TAE

**1**

**Title**:
Thyroid artery embolization of large solitary symptomatic benign thyroid nodules through transradial approach

**Summary**:
This retrospective study evaluated the feasibility, safety, and short-term outcomes of thyroid artery embolization (TAE) using a transradial approach (TRA) in six patients with large solitary benign thyroid nodules. All procedures were technically successful with no conversions to transfemoral access. Significant reductions in nodule volume (mean 81.8% at 3 months) and symptom scores were observed. Minor complications, such as transient neck pain and voice changes, resolved with conservative management. The findings suggest TRA TAE is a promising minimally invasive alternative to surgery or thermal ablation, especially in patients with large nodules who refuse surgery.

**Abstract**:
Objective: To assess the efficacy and safety of TRA thyroid artery embolization for large solitary symptomatic benign thyroid nodules.

Methods: Six patients (3 males, 3 females; mean age 36.3) with solid nodules >20 mL underwent TRA TAE between October 2021 and June 2022. Nodule volume, visual analog scale (VAS) symptom scores, thyroid hormone levels, and complications were recorded at 1 and 3 months post-procedure.

Results:

- 100% technical success rate with no need for transfemoral access conversion.
- Mean baseline nodule volume: 84.1 mL → 38.8 mL at 1 month → 14.8 mL at 3 months.
- Mean volume reduction rate: 54.9% at 1 month; 81.8% at 3 months.
- VAS scores significantly improved at 1 month (P=0.028) and improved further at 3 months (P=0.068).
- Minor complications included neck pain (n=5), transient voice change (n=1), and radial artery spasm (n=1). No major complications or cases of hypothyroidism occurred.

Conclusion: TRA TAE appears to be a safe and effective alternative for treating large benign thyroid nodules. It offers excellent volume reduction and symptom relief with minimal complications and avoids surgery or thermal ablation in selected patients.

**Reference**:
Cheng KL, Liang KW, Lee HL, Wang HY, Shen CY. *Thyroid artery embolization of large solitary*

*symptomatic benign thyroid nodules through transradial approach.* Quant Imaging Med Surg. 2023;13(8):5355–5361.
DOI: 10.21037/qims-22-1385

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**2**

**Title**: Thyroid Embolization for Nonsurgical Treatment of Nodular Goiter: A Single-Center Experience in 56 Consecutive Patients

**Summary**:
This retrospective study presents the largest cohort to date evaluating thyroid artery embolization (TAE) as a nonsurgical treatment for nodular goiter. Fifty-six patients with symptomatic benign nodular goiter (both solitary and multinodular types) underwent TAE using polyvinyl alcohol particles. The procedure led to significant nodule volume reduction and symptom relief, with most patients remaining euthyroid. TAE was well-tolerated with a low rate of major complications, offering a viable, minimally invasive alternative for patients unfit or unwilling to undergo surgery.

**Abstract**:
Purpose: To evaluate the safety and efficacy of thyroid artery embolization in patients with benign nodular goiter.

Materials and Methods: A total of 56 patients (33 women, 23 men; mean age 51.2 years) underwent TAE between March 2018 and December 2020. Patients were divided into two groups: solitary/dominant nodules (n=20) and multinodular goiter (n=36). Polyvinyl alcohol particles (300–500 μm) were used for embolization of 1–3 thyroid arteries per patient. Follow-up imaging and symptom assessments were conducted at 1, 3, and 6 months.

Results:

- Technical success was achieved in all cases.
- Mean nodule volume reduction was 60.8% at 6 months.
- Symptom improvement was reported by 89% of patients.
- 2 major complications (3.6%): one groin hematoma, one case of symptomatic hyperthyroidism requiring hospitalization.
- Minor complications included transient neck pain (39%), subclinical hyperthyroidism (13%), and hoarseness (3.6%).

Conclusion: TAE is a safe and effective nonsurgical option for treating benign nodular goiter, particularly in patients who are poor surgical candidates or prefer a less invasive approach. Larger studies with long-term follow-up are warranted.

**Reference**:
Yilmaz S, Habibi HA, Yildiz A, Altunbas H. *Thyroid Embolization for Nonsurgical Treatment of Nodular Goiter: A Single-Center Experience in 56 Consecutive Patients.* J Vasc Interv Radiol. 2021 Dec;32(12):1449–1456.e1.
Link to article

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**3**

**Title**:
Impact of Thyroid Arterial Embolization on Clinical and Biochemical Outcomes and Quality of Life in Patients with Nodular and Multinodular Goiter

**Summary**:
This prospective single-center study assessed thyroid artery embolization (TAE) in patients with symptomatic nodular or multinodular goiter who were poor surgical candidates or refused surgery. Twenty patients underwent TAE using polyvinyl alcohol (PVA) particles. The procedure was technically successful in all cases, with a median nodule volume reduction of 63.7% at 6 months. Significant improvements were observed in goiter symptoms, cosmetic appearance, and thyroid-related quality of life as measured by the ThyPRO-39 questionnaire. No major complications were reported, and most side effects were mild and self-limited. TAE proved to be a safe, effective, and well-tolerated treatment for symptomatic benign goiter.

**Abstract**:
Purpose: To assess the impact of thyroid arterial embolization (TAE) on clinical, biochemical, and quality-of-life outcomes in patients with symptomatic nodular or multinodular goiter.

Materials and Methods: In this prospective study, 20 patients (85% female, mean age 57.6 years) with symptomatic goiter underwent TAE using 300–500 μm PVA particles. Outcomes were assessed at baseline and 6 months post-procedure and included thyroid nodule volume (via ultrasound), thyroid hormone levels, symptom scoring, and the validated ThyPRO-39 quality-of-life questionnaire.

Results:

- Technical success: 100%.
- Median dominant nodule volume reduction: 63.7% (range 35.5–95.2%, $p < 0.001$).

- Significant improvement in ThyPRO-39 composite score ($p < 0.001$), especially in goiter, cosmetic, and overall quality-of-life domains.

- Biochemical euthyroid conversion observed in some hyperthyroid patients.

- No major complications occurred; minor adverse events included transient neck pain (60%) and low-grade fever (20%), all resolving conservatively.

Conclusion: TAE offers a non-surgical, minimally invasive alternative for the treatment of symptomatic nodular and multinodular goiter. It achieves substantial nodule reduction, symptomatic improvement, and favorable patient-reported outcomes with minimal morbidity.

**Reference**:
Singh S, Gupta A, Sheth RA, Deipolyi AR, Aruny JE, Ganguli S. *Impact of Thyroid Arterial Embolization on Clinical and Biochemical Outcomes and Quality of Life in Patients with Nodular and Multinodular Goiter.* Cardiovasc Intervent Radiol. 2025.
DOI: 10.1007/s00270-025-04055-1

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**4**
**Title**: Thyroid Arterial Embolization to Treat Graves' Disease

**Summary**:
In this prospective study, 28 patients with hyperthyroid Graves' disease underwent TAE and were followed for 12–22 months. Over 78% reached euthyroidism, with improvements seen in nearly all others. Thyroid hormone levels and antibody titers (TGAb, TMAb) normalized post-embolization. The procedure was well tolerated with no major adverse events, reinforcing TAE as a minimally invasive treatment option for hyperthyroid patients.

**Abstract**:
Twenty-eight patients with Graves' hyperthyroidism underwent TAE. Thyroid hormones spiked briefly post-procedure, then declined over months. At 6–12 months, nearly all hormone and antibody levels normalized. No serious complications occurred. TAE effectively managed Graves' symptoms in most patients.

**Reference**:
Zhao W, Gao BL, et al. *Thyroid Arterial Embolization to Treat Graves' Disease.* Acta Radiol. 2007;48(2):186–192.
DOI: 10.1080/02841850601128967

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**5**

**Title**: Graves' Disease Treated with Thyroid Arterial Embolization: A Pathological and Biochemical Study

**Summary**:
This prospective study analyzed the histopathological and biochemical effects of TAE in 37 patients with Graves' disease. Serial biopsies and lab tests showed the thyroid underwent infarction, necrosis, and long-term fibrosis, corresponding to significant reductions in hormone levels and TRAb. Over 70% of patients achieved euthyroidism with minimal complications. This study demonstrates how TAE alters thyroid structure and function to achieve disease remission.

**Abstract**:
TAE led to acute ischemia, followed by chronic fibrosis and atrophy in the thyroid. TRAb and thyroid hormone levels dropped steadily over time, while TSH increased. Biopsies at 7 days, 6 months, and 3 years confirmed tissue necrosis and remodeling. No serious complications occurred; TAE was well tolerated.

**Reference**:
Zhao W, Gao BL, et al. *Graves' Disease Treated with Thyroid Arterial Embolization.* Clin Invest Med. 2009;32(2):E158–E165.

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**6**

**Title**:The Calcium–Phosphate Balance, Modulation of Thyroid Autoimmune Processes and Other Adverse Effects Connected with Thyroid Arterial Embolization

**Summary**:
This study evaluated biochemical and autoimmune effects of TAE in 22 patients with various thyroid disorders including Graves' disease, retrosternal goiter, and post-amiodarone hyperthyroidism. TAE was associated with significant reductions in thyroid volume and antibody levels, and transient, non-serious changes in calcium-phosphate homeostasis. Over 70% of patients achieved euthyroidism or hypothyroidism without severe side effects, supporting TAE as a safe and effective therapy in complex thyroid conditions.

**Abstract**:
In 22 patients undergoing TAE, thyroid volume and TRAb titers significantly decreased, while autoimmune activity normalized over time. Temporary neck pain and fever were common but manageable. Transient biochemical changes (e.g., hypocalcemia) occurred in a subset but resolved without intervention. No serious complications were reported.

**Reference**:
Kaminski G, Jaroszuk A, et al. *The Calcium–Phosphate Balance, Modulation of Thyroid*

*Autoimmune Processes and Other Adverse Effects Connected with Thyroid Arterial Embolization.* Endocrine. 2014;46(2):292–299.
DOI: 10.1007/s12020-013-0072-2

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**7**

**Title**:Long-Term Immunological Study in Graves' Disease Treated with Thyroid Arterial Embolization

**Summary**:
This long-term prospective immunological study examined 41 patients with Graves' disease (GD) treated with TAE. Immune markers (TRAb, TSAb, TGAb, TMAb) and lymphocyte subsets were monitored for up to 3 years. Significant reductions in thyroid autoantibodies and normalization of CD4+/CD8+ ratios were observed by 6–12 months in responders, indicating restoration of immune balance. Patients with recurrent hyperthyroidism showed persistently elevated antibodies. The results support TAE not only as a thyroid function modulator but also as an immune regulatory treatment.

**Abstract**:
TAE was performed in 41 GD patients. Autoimmune antibodies and lymphocyte subsets were measured at intervals post-embolization. TRAb titers, CD4+/CD8+ ratios, and CD8+ cell levels normalized over time. In cases of recurrence, immune markers remained unchanged. These findings suggest that TAE helps restore immune function in GD.

**Reference**:
Zhao W, Gao BL, et al. *Long-Term Immunological Study in Graves' Disease Treated with Thyroid Arterial Embolization.* J Clin Immunol. 2008;28(5):456–463.
DOI: 10.1007/s10875-008-9209-0

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8

**Title**: Comparison of Clinical Outcomes of Thyroid Artery Embolization in the Treatment of Thyroid Nodules: A Meta-Analysis

**Summary**:
This 2025 meta-analysis pooled data from 10 studies (n = 347 patients) to evaluate the safety and efficacy of thyroid artery embolization (TAE) for treating thyroid nodules. Results demonstrated significant reduction in nodule volume (~45.6% decrease), a favorable increase in TSH, and decreased surgical duration, blood loss, and postoperative drainage when TAE was used preoperatively. The odds of minor vs major complications were strongly in favor of TAE's safety (OR: 42.6). Although quality-of-life improvements were observed, statistical significance

was not reached. This study supports TAE and selective embolization of thyroid arteries (SETA) as safe and effective options for managing symptomatic nodules and preparing patients for surgery.

**Abstract**:
Objective: To compare the clinical outcomes of thyroid artery embolization (TAE) in the treatment of thyroid nodules.

Methods: A systematic review and meta-analysis was conducted using PRISMA guidelines, covering publications from 1973 to 2023. Ten eligible studies with 347 patients were analyzed. Outcomes included changes in FT4, TSH, nodule volume, complication rates, quality of life, and surgical metrics.

Results:

- **Nodule Volume**: Mean reduction of 51.95 mL ($p = 0.0001$).
- **TSH Increase**: Mean difference of –0.63 μIU/mL ($p = 0.009$).
- **Complications**: Minor complications vastly outnumbered major ones (OR = 42.6, $p < 0.00001$).
- **Surgical Outcomes**: TAE reduced mean surgery time by ~31 minutes and blood loss by ~59 g.
- **Quality of Life**: Trend toward improvement, but not statistically significant (OR = 27.72, $p = 0.11$).

Conclusion: TAE significantly reduces nodule volume and improves surgical metrics with a high safety margin. It holds promise as a therapeutic or adjunctive treatment for thyroid nodules, though more randomized controlled trials are needed to reinforce these findings.

**Reference**:
Abdi A, Prihantono P, Hendra FN, Zainuddin AA, Smaradhania N, Syamsu SA. *Comparison of Clinical Outcomes of Thyroid Artery Embolization in the Treatment of Thyroid Nodules: A Meta-Analysis.* Asian Pac J Cancer Prev. 2025;26(8):2785–2792.
DOI: 10.31557/APJCP.2025.26.8.2785



**Title**: Partial Thyroid Arterial Embolization for the Treatment of Hyperthyroidism

**Summary**:
This prospective study evaluated partial thyroid artery embolization (PTAE) as a treatment for hyperthyroidism in patients who were poor candidates for surgery or radioactive iodine. Fifteen patients underwent embolization of one or more thyroid arteries. At 6–12 months, 86.7% of patients reached either euthyroid or hypothyroid states, with a significant reduction in FT4 levels. PTAE was well tolerated, with only minor complications such as neck pain and transient fever. The findings support PTAE as a viable, minimally invasive alternative for managing hyperthyroidism in select populations.

**Abstract**:
Purpose: To assess the safety and efficacy of partial thyroid artery embolization (PTAE) in treating patients with hyperthyroidism who are ineligible for or refuse standard therapies.

Materials and Methods: Fifteen patients (mean age 57, range 31–83) with Graves' disease or toxic nodular goiter underwent PTAE using polyvinyl alcohol (PVA) particles. Thyroid hormone levels and clinical symptoms were evaluated before the procedure and during follow-up at 1, 3, 6, and 12 months.

Results:

- Significant reduction in serum FT4 levels from a baseline mean of $17.67 \pm 4.56$ to $7.81 \pm 2.25$ pmol/L post-embolization ($p < 0.001$).
- At final follow-up, 13 of 15 patients (86.7%) were either euthyroid or hypothyroid.
- Complications were minor: 4 patients reported neck pain and 2 had transient fever.
- No cases of hypoparathyroidism, vocal cord paralysis, or major adverse events occurred.

Conclusion: PTAE is a safe and effective option for patients with hyperthyroidism who are not suitable for surgery or radioactive iodine. It offers a meaningful reduction in hormone levels with minimal risk.

**Reference**:
Brzozowski K, Piasecki P, Zięcina P, Frankowska E, Jaroszuk A, Kamiński G, et al. *Partial Thyroid Arterial Embolization for the Treatment of Hyperthyroidism.* Eur J Radiol. 2012;81(6):1192–1196.
DOI: 10.1016/j.ejrad.2011.03.071

# Thyroid Nodule Ablation

**1**

**Title**: Assessing the efficacy of thyroid nodule radiofrequency ablation using patient-reported outcome measures

**Summary**:

A prospective study evaluated 25 patients (32 nodules) undergoing thyroid RFA using a validated patient-reported outcome tool (ThyPRO). Results showed:

- **Significant improvement** in compressive symptoms by 3 and 6 months post-procedure
- **Marked reduction** in nodule volume and size at all follow-up points
- **Minimal complications**, confirming RFA as an effective, well-tolerated option for symptomatic benign thyroid nodules

**Abstract**:
Background: Radiofrequency ablation has recently emerged as an alternative treatment for thyroid nodules. Most studies are centered on volume reduction, whereas a few have assessed symptom improvement mainly with nonstandardized metrics. As experience in the United States is growing, we aim to assess the efficacy of radiofrequency ablation in treating benign thyroid nodules using the validated Patient-Reported Outcomes Measurement for Parathyroid and Thyroid Disease.

Methods: This is a prospective study of a newly established radiofrequency ablation program at a single tertiary referral center in 2022. Patients who underwent radiofrequency ablation were evaluated using the Patient-Reported Outcomes Measurement for Parathyroid and Thyroid Disease, a validated metric ranging from 0 to 100 at baseline, 2 weeks, 3 months, and 6 months. In addition, a thyroid ultrasound was done at those intervals to assess size and volume reduction. Procedure complications were evaluated as well.

Results: A total of 25 patients underwent radiofrequency ablation during the study period for a total of 32 nodules treated; 84% were female with a mean age of 51 years. The baseline mean nodule volume and largest dimension were 13 ± 11 mL and 3.4 ± 1 cm, respectively. A significant change in the Patient-Reported Outcomes Measurement for Parathyroid and Thyroid Disease compressive score was seen at 3 months (38.9 ± 26.4 to 21.0 ± 21.4; P = .004) and 6 months (32.7 ± 19.9 to 17.5 ± 21.0; P = .02) but not at 2 weeks (41.0 ± 22.7 to 36.1 ± 21.9; P = .28). Significant volume and size reductions were seen at all 3-time points. Two complications occurred.

Conclusion: Our initial results of the thyroid radiofrequency ablation program find that it effectively alleviates symptoms by reducing nodule size in patients with symptomatic benign thyroid nodules.

**Reference**: Akgun, Ege et al. “Assessing the efficacy of thyroid nodule radiofrequency ablation using patient-reported outcome measures.” Surgery vol. 175,3 (2024): 654-660. doi:10.1016/j.surg.2023.07.032

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2

**Title**: Radiofrequency Ablation for the Treatment of Benign Thyroid Nodules: 10-Year Experience

**Summary**:

This large, single-center retrospective study reports a 10-year experience using radiofrequency ablation (RFA) for the treatment of benign thyroid nodules. The authors evaluated 1,250 nodules in 1,096 patients, tracking outcomes such as nodule volume reduction, symptom relief, complications, and recurrence rates. RFA achieved sustained nodule shrinkage (mean volume reduction rate [VRR] of 81.6% at 5 years), excellent symptom improvement, and a low rate of complications or retreatment. These long-term results validate RFA as a safe and effective first-line, nonsurgical treatment for benign thyroid nodules.

**Abstract**:

Background: Radiofrequency ablation (RFA) is increasingly used as a minimally invasive treatment for benign thyroid nodules, but long-term outcome data are limited.

Methods: Between 2012 and 2022, 1,096 patients with 1,250 benign thyroid nodules were treated with RFA. Nodule volume, symptom and cosmetic scores, and thyroid function were assessed over a 10-year follow-up period. Complications, regrowth, and retreatment rates were recorded.

Results:

- Mean baseline nodule volume: $14.6 \pm 13.9$ mL.
- Mean VRR: 72.4% at 1 year, 81.6% at 5 years.
- Symptom and cosmetic scores improved significantly ($p < 0.001$).
- Thyroid function remained normal in nearly all patients.

- Complications were rare (1.6%), with no permanent vocal cord paralysis or hypothyroidism.

- Regrowth rate: 14.1% at 5 years; retreatment rate: 9.3%.

Conclusion: RFA offers durable nodule reduction and symptom relief with an excellent safety profile over long-term follow-up. It is an effective non-surgical alternative for managing benign thyroid nodules.

**Reference**:
Baek JH, Ha EJ, Lim HK, et al. *Radiofrequency Ablation for the Treatment of Benign Thyroid Nodules: 10-Year Experience.* Thyroid. 2024.
DOI: 10.1089/thy.2024.0082

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3 -
**Title**: Long-Term Results of Thermal Ablation of Benign Thyroid Nodules: A Systematic Review and Meta-Analysis

**Summary**:

This meta-analysis reviewed long-term outcomes of thermal ablation for benign thyroid nodules. The studies included evaluated both RFA and LA, the two most common minimally invasive treatment modalities used as alternatives to surgery.

**Abstract**:
Background: Ultrasound-guided thermal ablations have become one of the main options for treating benign thyroid nodules. To determine efficacy of thermal ablation of benign thyroid nodules, we performed a meta-analysis of studies with long-term follow-up of more than 3 years.

Methods: Databases were searched for studies published up to August 25, 2019, reporting patients with benign thyroid nodules treated with thermal ablation and with follow-up data of more than 3 years. Data extraction and quality assessment were performed according to PRISMA guidelines. The analysis yielded serial volume reduction rates (VRRs) of ablated nodules for up to 3 years or more, and adverse effect of ablation during follow-up. Radiofrequency ablation (RFA) and laser ablation (LA) were compared in a subgroup analysis.

Results: The pooled VRRs for ablated nodules showed rapid volume reduction before 12 months, a plateau from 12 to 36 months, and more volume reduction appearing after 36 months, demonstrating long-term maintenance of treatment efficacy. Thermal ablation had an acceptable complication rate of 3.8%. Moreover, patients undergoing nodule ablation showed no unexpected delayed complications during the follow-up period. In the subgroup analysis,

RFA was shown to be superior to LA in terms of the pooled VRR and the number of patients who underwent delayed surgery.

Conclusion: Thermal ablations are safe and effective methods for treating benign thyroid nodules, as shown by a long follow-up
analysis of more than 3 years. In addition, RFA showed superior VRRs compared with LA for the treatment of benign thyroid nodules, with less regrowth and less delayed surgery.

**Reference**

Cho SJ, Baek JH, Chung SR, Choi YJ, Lee JH. Long-Term Results of Thermal Ablation of Benign Thyroid Nodules: A Systematic Review and Meta-Analysis. Endocrinol Metab. 2020;35:339-350. doi:10.3803/EnM.2020.35.2.339.