



Chinese guidelines for ultrasound-guided thermal ablation of thyroid nodules (2024 edition)

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Abstract

The Chinese guidelines for ultrasound-guided thermal ablation of thyroid nodules (2024 edition) were jointly initiated by the Ultrasound Committee of Chinese Medical Association, the Interventional Ultrasound Committee of Chinese Association of Ultrasound in Medicine and Engineering, the Ultrasonic Intervention Committee of Chinese Colleges of Interventionalists, and the Oncological Intervention Committee of Chinese Research Hospital Association; 37 multidisciplinary experts in interventional ultrasound, ultrasound medicine, endocrinology, and thyroid surgery participated in the compilation of this guide, which expanded the depth and breadth of the perspective and enhanced the authority of the guide. Based on the systematic review of literature related to ultrasound-guided thermal ablation of thyroid nodules and the professional opinions of experts, the guidelines define the indications and contraindications of thermal ablation, including pre-ablation evaluation and preparation, thermal ablation techniques and operational procedures, post-ablation follow-up, therapeutic effect evaluation, complication prevention and treatment, and the writing of medical documents for ablation. According to the Grading of Recommendations Assessment, Development, and Evaluation (GRADE), a total of 17 objective and comprehensive recommendations were given. The publication and promotion of this guideline will play a positive role in promoting the standardization of ultrasound-guided thermal ablation of thyroid nodules.

Keywords: guideline, thermal ablation, thyroid, treatment

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

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Introduction

Management of thyroid nodules is one of the most common clinical problems. According to a large-scale authoritative epidemiological study published in 2020 on 78,470 residents in 31 provinces in China, the incidence of thyroid nodules diameter above 5 mm reached 20.43% in ultrasound (US) examination^[1,2]. Previous literature reported that the proportion of thyroid nodules detected by high-frequency US in the random population was 19%–68%^[3–5], and the incidence of thyroid cancer in the Global Cancer Statistics in 2020 was about 3%^[6]. For benign nodules causing discomfort such as compression and cosmetic problems and all malignant nodules, the classic treatment is surgery^[7]. Since Pacella *et al.* first reported the use of laser ablation (LA) to treat thyroid nodules in 2000^[8], thermal ablation techniques, such as microwave ablation (MWA)^[9–13], radiofrequency Ablation (RFA)^[14–18], LA^[19–24], and high-intensive focus ultrasound (HIFU)^[25–31], have been recommended by Chinese and interventional guidelines as the palliative treatment for recurrent or unresectable thyroid cancer and gradually promoted to benign thyroid nodules causing local symptoms or cosmetic problems and papillary thyroid carcinoma (PTC) with diameter less than 1 cm (cT1), which has obtained good medium- and long-term treatment effects^[32–38]. Compared with traditional surgery, thermal ablation has the advantages of simple operation, short operation time, no scar on the neck, low complication rates, outpatient treatment, and preservation of thyroid function, and most of them do not require lifelong medication^[39–43].

US-guided thermal ablation of thyroid nodules has received more and more attention and recognition, but there is still a lack of highly recognized clinical norms. Therefore, the Ultrasound Committee of Chinese Medical Association, the Interventional Ultrasound Committee of Chinese Association of Ultrasound in Medicine and Engineering, the Ultrasonic Intervention Committee of Chinese Colleges of Interventionalists, and the Oncological Intervention Committee of Chinese Research Hospital Association jointly organized and formulated the Chinese guidelines for US-guided thermal ablation of thyroid nodules (2024) to standardize the clinical practice of thermal ablation of benign and malignant thyroid nodules in China. This guide uses the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) to grade the quality of evidence and recommendations (Table 1)^[44]. Experts vote to finalize the recommendations (recommendations are summarized in Table 2, and the flowchart of diagnosis and treatment is presented in Fig 1).

Part 1: the diagnosis of thyroid nodules

Thyroid nodules are space-occupying lesions in the thyroid gland that can be detected by imaging examination and are distinguished from the surrounding thyroid tissue. Some palpable “nodules” may not correspond to the imaging examination^[45], and the imaging examination should prevail.

For all patients undergoing thermal ablation of thyroid nodules, puncture biopsy should be performed first to confirm the pathological diagnosis on the basis of the risk classification of thyroid US examination. Currently, fine-needle aspiration

Table 1
Grading of Recommendations Assessment, Development, and Evaluation

Classification	Hierarchical definition
Recommendation	Strong recommendation (for or against)
	Can apply to most patients in most circumstances
	Benefits clearly outweigh harms and burdens, or vice versa
	Weak recommendation (for or against)
	Best action may differ based on circumstances or patients' values
Evidence quality	Benefits closely balanced with harms and burdens.
	No recommendation (insufficient evidence to recommend for or against)
	High-quality evidence
	Evidence of a low risk of bias, such as consistent results from high-quality randomized trials, can be directly applied to recommendations
	Moderate-quality evidence
	Evidence of flawed research methods, inconsistent results, or indirect results
	Low-quality evidence
	Evidence of insufficient research, case analysis, or non-systematic clinical observation

biopsy (FNAB) and core needle biopsy (CNB) are the two main methods for the pathological diagnosis of thyroid nodules in non-surgical conditions. US-guided FNAB is accurate, economical, safe, and effective and has been recommended by multiple guidelines as the preferred method in the diagnosis of thyroid nodules^[44,46]. CNB has a high incidence of hemorrhage and is recommended for patients with FNAB-undiagnosed thyroid nodules, which can improve diagnosis rates^[47].

FNAB cytological diagnosis refers to the Bethesda System for Reporting Thyroid Cytopathology (BCRTS)^[48], and the corresponding management recommendations are given based on clinical characteristics. At the same time, BRAF/RAS, TERT, PIK3CA, TP53, and other gene tests can be used to assist in the diagnosis of benign and malignant cancer subtypes and prognosis^[49–54].

For benign thyroid nodules, cystic and cavernous nodules in US can undergo FNAB once, and other nodules need to undergo FNAB twice or in combination with CNB^[55,56]. However, neither FNAB nor CNB could distinguish thyroid follicular adenoma from adenocarcinoma. Thyroid radionuclide imaging is one of the methods to diagnose autonomously functional thyroid nodules and can be used as an auxiliary means to assess thyroid function and the presence of ectopic thyroid.

Cervical lymph nodes should be evaluated by US when thyroid nodules are found. If the lymph nodes show the following US characteristics: internal microcalcification, cystic change, hyper-echo, abnormal blood flow, rounded shape, irregular or blurred edges, uneven internal echo or disappearance of lymphatic portal, etc., which indicate suspected lymph node metastasis^[57,58], cytological or histological examination should be performed to confirm the pathological diagnosis^[59–61], and thyroglobulin detection of fine needle aspiration eluent can be performed at the same time^[62].

Recommendation 1: All patients undergoing thermal ablation of thyroid nodules should perform puncture biopsy to confirm the pathological diagnosis, and FNAB is the preferred method (strong recommendation, high-quality evidence).

International Journal of Surgery (2025) 111:1699–1710
Received 24 April 2024; Accepted 27 October 2024
Published online 26 December 2024
<http://dx.doi.org/10.1097/JS9.0000000000002209>

Table 2
Summary of Recommendations

No.	Contents	Recommendation	Evidence quality
1	All patients undergoing thermal ablation of thyroid nodules should perform puncture biopsy to confirm the pathological diagnosis, and FNAB is the preferred method	Strong recommendation	High-quality evidence
2	Thermal ablation is an optional treatment for patients with benign thyroid nodules that are enlarged gradually, have symptoms of compression, affect appearance, or for patients with autonomously functioning adenomas	Strong recommendation	Moderate-quality evidence
3	Thermal ablation is an optional treatment for low-risk patients with primary papillary thyroid carcinoma who meet the indications	Weak recommendation	Moderate-quality evidence
4	Prior to pursuing thermal ablation procedures, patients should be fully informed about the advantages and limitations of thermal ablation. Anticoagulant medications should be discontinued for patients undergoing anticoagulant therapy	Strong recommendation	Moderate-quality evidence
5	US examination should be performed prior to thyroid nodule ablation	Strong recommendation	High-quality evidence
6	CT examination can be used to assess the extent of nodules and the presence of retrosternal lymph nodes and lung metastases prior to thyroid nodule ablation	Moderate recommendation	Moderate-quality evidence
7	Vocal cord function should be adequately assessed prior to performance of ablation procedures	Strong recommendation	Moderate-quality evidence
8	All necessary laboratory tests should be completed prior to ablation procedures. This forms the basis for ensuring treatment safety	Strong recommendation	Moderate-quality evidence
9	Prior to pursuing ablation procedures, thyroid function and calcitonin tests should be performed.	Strong recommendation	Moderate-quality evidence
10	After complete thorough preoperative preparation and comprehensive evaluation, a thermal ablation procedure can be performed	Strong recommendation	Moderate-quality evidence
11	Local anesthesia, transisthmic approach, hydrodissection technique, and the moving-shot and/or fixed electrode technique are recommended as standard techniques. It is also recommended to promptly assess the effectiveness through a CEUS evaluation following thermal ablation	Strong recommendation	Moderate-quality evidence
12	Regular follow-up is required after thermal ablation of both benign and malignant thyroid nodules. Follow-up content should include VRR, improvements of compression symptoms and cosmetic problem, presence of residual nodules, recurrence, metastasis, recovery from complications, and thyroid function	Strong recommendation	Moderate-quality evidence
13	Following the thermal ablation of malignant thyroid nodules, it is advisable to implement TSH suppression therapy. The target TSH control value should be determined according to the initial risk of recurrence, the potential adverse effects of suppression therapy, and the patient's treatment outcome	Moderate recommendation	Moderate-quality evidence
14	In cases of bleeding during the ablation procedure, applying local compression, ablating the bleeding site, or utilizing hemostatic drugs for hemostasis are recommended	Strong recommendation	High-quality evidence
15	To effectively reduce the risk of nerve injury, it is strongly recommended to ensure adequate hydrodessection	Strong recommendation	High-quality evidence
16	NSAIDs are recommended for the prevention/treatment of nodular rupture after thermal ablation of larger nodules	Weak recommendation	Moderate-quality evidence
17	Standardized medical documentation is recommended after thermal ablation of thyroid nodules.	Strong recommendation	Low-quality evidence

Part 2: indications and contraindications of thermal ablation therapy

The advantages and limitations of thermal ablation of thyroid nodules should be fully informed to the patient on the premise of meeting the indications, and the patient’s informed consent should be obtained before treatment.

Indications and contraindications of thermal ablation for benign thyroid nodules

Indications

Chemical ablation is applicable to cysts or cystic nodules with solid composition less than 10%, and thermal ablation is applicable to solid nodules or cystic nodules with solid composition no less 10% confirmed as benign by biopsy and that meet any of the following criteria:

Nodules that cause clinical symptoms such as compression or cosmetic or anxiety problems;

Nodules with maximal diameter ≥ 2 cm and increasing gradually;

Autonomously functioning thyroid nodules;
Recurrent nodules after chemical ablation.

Contraindications

1. Patients with severe bleeding tendency;
2. Patients with severe cardiopulmonary insufficiency or other systemic diseases who are unable to tolerate or cooperate with thermal ablation;
3. Patients with contralateral vocal cord paralysis on the treatment side;
4. Pregnant and lactating women should be treated with caution.

Indications and contraindications of thermal ablation for malignant thyroid nodules

Indications

Thermal ablation is applicable to patients with primary malignant thyroid nodules confirmed as PTC by biopsy and who meet all of the following conditions:

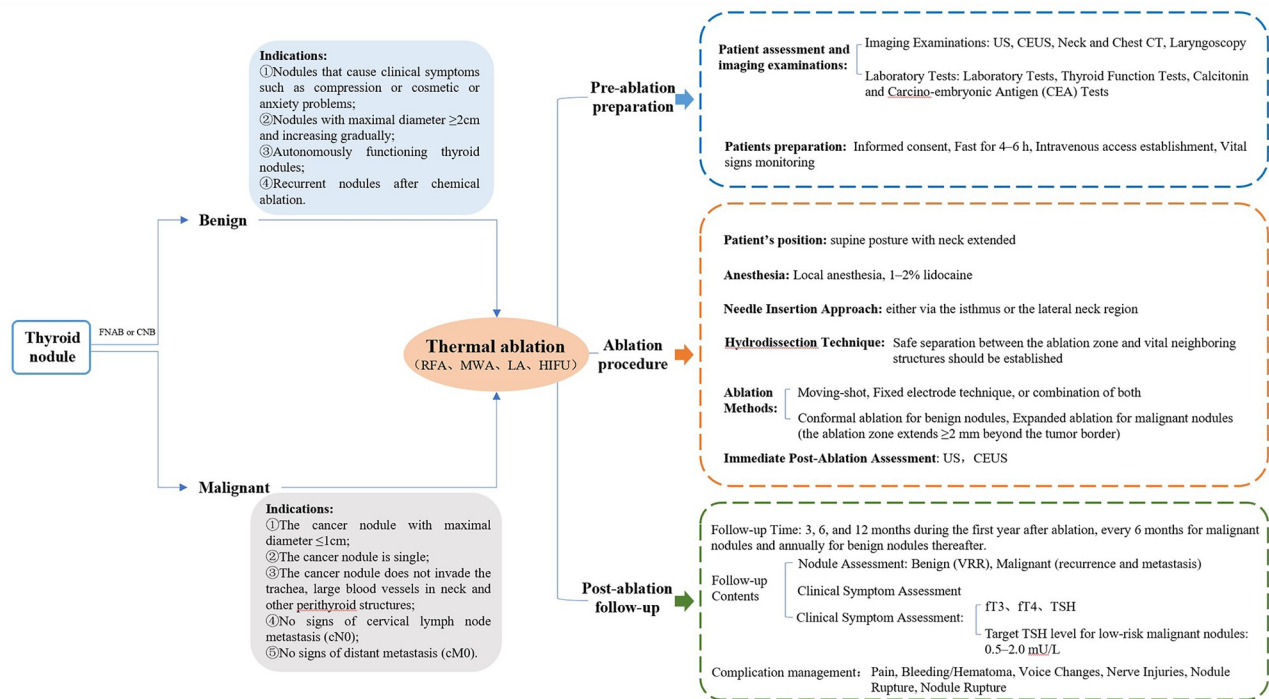


Figure 1. The flowchart of diagnosis and treatment. FNAB: fine-needle aspiration biopsy, CNB: core needle biopsy, RFA: radiofrequency ablation, MWA: microwave ablation, LA: laser ablation, HIFU: high-intensive focus ultrasound, US: ultrasound, CEUS: contrast-enhanced ultrasound, CEA: carcino-embryonic antigen, TSH: thyroid-stimulating hormone, and VRR: volume reduction rate.

- The cancer nodule with maximal diameter ≤ 1 cm;
- The cancer nodule is single;
- The cancer nodule does not invade the trachea, large blood vessels in the neck, and other perithyroid structures;
- No signs of cervical lymph node metastasis (cN0);
- No signs of distant metastasis (cM0).

Thermal ablation is an optional treatment for recurrent thyroid cancer and metastatic cervical lymph nodes with a limited number^[63–65].

Relative indications

Thermal ablation can be considered for malignant thyroid nodules confirmed as PTC by biopsy without signs of cervical lymph nodes and distant metastasis (cN0M0) and that meet any of the following criteria in the condition of available medical technical resources:

1. The cancer nodule located in isthmus;
2. The cancer nodule adjacent to the capsule or with US-detected capsular invasion;
3. The cancer nodule with maximal diameter > 1 cm and ≤ 2 cm;
4. Multiple cancer nodules (number ≤ 3 and maximal diameter ≤ 1 cm).

In addition, thermal ablation is an optional treatment for patients who cannot tolerate surgical resection due to concomitant diseases or refuse surgical resection for various reasons.

Contraindications

1. Consistent with contraindications of thermal ablation for benign nodules;
2. Diffuse sclerosing papillary carcinoma;
3. Other pathologic types of malignancies other than PTC.

Recommendation 2: Thermal ablation is an optional treatment for patients with benign thyroid nodules that are enlarged gradually, have symptoms of compression, affect appearance, or for patients with autonomously functioning adenomas (**strong recommendation, moderate-quality evidence**).

Recommendation 3: Thermal ablation is an optional treatment for patients with primary papillary thyroid carcinoma who meet the indications (**weak recommendation, moderate-quality evidence**).

Part III: pre-ablation evaluation and preparation

Patient assessment and imaging examinations

General assessment of procedural fitness

Patients scheduled for thyroid ablation should possess a comprehensive understanding of standardized diagnostic and therapeutic approaches for thyroid nodules, along with awareness of their advantages and limitations. Additionally, they should clearly comprehend potential complications and express a willingness to engage in the treatment process actively.

The general condition of patients should meet the procedural conditions. Individuals on extended regimens of anticoagulant or vasodilatory medications, such as aspirin, clopidogrel, or compound Danshen dripping pills, should discontinue their use for at least 7 days. In the case of warfarin, it should be discontinued for no less than 5 days. FNAB or thermal ablation treatment can only be performed after correcting coagulation dysfunction.

Recommendation 4: Prior to pursuing thermal ablation procedures, patients should be fully informed about the advantages and limitations of thermal ablation. Anticoagulant medications should be discontinued for patients undergoing anticoagulant therapy (**strong recommendation, moderate-quality evidence**).

Imaging examinations

Ultrasound (US): US is the routine and preferred imaging method for evaluating thyroid and cervical lymph nodes. Thyroid nodules can be categorized according to the thyroid imaging reporting and data system.

Contrast-enhanced ultrasound (CEUS): CEUS can efficiently evaluate the blood supply of thyroid nodules, assisting in gauging the extent of ablation and ascertaining the achievement of complete ablation. It enables an objective and precise evaluation of postoperative effectiveness.

Neck and chest CT: These examinations can accurately define the size and spatial location of thyroid nodules. Neck CT is capable of assessing the positioning of both benign and malignant nodules in relation to the trachea. Chest CT can determine whether benign nodules extend beyond the sternum and can also evaluate the presence of retrosternal lymph nodes or lung metastases in malignant nodules. If there are concerns about extrathyroidal invasion or cervical lymph node metastasis, conducting an enhanced neck CT examination for a more comprehensive assessment is advisable.

Recommendation 5: US examination should be performed prior to thyroid nodule ablation (**strong recommendation, high-quality evidence**).

Recommendation 6: CT examination can be used to assess the extent of nodules and the presence of retrosternal lymph nodes and lung metastases prior to thyroid nodule ablation. (**moderate recommendation, moderate-quality evidence**).

Laryngoscopy: A standard assessment of the function of both vocal cords is required prior to ablation. If there is a decrease or lack of function in the vocal cords on the side opposite to the treatment, it is essential to ascertain whether this is a result of previous surgery or other factors contributing to recurrent laryngeal nerve injury. Typically, indirect laryngoscopy can offer a clear view of the function of both vocal cords. In cases where the view is unclear or abnormal function is observed, the use of an electronic fiberoptic laryngoscope becomes necessary. The restricted activity of the contralateral vocal cord is generally considered a contraindication of ablation, and patients should be well-informed about the risks and potential complications of the procedure.

Recommendation 7: Vocal cord function should be adequately assessed prior to performance of ablation procedures (**strong recommendation, moderate-quality evidence**).

Laboratory tests

Basic laboratory tests

These tests include a comprehensive blood count, blood-type determination, assessment of coagulation function, blood biochemistry analysis, testing for hepatitis B surface antigen, evaluation of hepatitis C antibodies, screening for syphilis antibodies, HIV antibody testing, urinalysis, stool routine examination, and measurement of tumor markers.

Recommendation 8: All necessary laboratory tests should be completed prior to ablation procedures. This forms the basis for ensuring treatment safety (**strong recommendation, moderate-quality evidence**).

Thyroid function tests

This involves the assessment of thyroid hormones and thyroid autoantibodies. Among these, thyroid-stimulating hormone (TSH) testing holds significant importance as an initial screening measure for determining thyroid function. TSH levels are commonly utilized in clinical practice as a crucial indicator of thyroid dysfunction. Additionally, evaluating thyroid autoantibody levels can aid in diagnosing specific autoimmune thyroid diseases, such as Hashimoto's thyroiditis and Graves' disease.

Calcitonin and carcino-embryonic antigen (CEA) tests

Calcitonin and CEA tests have some reference value in the diagnosis of medullary thyroid carcinoma^[66,67].

Recommendation 9: Prior to pursuing ablation procedures, thyroid function and calcitonin tests should be performed (**strong recommendation, moderate-quality evidence**).

3.3 Pre-ablation preparation

3.3.1 Patients or their legal guardians (agents) must receive comprehensive information about the patient's condition, treatment goals, potential intraoperative risks, complications, alternative treatment options, and pre- and postoperative precautions related to thermal ablation. Informed consent must be obtained.

3.3.2 Patients should fast for 4–6 h before the procedure to prevent gastric content regurgitation and aspiration during the operation.

3.3.3 Preoperative intravenous access should be established to facilitate CEUS and intravenous drug administration when necessary.

3.3.4 Intraoperative multi-parameter vital sign monitoring, including an oscilloscope and recording device, should be used to simultaneously display parameters such as blood pressure, heart rate, electrocardiogram, and oxygen saturation, ensuring patient safety during the procedure.

Recommendation 10: After complete thorough preoperative preparation and comprehensive evaluation, a thermal ablation procedure can be performed (**strong recommendation, moderate-quality evidence**).

Part IV: thermal ablation techniques and operating procedures

Thermal ablation techniques

There are currently four main thermal ablation techniques: RFA, MWA, LA, and HIFU. While their principles may differ, they all achieve local tumor inactivation through coagulative necrosis

induced by high-temperature exposure^[68,69]. RFA and MWA are the most widely used techniques for thyroid nodule ablation, which achieves similar clinical results for thyroid ablation in most studies. RFA electrodes are sharp and facilitate easy puncturing. MWA offers strong vascular coagulation ability, providing clear advantages for highly vascularized tumors. MWA is typically recommended for patients with hyper-vascular nodules. In clinical practice, the choice of MWA or RFA is typically based on doctors' preference and the equipment you have. LA is usually used in PTC ablation due to the limited thermal field. HIFU has a more painful procedure than other ablative techniques, which takes longer time to perform and is highly sensitive to movement. Efficacy of HIFU is less established. LA and HIFU have limited thermal efficiency and thus have less clinical applications than MWA and RFA in thyroid ablation.

Thermal ablation procedure

Given the unique location and complex adjacent structures of the thyroid, a thyroid nodule thermal ablation procedure demands careful attention to a series of technical details to ensure safe and successful operations, ultimately achieving effective treatment. Physicians performing thermal ablation need to have more than three years of thyroid ultrasound examination experience, >200 US-guided percutaneous thyroid puncture biopsies, and be skilled in operating ultrasound and thermal ablation equipment.

Positioning

Normally, patients are positioned in a supine posture with their necks extended to ensure complete neck exposure. For obese patients, those with cervical spine conditions, or individuals with a hunchback, measures such as using a low pillow to support the upper back may be taken to ensure a more comfortable treatment position.

Anesthesia

Local anesthesia, utilizing 1–2% lidocaine, is routinely employed. In cases where patients exhibit reduced pain tolerance, concurrent systemic sedation and analgesia may be administered, contingent upon favorable conditions.

Needle insertion approach

Thermal ablation can be conducted either via the isthmus or the lateral neck region, with preference typically accorded to the transisthmic approach^[70-72].

Hydrodissection technique

Depending on the thyroid nodule's location, the hydrodissection technique may be employed to establish a safe separation between the ablation zone and vital neighboring structures. Typically, PTC needles or syringes are employed for injecting isolation fluid. In the case of MWA, a 0.9% sodium chloride injection is commonly used. In contrast, RFA often utilizes sterile distilled water or a 5% glucose injection to effectively distance the thyroid nodule from the recurrent laryngeal nerve, trachea, esophagus, and major neck vessels, among others^[73,74].

Ablation methods

Thermal ablation of thyroid nodules can be conducted either in a moving-shot or fixed electrode technique, or a combination of both. The fundamental principle is to achieve a conformal ablation for benign nodules and an expanded ablation for malignant nodules, which entails ensuring that the ablation zone extends at least 2 mm beyond the tumor border. The ablation zone should reach the capsule in nodules located adjacent to the capsule^[75,76].

Immediate post-ablation assessment

Post-operative observation should be carried out for bleeding, localized swelling, nausea, vomiting, belching, and hoarseness. It is recommended to use routine US combined with CEUS to assess ablation efficacy. Complete ablation is indicated by the absence of enhancement in the ablation zone, with the ablation zone completely covering the intended area. Incomplete ablation is indicated by the presence of remaining vessels, enhancement within the nodule, or inadequate coverage of the designated ablation region.

Recommendation 11: Local anesthesia, transisthmic approaches, hydrodissection techniques, and the moving-shot and/or fixed electrode technique are recommended as standard techniques. It is also recommended to promptly assess the effectiveness through a CEUS evaluation following thermal ablation (strong recommendation, moderate-quality evidence).

Part V: post-ablation follow-up

Post-ablation follow-up includes considerations for both timing and content. The aim is to assess long-term treatment efficacy, regularly monitor complications, and track the patient's condition changes, thereby providing a basis for subsequent disease treatment.

Follow-up time

It is advisable to initiate the initial follow-up one month after the procedure, followed by subsequent assessments at 3, 6, and 12 months during the first year. After the initial 12 months, it is recommended to re-evaluate malignant nodules every 6 months and benign nodules annually.

Follow-up contents

Post-ablation follow-up content comprises thyroid and neck US, improvement of clinical symptom and complications, and laboratory tests. When deemed necessary, it is advisable to conduct assessments of other organs, such as the lungs and bones, to detect potential metastases.

Nodule assessment

Traditional grayscale US is the most frequently employed non-invasive method for assessing the thyroid and cervical lymph nodes following ablation. CEUS can exhibit microvascular perfusion in the ablation zone, facilitating precise evaluation of the extent of the non-enhanced zone after ablation. Consequently, it is advisable to employ CEUS to assess the extents and blood supply of the ablation zone post-ablation.

A reduction in thyroid nodule volume after treatment is an important objective indicator of treatment success. **The recommended formula for assessing nodule volume reduction is as follows:**

Volume reduction rate (VRR) = [(Preoperative nodule volume – ablation zone volume at follow-up) × 100]/preoperative volume (%)^[77].

In the event of confirmed residual or recurrent disease in malignant thyroid nodules, it is imperative to promptly initiate supplementary treatment. Following the thermal ablation of malignant nodules, it is imperative to monitor both the ipsilateral and contralateral cervical lymph node metastasis. When deemed necessary, FNAB should be conducted.

Clinical symptom assessment

Several validated instruments such as symptom scores, anxiety scale, and quality of life instruments may be utilized to document improvements in nodule-related symptoms^[78,79]. The treatment and recovery of related complications also need to be documented.

Laboratory tests

For patients exhibiting thyroid function abnormalities or suspected diffuse thyroid diseases as indicated by US, it is recommended to conduct routine thyroid function tests before and after ablation. In cases involving autonomously functional thyroid nodules treated with ablation, thyroid function tests, including TSH, fT3, and fT4, should be carried out at each follow-up until normal function is restored. Additionally, for patients with elevated thyroid antibodies before ablation, a thorough assessment of thyroid function is necessary to prevent post-ablation hyperthyroidism or hypothyroidism.

Following the thermal ablation of malignant thyroid nodules, it is advisable to implement TSH suppression therapy^[80–83]. The target TSH level for nodules meeting absolute indications should be maintained within the range of 0.5–2.0 mU/L, while for nodules meeting relative indications, the target TSH level should be kept below 0.5 mU/L. Depending on the patient's response to medication, follow-up assessments should be conducted at 3, 6, and 12 months during the first year, followed by evaluations every 6 months once TSH control is achieved.

Recommendation 12: Regular follow-up is required after thermal ablation of both benign and malignant thyroid nodules. Follow-up content should include VRR, improvements of compression symptoms and cosmetic problem, presence of residual nodules, recurrence, metastasis, recovery from complications, and thyroid function (**strong recommendation, moderate-quality evidence**).

Recommendation 13: Following the thermal ablation of malignant thyroid nodules, it is advisable to implement TSH suppression therapy. The target TSH control value should be determined according to the initial risk of recurrence, the potential adverse effects of suppression therapy, and the patient's treatment outcome (**moderate recommendation, moderate-quality evidence**).

Part VI: efficacy of ablation

Currently, studies on thermal ablation for thyroid nodules have relatively short follow-up periods, and long-term follow-up studies with large samples are still required to validate their efficacy.

Thermal ablation for benign thyroid nodules

Currently, the most frequently reported thermal ablation technique for benign thyroid nodules is RFA, followed by MWA. Various thermal ablation techniques can achieve satisfactory VRR, and the incidence of complications is generally low^[36,84–86].

An extensive meta-analysis, which included 12 studies on RFA and an additional 12 studies on LA, evaluating a total of 1186 and 2009 benign non-functioning solid thyroid nodules, respectively, reported VRRs of 68%, 75%, and 87% at 6, 12, and 24 months post-RFA. For LA, the VRRs were 48%, 52%, and 45% at the same time intervals^[87]. Another meta-analysis, comprising 1,461 patients with 1,845 benign thyroid nodules, indicated that the VRR stood at 54%, 74%, and 89% at 3, 6, and 12 months post-treatment, respectively^[88]. The literature on HIFU for benign thyroid nodules is relatively scarce, with small-sample studies suggesting a VRR range of 49% to 69% at 3 to 12 months post-treatment^[89].

It is important to note that thermal ablation treatment for benign thyroid nodules is generally associated with a low incidence of postoperative hoarseness, hypothyroidism, and postoperative pain. Additionally, patients typically experience shorter hospital stays and better cosmetic outcomes compared to conventional thyroidectomy^[90]. Nevertheless, owing to the limited size of the thyroid and intricate neighboring structures, HIFU therapy for thyroid nodules presents an elevated risk of complications^[89,91,92].

Thermal ablation for malignant thyroid nodules

RFA is the most commonly reported thermal ablation technique for malignant thyroid nodules, followed by MWA, with fewer reports on HIFU treatment.

Following ablation therapy, malignant tumors can be rendered completely inactive, and the ablation zone gradually diminishes or even disappears entirely^[35,93]. A meta-analysis scrutinized the therapeutic outcomes of thermal ablation in 1,187 patients with 1,284 T1a-stage PTCs, revealing no statistically significant disparities in volume reduction rates or complete disappearance rates among RFA, MWA, and LA. Furthermore, none of the patients experienced distant metastasis during the follow-up^[94]. Another meta-analysis, incorporating 715 T1a-stage PTCs from 11 studies, reported complete disappearance rates of 57.6% for nodules and a tumor recurrence rate of 0.4%. Among three studies, including 207 T1a-stage PTC patients with follow-up periods exceeding 5 years, there were no instances of local tumor recurrence, lymph node metastasis, or distant metastasis post-thermal ablation. However, four patients did develop new cancer foci in the residual thyroid tissue^[95]. In a comparative study of 339 thermal ablation-treated and 314 surgically resected T1a-stage PTCs, no local recurrence or distant metastasis was observed in either group during the follow-up period. The rates of cervical lymph node metastasis were 2.6% and 3.3%, and the rates of new tumors were 1.4% and 1.3%, respectively, with no statistically significant differences between them. Importantly, the complication rate for thermal ablation (3.3%) was significantly lower than that for surgical resection (7.8%)^[96].

Extend treatment effects

For patients with PTC who meet relative indications, preliminary research suggests that thermal ablation can still yield

effective and safe outcomes. However, high-level evidence-based medical evidence is currently lacking.

Three retrospective studies have demonstrated that thermal ablation achieves a technical success rate of 100% in the treatment of T1a-stage PTCs located in the isthmus. These studies reported no major complications, a recurrence rate of less than 1% within 17–36 months postoperatively, and the absence of lymph node or distant metastases^[97–99]. Results from a prospective multicenter cohort study involving 461 patients have indicated a technical success rate of 99% for thermal ablation in the case of T1a-stage PTCs suspected of capsular invasion on US examination. Furthermore, this study reported a low complication rate of 1% and a recurrence rate of 2% at 20 months postoperatively, with no significant differences when compared to non-invasive PTCs^[13]. Another retrospective study, involving 106 T1a-stage PTC patients, revealed a 100% technical success rate in the thermal ablation of PTCs situated near the thyroid capsule. This study reported a complication rate of 5.7% and an incidence of 2% for lymph node metastasis and the development of new cancer foci at 25 months postoperatively^[100].

In a study, including 847 T1b-stage PTC patients, the complication rate was 6.3%, with a disease progression rate of 1.7% observed at 22 months following thermal ablation. These results showed no significant disparities when compared to T1a-stage cases^[101].

Furthermore, in a multi-center study involving 775 T1-stage PTC patients treated with MWA or surgical resection, comparable treatment effects were achieved with 5-year progression-free survival rates of 77.2% and 83.1% in MWA and surgical resection groups, and MWA resulted in fewer complications^[102]. In a study involving 504 T1-stage PTC patients, the complication rate associated with thermal ablation for multifocal PTC was 4.6%. The disease progression rate at 18 months post-ablation was 4.3%, and no significant difference was noted in comparison to surgical resection^[103]. Another study, including 57 T1-stage PTC patients, reported a disease progression rate of 7% at 18 months following thermal ablation for PTC with up to three cancerous nodules^[104].

Part VII: complication prevention and management

Thermal ablation for thyroid nodules, whether benign or malignant, is generally considered safe, with a complication rate ranging from 1.7% to 3.5%^[9,10,14,105–108]. Complications are classified into three categories: major complications, minor complications, and side effects. Major complications are described as unexpected adverse events that, if not treated, may pose a risk to life or lead to significant illness or disability, necessitating extended hospitalization or care. Side effects are characterized as anticipated adverse consequences that do not necessitate treatment or medication. They have a higher likelihood of occurrence but rarely result in severe conditions. All remaining complications are considered minor. Early complications are those occurring within 30 days of ablation, while delayed complications manifest after 30 days^[109–111].

Pain

Pain represents the most frequent side effect, presenting as discomfort in the ipsilateral neck, jaw, teeth, ears, face, back of the shoulder, and chest. It can occur during and after the procedure.

Potential causes include insufficient anesthesia, periosteal injury, and parenchymal edema. Assessing pain levels using the visual analog scale (VAS) and the numerical rating scale (NRS) is recommended^[112]. Mild pain or a sensation of warmth is considered a side effect, with an incidence of up to 100%. Typically, it is transient and self-limiting, requiring no intervention. Moderate to severe pain is classified as a minor complication and can be mitigated during the procedure by administering additional anesthesia, adjusting the ablation location, reducing power, or temporarily halting ablation. Analgesic medications can be employed if necessary^[106].

Bleeding/hematoma

The incidence of bleeding and hematoma during ablation varies from 0.35% to 17.00%^[9,10,14,105–108]. These events predominantly occur around the thyroid, subcapsular regions, within nodules, and in the thyroid parenchyma. Causes of bleeding include mechanical damage to blood vessels around the thyroid or solid nodules and a sudden drop in pressure within cystic (solid) nodules.

Real-time ultrasound monitoring enables the prompt detection of bleeding, often manageable through local compression or, if necessary, intravenous administration of hemostatic drugs. Hematomas typically resolve within 2–3 days, with larger hematomas taking approximately 2 weeks to absorb. In instances of severe diffuse bleeding within the thyroid parenchyma, the procedure should be temporarily suspended. Local compression and hemostatic drugs should be administered, closely monitoring the patient's condition until stability is achieved, permitting the resumption of ablation therapy^[111,113].

Voice changes

Transient voice alterations, usually recovering within 1–3 days, are typically attributed to temporary paralysis of the recurrent laryngeal nerve and/or superior laryngeal nerve due to lidocaine or local bleeding, with an incidence ranging from 0.5% to 7.9%^[105,106]. Hoarseness of voice occurs at a rate of 1.2%–5.0% and is often associated with injury to the superior laryngeal nerve and/or recurrent laryngeal nerve, or it may result from thermal injury to the vagus nerve^[107].

Following the onset of hoarseness, administering steroids to reduce swelling and inflammation and providing neurotrophic drugs can be considered. In the majority of cases, recovery occurs within 1–3 months. Permanent vocal cord paralysis is exceedingly rare, with rates ranging from 0.04% to 0.17%, and it is categorized as a major complication. Minimizing nerve damage during the ablation process can be achieved through meticulous inserting the needle via the isthmus, employing moving-shot ablation techniques, utilizing hydrodissection methods, and continuously monitoring the needle tip's position^[105,106,114]. Appropriate communication with the patient during the ablation process can help detect changes in the patient's voice.

Other nerve injuries

Thermal ablation can potentially damage sympathetic ganglia and brachial plexus nerves (including accessory nerve) directly or indirectly. These complications, though rare, have reported incidences ranging from 0.04% to 0.08% for sympathetic

ganglia injury and 0.03% to 0.07% for brachial plexus injury^[105-107,111,115].

Sympathetic ganglion injury presents as Horner's syndrome, initially causing ocular discomfort and conjunctival redness, followed by progressive ptosis, miosis, and a lack of facial sweating^[115]. Brachial plexus injury may manifest as immediate limitations in shoulder abduction or shoulder drooping, typically observed in the ablation of neck metastatic lymph nodes. Reducing the risk of these injuries entails clear anatomical knowledge, comprehensive preoperative assessments, adequate fluid isolation during the procedure, and real-time monitoring. Treatment options may involve administering hormones and neurotrophic drugs based on the severity.^[111] Symptoms generally improve gradually after 6 months, but recovery extent varies, with some cases experiencing persisting symptoms

Nodule rupture

Nodule rupture is relatively rare, with incidences ranging from 0.08% to 0.21%^[116-118]. Early patient symptoms include neck discomfort and swelling, alongside reduced echogenicity in the ablation zone around the thyroid parenchyma and increased blood flow signals on ultrasound examination. As the condition advances, the thyroid capsule may rupture, leading to the leakage of necrotic material from the ablated nodule into the extracapsular space, muscles, and skin. This can potentially result in sinus tracts, fasciitis, or abscess formation. Nonsteroidal anti-inflammatory drugs (NSAIDs) are a potential recommendation to prevent or treat nodule rupture in larger nodules. For symptomatic nodule rupture, early administration of NSAIDs can improve the prognosis. Depending on the severity, treatment options may include analgesia and incision and drainage^[116-118]. Surgical excision may be necessary when extensive cellulitis develops.

Vasovagal reflex

Vagal reflex is more prevalent in patients with vagal nerve variations, particularly when large nodules compress the carotid artery and veins. During the ablation procedure, this reflex presents as bradycardia, hypotension, generalized sweating, nausea/vomiting, and urinary incontinence. Immediate cessation of the procedure and placing the patient in a head-down position are imperative. Typically, recovery occurs within 2–3 min^[107].

In addition to these complications, common minor complications and side effects include nausea/vomiting, coughing, neck edema/swelling, fever (≥ 38.5 °C postoperatively), intraoperative hypertension (an increase of ≥ 40 mmHg), muscle tremors, and others. Less frequent complications include infection, esophageal injury/esophageal fistula, tracheal injury/tracheal fistula, skin injury, thyroid dysfunction, among others. The above complications should be dealt with according to the symptoms.

Recommendation 14: In cases of bleeding during the ablation procedure, applying local compression, ablating the bleeding site, or utilizing hemostatic drugs for hemostasis are recommended (**strong recommendation, high-quality evidence**).

Recommendation 15: To effectively reduce the risk of nerve injury, it is strongly recommended to ensure adequate hydrodissection (**strong recommendation, high-quality evidence**).

Recommendation 16: NSAIDs are recommended for the prevention/treatment of nodular rupture after thermal ablation of larger nodules (**weak recommendation, moderate-quality evidence**).

Part VIII: medical documentation for ablation

Ablation documentation practices may vary regionally, but it is generally agreed that the following elements should be included: patient positioning, methods of anesthesia, needle insertion approaches, use of hydrodissection techniques, ablation techniques, power and duration of ablation, the number and locations of ablated thyroid nodules, and immediate post-ablation evaluation using CEUS (the contrast agent used, its dosage, and the extent of the non-perfused area at the original ablation site). Additionally, post-ablation precautions should be documented.

Recommendation 17: Standardized medical documentation is recommended after thermal ablation of thyroid nodules (**strong recommendation, low-quality evidence**).

Conclusion

US-guided thermal ablation is increasingly employed as a safe and effective therapeutic method for both benign and malignant thyroid nodules. For benign thyroid nodules, thermal ablation can result in complete necrosis of the lesions, gradual reduction in nodule volume, alleviation of related symptoms, and even partial or complete cure, which effectiveness and safety have garnered widespread recognition. For T1aN0M0 PTCs, thermal ablation can lead to *in situ* tumor inactivation, which has been recognized by several guidelines. Nevertheless, for PTCs with relative indications, high-level evidence-based medical evidence is still awaited.

Ethical approval

Not applicable.

Consent

Not applicable.

Sources of funding

None.

Author's contribution

Concept or design: Ping Liang and Zhi yu Han; Data collection: Zhi yu Han, Lin Zheng and Jianping Dou; Interpretation: Lin Zheng and Min Xu; Supervision and revision: All authors. Writing the paper: Zhi-yu Han.

Conflicts of interest disclosure

All authors declared that they do not have anything to disclose regarding funding or conflict of interest with respect to this manuscript.

Research registration unique identifying number (UIN)

Not applicable.

Guarantor

Ping Liang.

Provenance and peer review

Not applicable.

Assistance with the study

None.

Data availability statement

No other datasets were generated during and/or analyzed during the current study. All the information is available with the manuscript.

Presentation

None.

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