 1). Selective arteriograms of the right and left inferior thyroid arteries demonstrated hypervascular tumor blush (Figure 1). The right and left inferior thyroid arteries were embolized using a pressure-enabled technique with 3.5 cc of 100-300 µm microspheres and 3.2 cc of 100-300 µm microspheres, respectively. At a 3-month follow-up, the patient reported improved energy levels and denied throat pain, dysphagia, or dyspnea with a significantly reduced bilateral goiter size.

In another case, an adult patient presented with a large, solitary, nontoxic right thyroid nodule and globus sensation. An axial contrast-enhanced CT image of the neck demonstrated a large, expansile, heterogeneously enhancing right thyroid mass with central necrotic degeneration causing significant mass effect (Figure 2). Intraprocedural cone-beam CT and right inferior thyroid arteriogram supported microcatheter positioning (Figure 2). The right inferior thyroid artery was embolized with 3.7 cc of 100-300 µm microspheres (Figure 2). Post-procedural imaging demonstrated a marked reduction in gland volume (Figure 2).

Clinical Efficacy

A growing body of literature, including a meta-analysis of 10 studies encompassing 347 patients, describes the feasibility and efficacy of TAE for the treatment of thyroid nodules and multinodular goiters. Volume reduction is the primary measure of clinical efficacy, with a significant mean reduction in nodule volume of approximately 52 mL in the meta-analysis.[30] Individual studies have reported volume reduction ranging from 53% to 69% at 6-24 months.[27,28,31] In patients with non-Graves' hyperthyroidism, TAE has also demonstrated efficacy in restoring euthyroidism, with 86% of hyperthyroid patients becoming euthyroid after the procedure.[31]

Emerging data also support the use of TAE in Graves' disease. Although data are limited, preliminary studies have shown it to reduce thyroid volume, normalize thyroid function tests, and decrease TRAb levels in patients with Graves' hyperthyroidism.[32,33]

TAE Versus Alternative Treatment Modalities

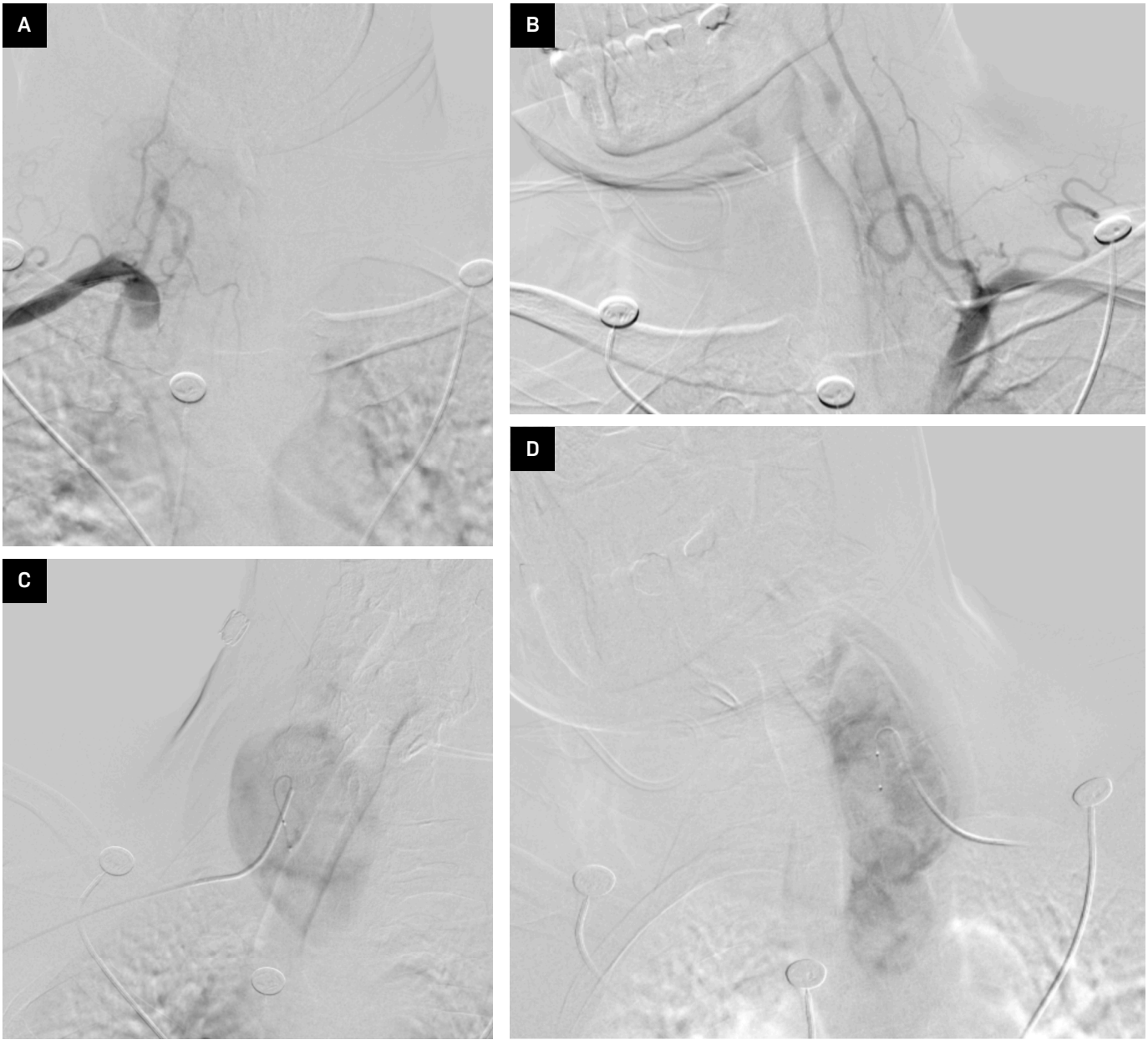
Early comparative data suggest that TAE may offer advantages over RFA for large thyroid nodules. At 6 months, TAE was associated with a significantly greater VRR than RFA for nodules larger than 100 mL.[34] The study also reported a higher complication rate with RFA than with TAE. Although not based on a direct comparison, another study reported a greater VRR with combined TAE and RFA than with 2 sessions of RFA alone.[21]

Although no direct comparisons between TAE and surgical treatment currently exist, early case series data suggest TAE has a favorable safety profile with predominantly minor, self-limited adverse events such as neck pain and transient fever.[33] Serious complications appear rare, though long-term recurrence data remain limited by small sample sizes and short follow-up periods.

A network meta-analysis of minimally invasive treatments for benign thyroid nodules found no significant differences among RFA, laser ablation, microwave ablation, high-intensity focused US, and

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Figure 1. (A) Right subclavian arteriogram demonstrating a hypertrophied right inferior thyroid artery feeding the large thyroid nodule. (B) Left subclavian arteriogram demonstrating a hypertrophied left inferior thyroid artery feeding the large thyroid nodule. (C) Right inferior thyroid arteriogram demonstrating prominent hypervascular tumor blush outlining the large thyroid nodule. (D) Left inferior thyroid arteriogram demonstrating prominent hypervascular tumor blush outlining the large thyroid nodule.



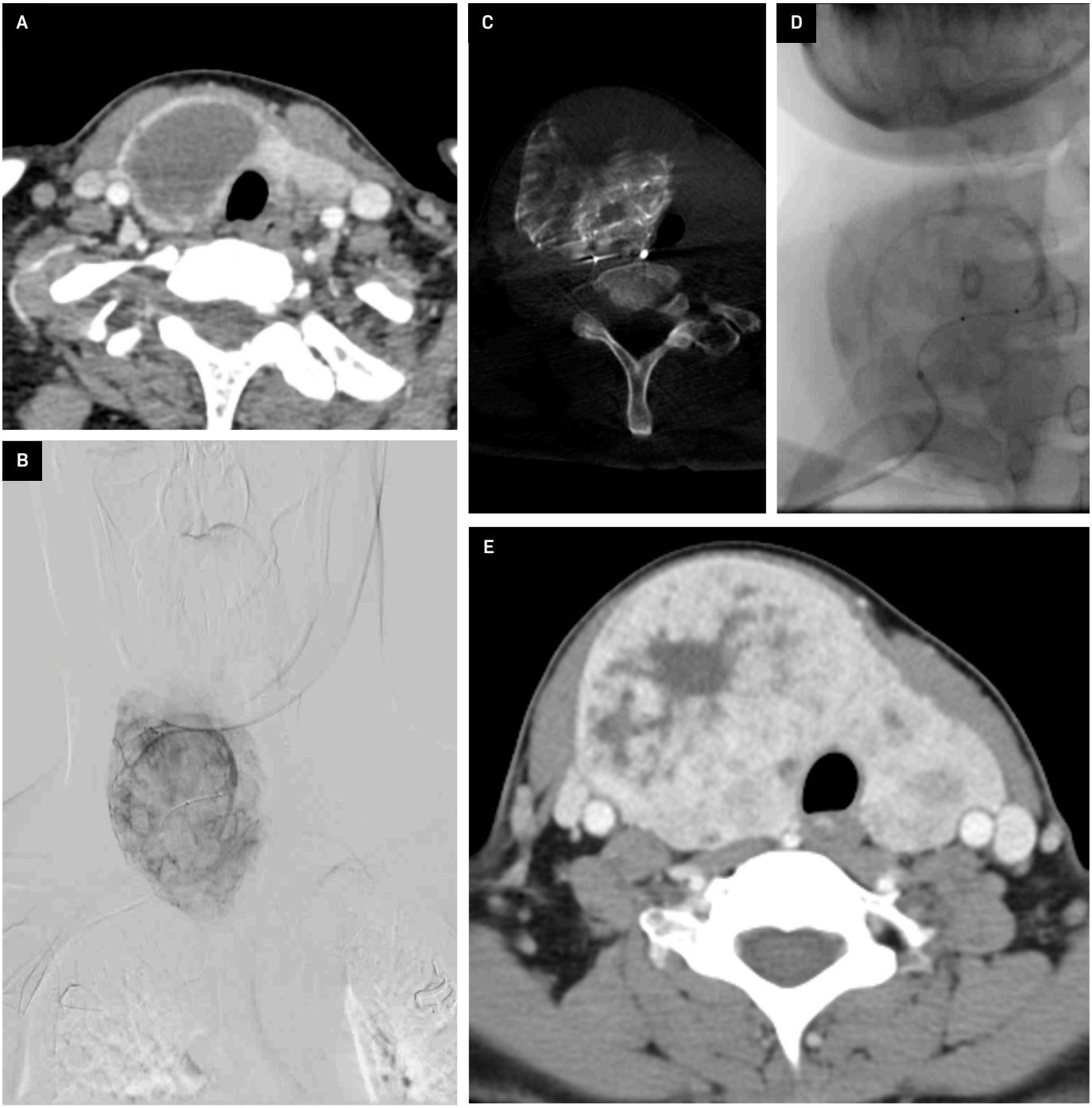
conventional surgery regarding VRR, symptomatic score, and cosmetic score improvement. One of these thermal ablation modalities, RFA, was associated with a reduced risk of vocal complications, hypothyroidism, and nodular regrowth compared to surgery.[35]

Safety

TAE maintains a generally favorable safety profile. The most common adverse events are minor and transient, consistent with postembolization syndrome, which typically includes neck pain, low-grade fever, and mild swelling that is usually self-resolving in a few days.[20,28,33]

Major complications, although rare, have been reported. In a single-center series of 40 patients, the major adverse event rate was 5%, comprising one cerebellar infarction from non-target embolization and one perithyroidal

Figure 2. (A) Pre-thyroid artery embolization (TAE) axial contrast-enhanced CT image demonstrating the size of the solitary large right thyroid nodule with compression of the trachea. (B) Right inferior thyroid arteriogram demonstrating prominent hypervascular tumor blush outlining the large right thyroid nodule. (C) Axial intraprocedural cone-beam CT image demonstrating selective microcatheter positioning and dense parenchymal contrast opacification throughout the targeted right thyroid nodule. (D) Intraprocedural inferior thyroid arteriogram demonstrating the final embolization endpoint, characterized by diminished parenchymal blush of the hypervascular right thyroid nodule. (E) Post-TAE axial contrast-enhanced CT image demonstrating extensive central hypoattenuation within the treated right thyroid nodule alongside marked reduction in solid enhancement and mass effect on the adjacent trachea.



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hematoma requiring percutaneous drainage.[27] Given the possibility of cerebral infarcts, it is imperative that an experienced interventional radiologist performs these with proper equipment and training.

In another single-center series of 56 patients, a mortality rate of 1.8% at 30 days was reported after a patient passed away from a myocardial infarction that was possibly procedure related.[31] Reflecting these safety concerns, a 2026 systematic review of 24 studies concluded that the potential for serious complications and the absence of a standardized protocol currently preclude routine use of TAE, which should be reserved for exceptional cases performed at specialized centers.[26] More recently, the 2026 North American Society for Interventional Thyroidology (NASIT) consensus statement took a more supportive position, concluding that TAE is a safe, effective, and durable option for selected patients with large symptomatic benign nodules and goiters while still emphasizing the need for further studies to standardize technique and define its role relative to other therapies.[20]

Given the catheter-based, minimally invasive nature of the procedure, TAE does not carry the risks of recurrent laryngeal nerve injury, permanent hypothyroidism, wound infection, or delayed healing that are associated with thyroidectomy.[23,36]

Conclusion

TAE is an emerging, minimally invasive treatment option for patients with symptomatic thyroid nodules or goiter who are poor surgical candidates or wish to avoid surgery. Preliminary evidence also suggests potential benefits for selected patients with Graves' disease. Reported reductions in thyroid volume, restoration of euthyroidism in some patients, and the 2026 NASIT consensus statement support further consideration of TAE in selected patients. However, serious complications have been reported, and a 2026 systematic review concluded that current evidence does not support its routine use. Although TAE shows promise, further prospective studies, standardized techniques, direct comparisons with surgery and thermal ablation, and long-term outcome data are needed to better define its safety, efficacy, and role in thyroid disease management.

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