

Ultrasound-guided microwave ablation combined with polidocanol versus anhydrous ethanol for benign cystic-solid thyroid nodules: a retrospective comparative study

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Research Article

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Abstract

Background

Evidence directly comparing polidocanol with anhydrous ethanol as adjunctive sclerosing agents during microwave ablation (MWA) for benign cystic-solid thyroid nodules is limited. This study compared the efficacy and safety of MWA combined with polidocanol versus MWA combined with anhydrous ethanol.

Methods

This single-center retrospective comparative study included 152 patients with benign cystic-solid thyroid nodules treated between January 2023 and July 2025. Patients received MWA combined with anhydrous ethanol (ethanol group, n = 75) or MWA combined with polidocanol (polidocanol group, n = 77). Nodule volume reduction rate (VRR) was assessed at 1, 3, 6, and 12 months. Subgroup analyses were performed according to cystic-component proportion and intranodular blood-flow grade. Cosmetic scores, thyroid-function indices, and perioperative adverse events were also compared. Between-group comparisons used independent-samples t tests or Wilcoxon rank-sum tests for continuous variables and χ^2 or Fisher exact tests for categorical variables.

Results

All 152 patients completed ultrasound-guided MWA. VRR did not differ significantly between groups at 1, 3, 6, or 12 months (all $P > 0.05$); at 12 months, VRR was $86.85 \pm 6.50\%$ in the ethanol group and $88.03 \pm 6.21\%$ in the polidocanol group ($P = 0.253$). No significant between-group differences were found in 12-month VRR across subgroups defined by cystic-component proportion or blood-flow grade, in cosmetic scores, or in thyroid-function indices. The overall recorded adverse-event rate was lower in the polidocanol group than in the ethanol group (10.39% vs 30.67%, $P = 0.002$). No serious adverse events occurred in either group.

Conclusions

MWA combined with polidocanol was associated with nodule volume reduction, cosmetic improvement, and preservation of thyroid function comparable to MWA combined with anhydrous ethanol, with a lower incidence of recorded adverse events. Prospective studies are needed to confirm these findings.

Trial registration:

Not applicable (retrospective observational study).

Background

Ultrasonography detects thyroid nodules in a substantial proportion of adults, with reported prevalence as high as approximately 68% [1]. Most cystic-solid thyroid nodules are benign and asymptomatic and can be managed with observation [2]. However, active treatment may be considered for patients with compressive symptoms, cosmetic concerns, or substantial anxiety after benignity has been established. Surgical treatment is effective but entails anesthesia, a cervical incision, recovery, and risks of postoperative complications; some patients may also require thyroid hormone replacement [3–5]. Image-guided minimally invasive treatments have therefore become important alternatives for selected benign nodules [6]. Simple aspiration can rapidly decrease the cystic component, but fluid reaccumulation is common [7]. Microwave ablation (MWA) can reduce the solid component while preserving surrounding thyroid tissue [8, 9]. In cystic-solid nodules, however, intracystic bleeding or fluid leakage may interfere with ablation and contribute to incomplete treatment or retreatment [10]. Combining MWA with sclerotherapy may therefore provide complementary treatment of the solid and cystic components. Anhydrous ethanol is an established sclerosant, but extravasation can cause pain and injury to adjacent structures [11]. Polidocanol (lauromacrogol) is a detergent-type sclerosant used in several cystic and vascular lesions and has also been applied to thyroid nodules [12].

Direct evidence comparing polidocanol with anhydrous ethanol when each is combined with MWA for benign cystic-solid thyroid nodules remains limited. We therefore retrospectively compared clinical efficacy and adverse events between these two combination strategies.

Methods

Study design and ethics

This single-center retrospective comparative study was conducted at The Affiliated Huai'an No. 1 People's Hospital of Nanjing Medical University. The study was approved by the institutional ethics committee (KY-2026-228-01), and written informed consent was obtained from all participating patients. The study was conducted in accordance with the Declaration of Helsinki.

Study participants

A total of 152 patients with benign cystic-solid thyroid nodules treated between January 2023 and July 2025 were included. According to the treatment received, 75 patients underwent MWA combined with anhydrous ethanol (ethanol group) and 77 underwent MWA combined with polidocanol (polidocanol group).

Eligibility criteria

The inclusion criteria were: (1) benign cytology or pathology on preoperative needle biopsy; (2) maximum nodule diameter ≥ 2 cm; (3) refusal of or intolerance to surgical resection; (4) neck swelling affecting appearance, a foreign-body sensation in the neck, or substantial psychological burden; (5) no severe cardiac, hepatic, pulmonary, or renal dysfunction; (6) treatment with both ultrasound-guided thermal ablation and

chemical sclerotherapy during the same procedure; and (7) ability to communicate effectively with the treating team.

The exclusion criteria were: (1) malignant or indeterminate biopsy findings; (2) severe medical or surgical comorbidity; (3) large retrosternal goiter; (4) severe coagulation dysfunction; (5) concurrent infectious disease; (6) pre-existing contralateral vocal-cord dysfunction; and (7) known allergy to ultrasound contrast agents.

Equipment and treatment procedures

Ultrasonography was performed using Samsung RS80A and XR85 systems with L3-12A high-frequency probes. MWA was performed using an ECO-100C microwave ablation system and a disposable ECO-100A3 microwave antenna (Nanjing Yigao Co., Ltd., China). Sulfur hexafluoride microbubbles were used for contrast-enhanced ultrasonography. The ethanol group received anhydrous ethanol ($\geq 99.7\%$; Sinopharm Group, China), whereas the polidocanol group received 1% polidocanol (20 mg/2 mL; Siegfried Hameln GmbH, Germany).

Patients were placed supine with the neck fully exposed. Preprocedural ultrasonography was used to define the nodule and its relationship to adjacent vessels, trachea, esophagus, and nerves and to plan the puncture route. After sterile preparation, local anesthesia was achieved with 2% lidocaine. Hydrodissection with normal saline was performed when needed to separate the thyroid from adjacent critical structures. An 18-gauge needle was introduced into the cystic component, and the cyst fluid was slowly aspirated. The cavity was repeatedly irrigated with normal saline until the aspirate became clear; viscous contents were diluted by repeated saline irrigation to facilitate aspiration. In the ethanol group, a volume of anhydrous ethanol equal to approximately one-third of the aspirated cyst volume was used for intracystic irrigation. After three irrigation cycles, the final ethanol instillation was retained for 10 min and then completely aspirated. In the polidocanol group, 1% polidocanol, at a volume equal to approximately one-third of the aspirated cyst volume, was injected into the cystic cavity and used for repeated irrigation; the final instillation was retained for 10 min and then aspirated. MWA was then performed in both groups using a moving, multi-level, multi-point technique under real-time ultrasound guidance. Output power and ablation duration were adjusted according to intraprocedural findings and patient tolerance until the target nodule was covered by the hyperechoic ablation zone. Contrast-enhanced ultrasonography was performed immediately after ablation; residual enhancement prompted supplementary MWA until no residual enhancement was observed.

After the procedure, the puncture site was covered with a sterile dressing. Once ultrasonography showed no bleeding and vital signs were stable, patients returned to the ward. A cold compress was applied to the neck for 4 h, and routine postoperative monitoring, including electrocardiographic monitoring, was provided.

Outcome measures

Treatment response was assessed at 1, 3, 6, and 12 months using the target-nodule volume reduction rate (VRR). Prespecified subgroup comparisons were performed according to the proportion of the cystic component ($< 50\%$ vs $\geq 50\%$) and intranodular blood-flow grade on color Doppler ultrasonography [13]. Blood-flow grade was defined as follows: grade 0, no intranodular blood-flow signal; grade 1, blood flow confined to

the nodule periphery; grade 2, blood-flow signals involving < 50% of the nodule; and grade 3, blood-flow signals involving ≥ 50% of the nodule.

Nodule volume was calculated using the ellipsoid formula: $\text{volume} = \pi/6 \times A \times B \times C$, where A was the maximum nodule diameter and B and C were the two mutually perpendicular diameters in the transverse plane. VRR was calculated as $[(\text{baseline volume} - \text{follow-up volume}) / \text{baseline volume}] \times 100\%$.

Cosmetic status was assessed at baseline and 12 months using a four-point cosmetic score [14]: 1, nodule not palpable; 2, palpable but not visible; 3, visible only during swallowing; and 4, readily visible at rest.

Perioperative adverse events were recorded, including neck pain, fever, cervical hematoma, hoarseness, nausea or vomiting, and alcohol-like reactions.

Thyroid function was assessed at baseline and 1 month after treatment using serum thyroid-stimulating hormone (TSH), free triiodothyronine (FT3), and free thyroxine (FT4).

Statistical analysis

Statistical analyses were performed using SPSS version 22.0. Normally distributed continuous variables are presented as mean ± standard deviation and were compared between groups using independent-samples t tests; paired-samples t tests were used for within-group comparisons. Non-normally distributed continuous variables are presented as median (25th-75th percentile) and were compared using the Wilcoxon rank-sum test. Categorical variables are presented as n (%) and were compared using the χ^2 test or Fisher exact test, as appropriate. A P value < 0.05 was considered statistically significant.

Results

Patient characteristics

Baseline characteristics are summarized in Table 1. The ethanol group included 13 men and 62 women, with a mean age of 48.12 ± 12.27 years and a mean maximum nodule diameter of 3.37 ± 0.98 cm. The polidocanol group included 15 men and 62 women, with a mean age of 47.68 ± 13.53 years and a mean maximum nodule diameter of 3.25 ± 1.06 cm. No statistically significant baseline differences were observed between groups (all P > 0.05).

Table 1
Baseline characteristics of the study groups

Characteristic	Ethanol group (n = 75)	Polidocanol group (n = 77)	P value
Age (years)	48.12 ± 12.27	47.68 ± 13.53	0.832
Sex			
Male, n	13	15	0.733
Female, n	62	62	
BMI (kg/m ²)	24.38 ± 3.44	24.49 ± 3.08	0.833
HR (beats/min)	76.73 ± 5.57	77.22 ± 4.03	0.538
SBP (mmHg)	126.56 ± 10.10	124.43 ± 8.73	0.166
DBP (mmHg)	76.67 ± 8.09	77.36 ± 6.67	0.564
Glucose (mmol/L)	4.97 ± 0.91	4.83 ± 0.64	0.252
Nodule volume (mL)	7.48(3.93, 14.39)	6.30(3.34, 11.61)	0.182
Maximum diameter (cm)	3.37 ± 0.98	3.25 ± 1.06	0.505

Nodule volume reduction

All 152 patients completed ultrasound-guided MWA. Immediate post-ablation contrast-enhanced ultrasonography showed no residual enhancement in 70 of 75 nodules in the ethanol group and 73 of 77 nodules in the polidocanol group. Residual enhancement was detected in 5 ethanol-treated nodules and 4 polidocanol-treated nodules, and supplementary ablation was performed. During follow-up at 1, 3, 6, and 12 months, VRR did not differ significantly between the two groups at any time point (all $P > 0.05$; Figs. 1 and 2; Table 2).

Table 2
Volume reduction rate during follow-up

Follow-up	Ethanol group (n = 75)	Polidocanol group (n = 77)	P value
1 month	43.59 ± 12.64	45.73 ± 10.50	0.257
3 months	57.88 ± 12.13	60.10 ± 10.02	0.219
6 months	73.54 ± 9.90	74.80 ± 8.63	0.404
12 months	86.85 ± 6.50	88.03 ± 6.21	0.253
<i>Note: VRR, volume reduction rate.</i>			

Subgroup analysis by cystic-component proportion

At 12 months, VRR did not differ significantly between treatment groups among nodules with a cystic component < 50% or among those with a cystic component ≥ 50% (both $P > 0.05$; Table 3).

Table 3
Twelve-month VRR by cystic-component proportion

Group	Cystic component (%)	
	< 50	≥ 50
Ethanol group (n = 75)	82.26 ± 4.70	92.68 ± 2.57
Polidocanol group (n = 77)	83.44 ± 5.03	92.99 ± 2.31
P value	0.278	0.591

Subgroup analysis by blood-flow grade

At 12 months, VRR did not differ significantly between treatment groups in any blood-flow grade subgroup (grades 0–3; all $P > 0.05$; Table 4).

Table 4
Twelve-month VRR by intranodular blood-flow grade

Group	Blood-flow grade			
	0	1	2	3
Ethanol group (n = 75)	93.08 ± 2.63	87.30 ± 5.34	81.17 ± 5.33	82.50 ± 3.83
Polidocanol group (n = 77)	93.05 ± 2.42	87.48 ± 5.71	82.51 ± 4.17	83.76 ± 6.65
P value	0.970	0.919	0.400	0.567

Cosmetic score

- Cosmetic scores improved from baseline to 12 months in both groups (both $P < 0.001$). Between-group differences were not significant either at baseline or at 12 months (both $P > 0.05$; Table 5).

Table 5
Cosmetic scores at baseline and 12 months

Group	Baseline	12 months	Within-group P
Ethanol group (n = 75)	2.52 ± 0.76	1.21 ± 0.44	< 0.001
Polidocanol group (n = 77)	2.45 ± 0.74	1.19 ± 0.43	< 0.001
Between-group P	0.590	0.794	—

Thyroid function

- There were no significant between-group differences in FT3, FT4, or TSH at baseline or at 1 month after treatment (all $P > 0.05$; Table 6).

Table 6
Thyroid-function indices before and after treatment

Group	FT3 (pmol/L)	FT4 (pmol/L)	TSH (mU/L)
Baseline			
Ethanol group (n = 75)	4.71 ± 0.54	16.03 ± 2.88	2.01 ± 1.66
Polidocanol group (n = 77)	4.73 ± 0.57	15.92 ± 2.02	2.03 ± 1.42
P value	0.868	0.788	0.927
1 month after treatment			
Ethanol group (n = 75)	4.68 ± 0.60	15.57 ± 2.61	2.07 ± 1.26
Polidocanol group (n = 77)	4.72 ± 0.59	15.71 ± 2.26	2.06 ± 0.73
P value	0.667	0.720	0.930

Adverse events

The overall recorded adverse-event rate was lower in the polidocanol group than in the ethanol group (8/77 [10.39%] vs 23/75 [30.67%], $P = 0.002$; Table 7). Across both groups, three patients developed hoarseness after treatment, which was considered potentially related to recurrent laryngeal nerve irritation or injury during thermal ablation. After symptomatic treatment with glucocorticoids and neurotrophic agents, these patients achieved near-complete recovery within approximately 3 months. No serious adverse events occurred in either group.

Table 7
Adverse events by treatment group

Group	Pain	Fever	Cervical hematoma	Hoarseness	Nausea/vomiting	Alcohol-like reaction	Any adverse event, n (%)
Ethanol group	9	1	2	2	6	3	23(30.67%)
Polidocanol group	3	1	1	1	2	0	8(10.39%)
Overall comparison of any adverse event: $P = 0.002$.							

Discussion

Cystic-solid thyroid nodules contain both fluid and solid components, which can make treatment with a single modality less efficient. Aspiration alone is associated with fluid reaccumulation, whereas sclerotherapy alone may be insufficient when a substantial solid component remains. MWA produces thermal coagulative necrosis of solid tissue, while sclerosants damage the cyst-wall epithelium and vascular endothelium and promote inflammation, thrombosis, adhesion, and fibrosis. The combination may therefore target the two

components in a complementary manner. Current guidance supports image-guided ablation for selected patients with cytologically benign thyroid nodules that cause compressive symptoms or cosmetic concerns; ethanol ablation is well established for cystic or predominantly cystic nodules, whereas thermal ablation may be considered when a substantial solid component persists or after recurrence [1, 15].

In this cohort, VRR at 1, 3, 6, and 12 months was similar in the polidocanol and ethanol groups. This finding suggests that, when both agents are combined with MWA, the choice of sclerosant may have limited influence on overall nodule shrinkage over 12 months. MWA likely contributes substantially to treatment of the solid component, while both polidocanol and ethanol can achieve sclerosis of the residual cyst cavity and wall.

These results are consistent with the study by Gong et al. [16], which directly compared ultrasound-guided polidocanol and ethanol injection for benign cystic or predominantly cystic thyroid nodules and found similar volume reduction and clinical efficacy, with fewer complications in the polidocanol group. A multicenter study also reported comparable VRR after lauromacrogol injection ablation and MWA for predominantly cystic thyroid nodules [17]. Together, these findings support polidocanol as an effective sclerosant for cystic thyroid lesions.

By contrast, Yang and Huang [18] reported greater nodule-volume reduction, fewer adverse events, and a lower recurrence rate with MWA plus polidocanol than with MWA plus anhydrous ethanol. The difference from our efficacy findings may reflect variation in baseline nodule characteristics, cystic proportion, ablation coverage, follow-up duration, and study design. This inconsistency highlights the need for adequately powered prospective comparative studies.

Subgroup analyses according to cystic-component proportion showed no significant between-group difference in 12-month VRR for nodules with either $< 50\%$ or $\geq 50\%$ cystic content. In predominantly cystic nodules, aspiration immediately reduces volume and allows a sclerosant to contact a relatively large cyst-wall surface. In nodules with a larger solid component, response may depend more strongly on the extent of thermal ablation. Previous studies have shown that baseline nodule size and cystic proportion can influence response to ethanol or thermal ablation [19, 20], although our data did not demonstrate a differential effect between the two sclerosants across the prespecified cystic-proportion categories.

Similarly, no significant between-group differences in 12-month VRR were observed across blood-flow grades 0–3. Greater vascularity can theoretically dissipate thermal energy, whereas MWA rapidly heats tissue and coagulates small vessels. Both ethanol and polidocanol can also injure vascular endothelium and promote local thrombosis and fibrosis. These mechanisms may partly explain the comparable response across blood-flow strata, although the subgroup findings should be interpreted cautiously because subgroup sample sizes were limited.

Cosmetic scores improved substantially in both groups and did not differ between groups at 12 months. This result is consistent with the similar VRR observed during follow-up. Progressive resorption and fibrosis of ablated tissue can reduce neck prominence as the nodule shrinks, and previous MWA studies have reported sustained reductions in nodule volume accompanied by improvement in symptom and cosmetic scores [10, 21, 22].

Serum FT3, FT4, and TSH were also similar between groups before treatment and at 1 month. These findings are consistent with prior reports that thyroid function is generally preserved after MWA for benign thyroid nodules [21–23], reflecting the localized nature of ablation and preservation of most surrounding thyroid parenchyma.

The main between-group difference was the overall recorded adverse-event rate, which was lower in the polidocanol group. Because this was a retrospective, non-randomized comparison, the finding should be interpreted as an association rather than proof of a causal safety advantage. Nevertheless, the difference is clinically relevant and is consistent with prior comparative reports of better procedural tolerability or fewer adverse events with polidocanol [16, 19].

Anhydrous ethanol causes cellular dehydration, protein denaturation, endothelial injury, thrombosis, and tissue necrosis but is also strongly irritating. Leakage through the puncture tract or cyst wall can produce pain, local inflammation, edema, and irritation of adjacent nerves; systemic absorption may contribute to flushing, dizziness, nausea, vomiting, or alcohol-like reactions [15, 19]. These effects may account for part of the higher adverse-event burden observed in the ethanol group.

Polidocanol is a detergent-type sclerosant that disrupts endothelial cell membranes, thereby promoting thrombosis, inflammation, and subsequent fibrosis. It also has a mild local anesthetic effect and is generally less irritating than anhydrous ethanol [16, 24]. These pharmacologic characteristics provide a plausible explanation for the lower frequency of recorded adverse events in the polidocanol group.

From a clinical perspective, when volume reduction, cosmetic outcome, and thyroid function are comparable, tolerability may influence the choice of adjunctive sclerosant. Polidocanol may be particularly useful when avoidance of ethanol-related pain or systemic reactions is a priority, although treatment selection should also reflect operator experience, nodule characteristics, availability, and patient preference.

This study has several limitations. First, its retrospective, non-randomized design is susceptible to treatment-selection bias and residual confounding. Second, this was a single-center study with a modest sample size, limiting precision in subgroup analyses. Third, follow-up was limited to 12 months, so longer-term recurrence and durability could not be assessed. Fourth, an MWA-only control group was not included. Larger multicenter prospective randomized or well-designed non-randomized studies with standardized ablation protocols and longer follow-up are needed.

Conclusions

Both MWA combined with polidocanol and MWA combined with anhydrous ethanol achieved substantial volume reduction in benign cystic-solid thyroid nodules over 12 months, with similar cosmetic outcomes and thyroid-function results. Polidocanol was associated with a lower overall recorded adverse-event rate in this retrospective cohort. Prospective comparative studies are warranted to confirm the relative safety and long-term effectiveness of these strategies.

Abbreviations

MWA
microwave ablation
VRR
volume reduction rate
CEUS
contrast-enhanced ultrasonography
CDFI
color Doppler flow imaging
FT3
free triiodothyronine
FT4
free thyroxine
TSH
thyroid-stimulating hormone
BMI
body mass index
HR
heart rate
SBP
systolic blood pressure
DBP
diastolic blood pressure.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of The Affiliated Huai'an No. 1 People's Hospital of Nanjing Medical University (KY-2026-228-01). Written informed consent to participate was obtained from all participants.

Consent for publication

Written informed consent for publication of clinical data was obtained from all participants. Written informed consent for publication of the accompanying ultrasound images was also obtained from the patients whose images are presented in this manuscript.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

YF and CX conceived and designed the study. FZ and QZ acquired the data. QZ and ZM analyzed and interpreted the data. RL and FZ prepared the visualizations. FZ and QZ drafted the manuscript. YF critically revised the manuscript. All authors reviewed the manuscript.

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Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

References

1. Papini E, Monpeyssen H, Frasoldati A, Hegedüs L. 2020 European Thyroid Association clinical practice guideline for the use of image-guided ablation in benign thyroid nodules. *Eur Thyroid J.* 2020;9(4):172–185.
2. In HS, Kim DW, Choo HJ, Jung SJ, Kang T, Ryu JH. Ethanol ablation of benign thyroid cysts and predominantly cystic thyroid nodules: factors that predict outcome. *Endocrine.* 2014;46(1):107–13.
3. Rovira A, Nixon IJ, Simo R. Papillary microcarcinoma of the thyroid gland: current controversies and management. *Curr Opin Otolaryngol Head Neck Surg.* 2019;27(2):110–6.
4. Patel KN, Yip L, Lubitz CC, et al. The American Association of Endocrine Surgeons guidelines for the definitive surgical management of thyroid disease in adults. *Ann Surg.* 2020;271(3):e21–93.
5. Koimtzis GD, Stefanopoulos L, Giannoulis K, et al. What are the real rates of temporary hypoparathyroidism following thyroidectomy? It is a matter of definition: a systematic review. *Endocrine.* 2021;73(1):1–7.
6. Cheong CWS, Au JXY, Lim MY, et al. The efficacy and safety of high-intensity focused ultrasound in the treatment of benign thyroid nodules: a systematic review and meta-analysis from 1990 to 2021. *Ann Acad Med Singap.* 2022;51(2):101–8.
7. Kim JH, Lee HK, Lee JH, Ahn IM, Choi CG. Efficacy of sonographically guided percutaneous ethanol injection for treatment of thyroid cysts versus solid thyroid nodules. *AJR Am J Roentgenol.* 2003;180(6):1723–6.

8. Luo F, Huang L, Gong X, et al. Microwave ablation of benign thyroid nodules: 3-year follow-up outcomes. *Head Neck*. 2021;43(11):3437–47.
9. Lim H, Cho SJ, Baek JH. Comparative efficacy and safety of radiofrequency ablation and microwave ablation in benign thyroid nodule treatment: a systematic review and meta-analysis. *Eur Radiol*. 2025;35(2):612–23.
10. Su C, Liu YJ, Qian LX. Modified percutaneous ethanol injection method combined with microwave ablation for the treatment of symptomatic, predominantly cystic, benign thyroid nodules: a retrospective study of 201 cases. *Int J Hyperth*. 2021;38(1):995–1001.
11. Perez CL, Figuera TM, Miasaki F, et al. Evaluation of percutaneous ethanol injections in benign thyroid nodules. *Arq Bras Endocrinol Metabol*. 2014;58(9):912–7.
12. Zhou G, Li S, Jiang M, Zhou W, Yin J. Comparison of polidocanol sclerotherapy with laparoscopic deroofing in the management of pediatric symptomatic simple renal cysts: a long-term study. *J Endourol*. 2022;36:99–103.
13. Kim YJ, Baek JH, Ha EJ, et al. Cystic versus predominantly cystic thyroid nodules: efficacy of ethanol ablation and analysis of related factors. *Eur Radiol*. 2012;22(7):1573–8.
14. Valcavi R, Tsamatropoulos P. Health-related quality of life after percutaneous radiofrequency ablation of cold, solid, benign thyroid nodules: a 2-year follow-up study in 40 patients. *Endocr Pract*. 2015;21(8):887–96.
15. Hahn SY, Shin JH, Na DG, Ha EJ, Ahn HS, Lim HK, et al. Ethanol ablation of thyroid nodules: 2018 consensus statement by the Korean Society of Thyroid Radiology. *Korean J Radiol*. 2019;20(4):609–20.
16. Gong X, Wang F, Du H, Chen X, Shi B. Comparison of ultrasound-guided percutaneous polidocanol injection versus percutaneous ethanol injection for treatment of benign cystic thyroid nodules. *J Ultrasound Med*. 2018;37(6):1423–9.
17. Min X, Zhang Z, Chen Y, Zhao S, Ge J, Zhao H, et al. Comparison of the effectiveness of lauromacrogol injection for ablation and microwave ablation in the treatment of predominantly cystic thyroid nodules: a multicentre study. *BMC Cancer*. 2023;23:785.
18. Yang S, Huang D. Application of ultrasound-guided microwave ablation combined with polidocanol injection in benign cystic-solid thyroid nodules and recurrence analysis. *Discov Oncol*. 2025;16(1):736.
19. Yang CC, Hsu Y, Liou JY. Efficacy of ethanol ablation for benign thyroid cysts and predominantly cystic nodules: a systematic review and meta-analysis. *Endocrinol Metab (Seoul)*. 2021;36(1):81–95.
20. Zhang Y, Chu X, Liu Y, Zhao Y, Han X, Hu X, et al. The influence of nodule size on clinical efficacy of ethanol ablation and microwave ablation on cystic or predominantly cystic thyroid nodules. *Endocr Connect*. 2022;11(11):e220248.
21. Liu YJ, Qian LX, Liu D, Zhao JF. Ultrasound-guided microwave ablation in the treatment of benign thyroid nodules in 435 patients. *Exp Biol Med (Maywood)*. 2017;242(15):1515–23.
22. Du JR, Li WH, Quan CH, Wang H, Teng DK. Long-term outcome of microwave ablation for benign thyroid nodules: over 48-month follow-up study. *Front Endocrinol (Lausanne)*. 2022;13:941137.
23. Erturk MS, Cekic B, Celik M, Ucar H. Microwave ablation of symptomatic benign thyroid nodules: short- and long-term effects on thyroid function tests, thyroglobulin and thyroid autoantibodies. *Clin Endocrinol*

(Oxf). 2021;94(4):677–83.

24. Gong X, Zhou Q, Wang F, Wu W, Chen X. Efficacy and safety of ultrasound-guided percutaneous polidocanol sclerotherapy in benign cystic thyroid nodules: preliminary results. *Int J Endocrinol.* 2017;2017:8043429.

Figures

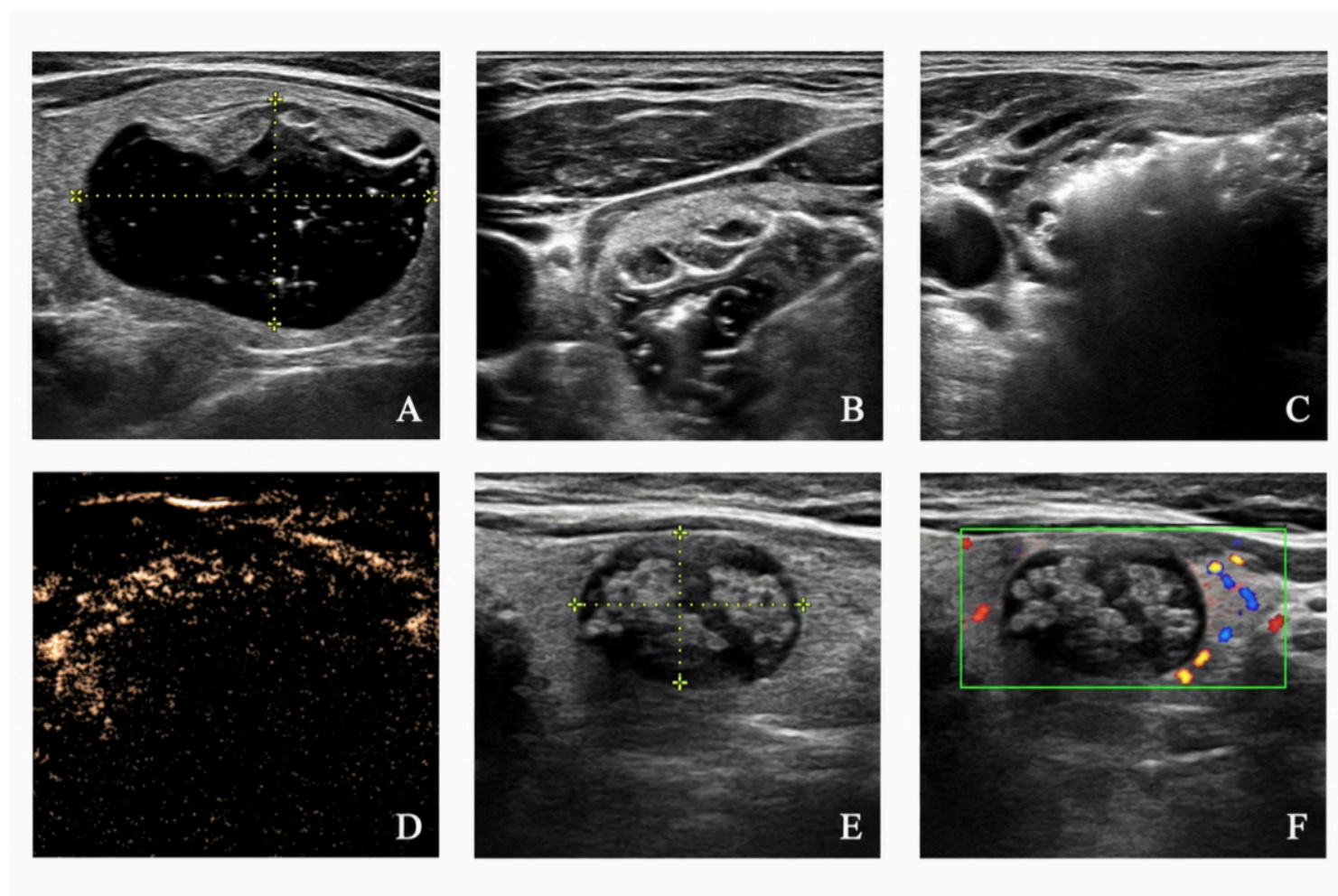


Figure 1

Ultrasound findings after polidocanol-assisted MWA. A 61-year-old woman with a cystic-solid nodule in the left thyroid lobe. (A) Pre-ablation ultrasonography. (B) Intracystic polidocanol treatment. (C) Microwave ablation. (D) Post-ablation contrast-enhanced ultrasonography showing no residual enhancement. (E) Marked nodule-volume reduction at 12 months. (F) Color Doppler flow imaging showing no obvious intranodular blood-flow signal at 12 months.

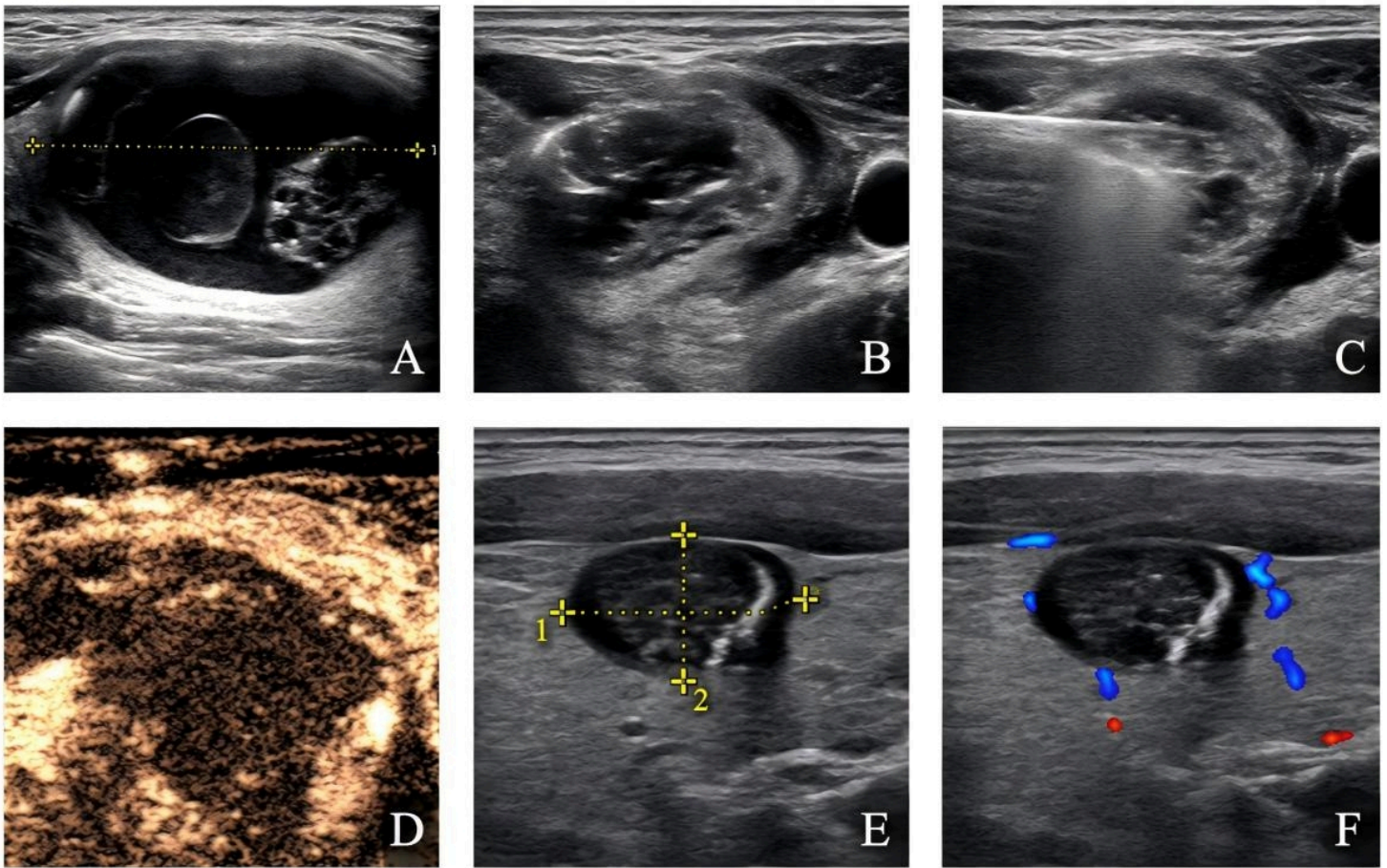


Figure 2

Ultrasound findings after ethanol-assisted MWA. A 31-year-old woman with a cystic-solid nodule in the right thyroid lobe. (A) Pre-ablation ultrasonography. (B) Intracystic anhydrous ethanol treatment. (C) Microwave ablation. (D) Post-ablation contrast-enhanced ultrasonography showing no residual enhancement. (E) Marked nodule-volume reduction at 12 months. (F) Color Doppler flow imaging showing no obvious intranodular blood-flow signal at 12 months.