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CASE REPORT

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Incomplete ablation of thyroid cancer: Achilles' Heel?

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Abstract

Background In recent years, the incidence of thyroid nodules has increased significantly. There are various ways to treat thyroid nodules, and ablation therapy is one of the important ways to treat thyroid nodules. However, there are many complications and deficiencies in the current ablation treatment of thyroid nodules, especially the incomplete ablation of thyroid cancer nodules, which limits the further application of ablation technology.

Case Summary In this paper, we report two cases of incomplete ablation of thyroid nodules, one of which underwent surgical treatment due to anxiety after ablation, and the postoperative pathology confirmed that there was still residual papillary thyroid carcinoma, and the other patient underwent an operation after ablation, but visited our medical institution again due to cervical lymph node metastasis in a short period of time, and after radical cervical lymph node dissection, pathology confirmed multiple cervical lymph node metastasis. Radionuclide therapy was performed after surgery, and two patients are currently receiving endocrine suppression therapy, and their condition is stable with no signs of recurrence.

Conclusion The incomplete ablation of thyroid cancer nodules limits the development of ablation therapy, making ablation treatment a double-edged sword. Guidelines and expert consensus can guide their development, but they need to evolve with the times, and a multidisciplinary diagnostic team can help screen the most suitable patients. Only by using this technology more standardly, using the most appropriate technology, and treating the most suitable patients, can benefit more and more patients.

Keywords Thyroid nodules, Ablation, PTMC, MDT, Case report

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Core Tip

Ablation is one of the important methods for the treatment of thyroid nodules, but there are still many problems in the treatment of thyroid malignant nodules, especially the incomplete ablation of thyroid cancer. We reported two patients with incomplete ablation who were stable after surgery and endocrine therapy. In view of this, we reviewed the literature on thyroid nodule ablation, in order to provide some reference for future medical practitioners in the treatment of thyroid nodule ablation.

Introduction

Thyroid nodules are one of the most common diseases of the endocrine system, with studies showing that 68% of the population suffers from thyroid nodules [1]. Exposure to ionizing radiation in childhood, bad mood, irregular work and rest, abnormal hormone secretion, and heredity are associated with the onset of thyroid nodules [2]. Some thyroid nodules are presented with a neck mass, but most patients with nodules have no obvious symptoms and are mostly found during physical examination. The treatment methods for thyroid nodules include drug treatment, dynamic observation (including dynamic monitoring of cancer nodules), surgery, ablation therapy, etc., and the current treatment strategies for thyroid cancer nodules are mainly the latter three strategies [3].

The development of thyroid ablation technology has been rapid in the last 20 years since the beginning of the 21st century. The efficacy of ablation in the treatment of benign thyroid nodules, especially cystic solid nodules, has been affirmed by many studies and has been recognized and recommended by many medical experts [4, 5]. Its treatment of malignant thyroid nodules is still under clinical research, and some existing studies have affirmed its efficacy [6–8], but some studies and case reports also question and worry about its application in the treatment of malignant nodules, especially the incomplete ablation discourages many medical workers and patients [9].

This article reported two cases of incomplete ablation, summarized the application status of ablation in the treatment of thyroid nodules by reviewing the relevant literature, and put forward some thoughts on the future ablation in the treatment of thyroid nodules. Hopefully, our article can provide some reference for medical professionals who perform thyroid malignant nodule ablation in the future.

Case presentation 1

Chief complaints

The patient Song, female, 34 years old, farmer, was admitted to the hospital because of "After ablation of thyroid carcinoma, anxiety persisted for 1 month.".

History of present illness

The patient was admitted to the local hospital for neck discomfort 1 month before admission, and thyroid B ultrasound showed hypoechoic nodules (size, 4×3 mm) in the right lobe of the thyroid gland (TI-RAIDS IV class), papillary thyroid carcinoma was considered after FNA, and microwave ablation of the right lobe nodule of the thyroid gland under ultrasound guidance was performed in the local hospital. After ablation, the surface skin was not red, swollen or ulcerated, there was no hoarseness, no cough when drinking water, no chest tightness, shortness of breath, no dizziness, headache, no emotional irritability, no trembling hands, sweating. But the patient was now undergoing persist anxiety. She was admitted to our hospital and admitted to the outpatient clinic with "thyroid malignancy". During the period of the disease, the patient was in anxiety spirits, ate and slept well, and had no other symptoms, and there is no significant change in recent body weight.

History of past illness

The patient underwent thyroid cancer ablation treatment 1 month, In addition, there had no history of other specific medical conditions.

Personal and family history

The patient had no family history.

Physical examination

The neck was soft, there was no resistance, the jugular veins were not distended, the carotid artery was not abnormal, the trachea was centered, the left thyroid gland was not palpated, and the right thyroid gland was locally hard.

Laboratory examinations

The patient had normal CEA, PTH, and calcitonin, thyroid-stimulating hormone 0.120 mIU/L, total thyroxine 18.28 ug/dL, free thyroxine 1.92 ng/dL, and thyroglobulin 66.04 ng/mL. The rest of the test results were not abnormal.

Imaging examinations

Thyroid ultrasound showed: Mixed echogenic nodule in the right lobe of the thyroid gland (TI-RADS category III) (Fig. 1). CT examination of neck showed: The right lobe of the thyroid gland was round and mixed with dense shadows (Fig. 2). Pathological section consultation: (right thyroid nodules) consider papillary carcinoma (Fig. 3).

Final diagnosis

According to the patient's medical history, clinical characteristics, and test results, the patient was diagnosed with after ablation of thyroid cancer.

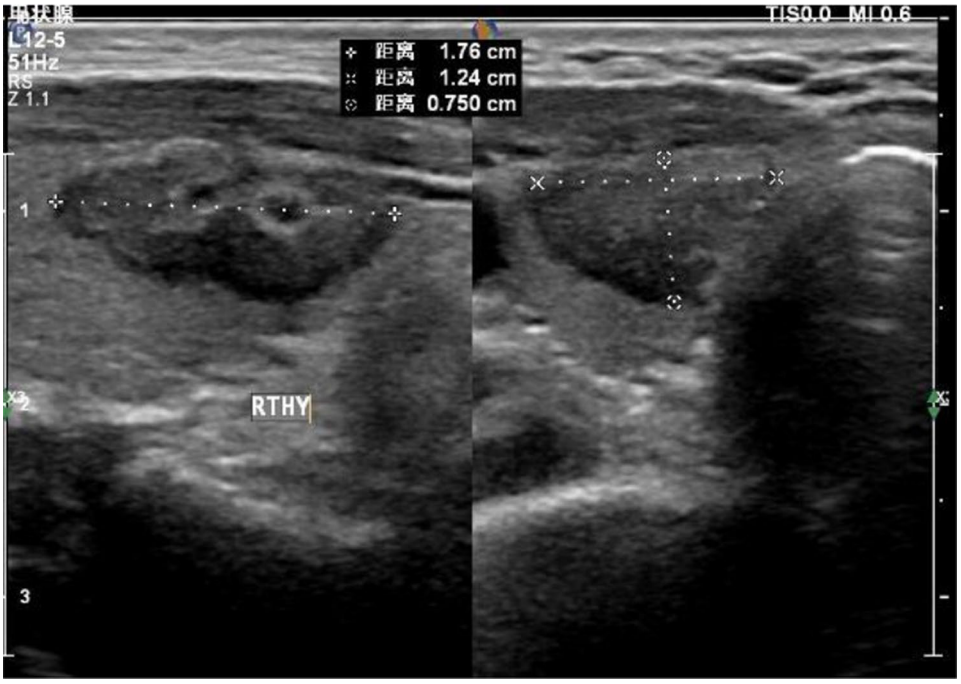

Fig. 1 Ultrasound (US) showed changes in the right lobe of the thyroid gland after ablation

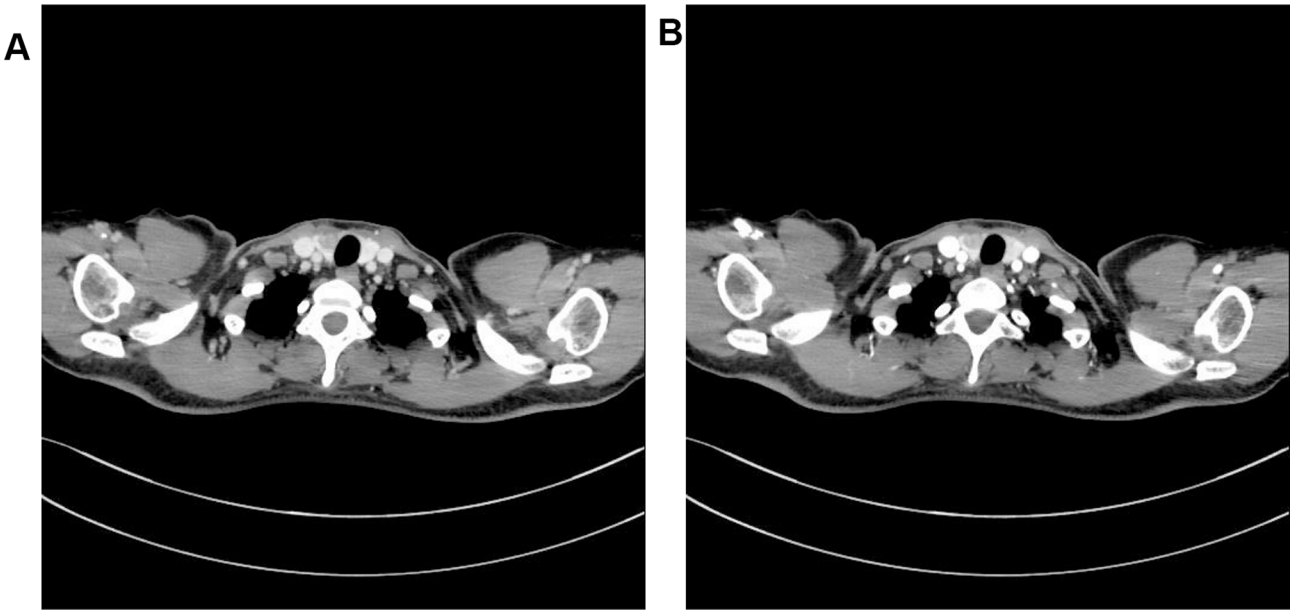

Fig. 2 Computerized Tomography (CT) imaging showed hypoechoic lesions in the right lobe of the patient's thyroid gland

Treatment

Due to the patient's severe anxiety after thyroid ablation, we then performed the total thyroidectomy with right central node dissection for right-sided thyroid cancer and lymph node dissection in the right central area, and the postoperative pathology showed that papillary thyroid carcinoma (right and isthmus thyroid), no lymph node metastasis in the central area and anterior laryngeal tissue (0/6), AJCC-p TNM stage: T1aN0Mx (Fig. 4).

Outcome and follow-up

The patient underwent regular endocrine suppression therapy after surgery, and at present, 75ug levothyroxine sodium tablets were taken orally every day, and thyroid function and thyroid ultrasound were monitored dynamically, and there was no sign of recurrence.

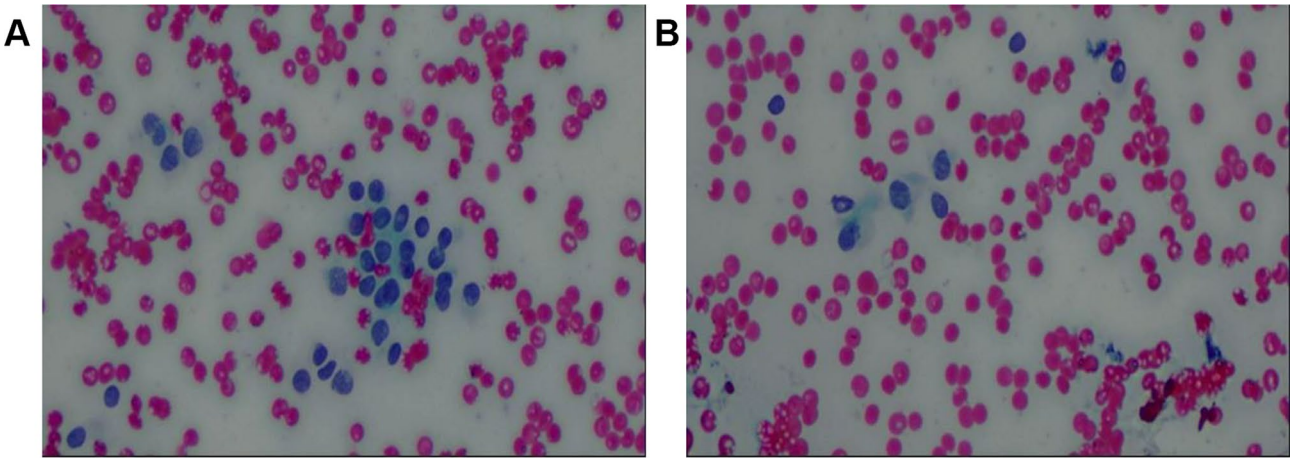

Fig. 3 Pathological consultation on needle cell smear suggested that papillary thyroid carcinoma should be considered

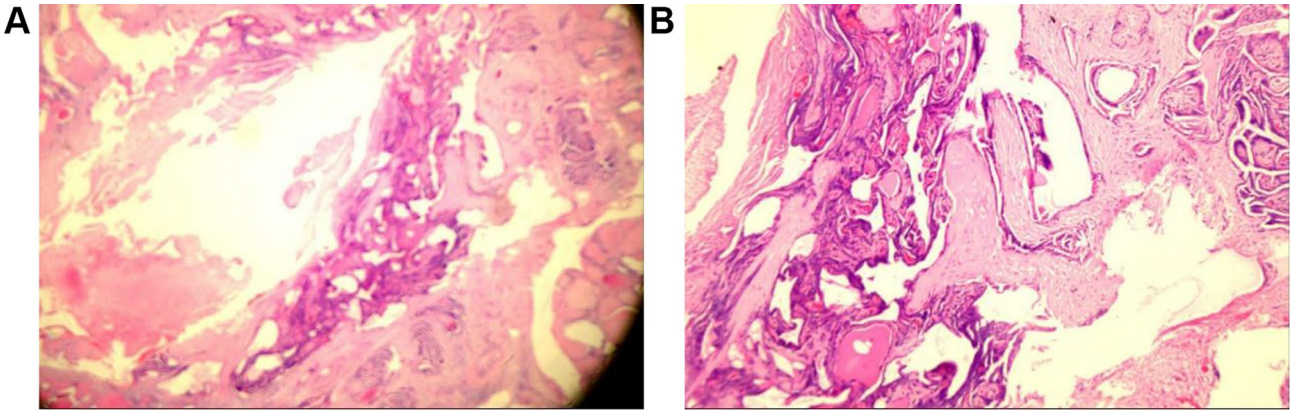

Fig. 4 Immunohistochemistry (IHC) showed papillary carcinoma of the right lobe of the thyroid gland

Case presentation 2

Chief complaints

The patient An, male, 47 years old, employee, was admitted to the hospital because of " Six months after thyroid ablation, cervical lymphadenopathy was found to be swollen for one month.".

History of present illness

The patient complained of thyroid radiofrequency ablation + thyroid tumor needle biopsy in a local hospital for "thyroid nodules" 6 months before admission, and the postoperative pathology showed papillary carcinoma of the left lobe of the thyroid gland, and then endoscopic left lobe and isthmus resection of the thyroid gland under general anesthesia on 2023-02-10. The operation went smoothly, and the patient was regularly taken levothyroxine sodium tablets after surgery. The patient's cervical lymphadenopathy was found to be abnormally swollen in the re-examination 1 month ago, and now the patient is admitted to our hospital for further treatment, and is admitted to the outpatient clinic with "thyroid malignant tumor". During the period of the disease, the patient was in anxiety spirits, ate and slept well, and had no other symptoms, and there is no significant change in recent body weight.

History of past illness

The patient underwent thyroid cancer ablation and surgery 6 month ago. In addition, there was no history of other specific medical conditions.

Personal and family history

The patient had no family history.

Physical examination

The neck was soft, there was no resistance, the jugular veins were not distended, the carotid artery was not abnormal, the trachea was centered, the thyroid gland was not palpated.

Laboratory examinations

The test results were not abnormal.

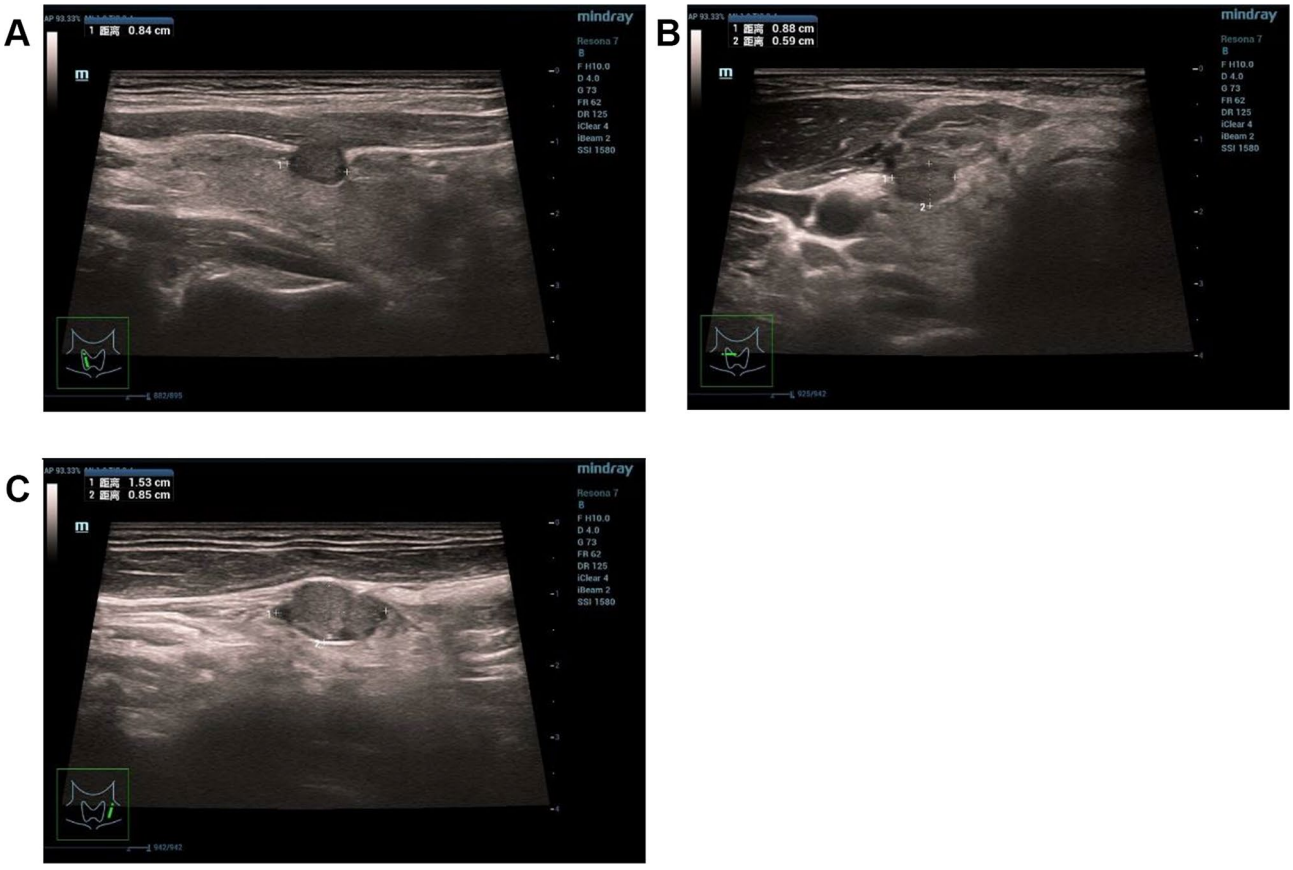

Fig. 5 Ultrasound (US) showed hypoechoic nodular lesions in the right lobe of the thyroid gland that break through the dorsal membrane of the thyroid gland. Multiple abnormally enlarged lymph nodes may be seen in the neck

Imaging examinations

Thyroid ultrasound showed: Hypoechoic nodules in the right lobe of the thyroid gland (TI-RADS category IVa class) and multiple abnormally enlarged lymph nodes in the left side of the neck (Fig. 5). CT examination of neck showed: After thyroid surgery, lymph nodes in the left neck zones 2 and 5 enlarged and abnormally strengthened (Fig. 6).

Final diagnosis

According to the patient's medical history, clinical characteristics, and test results, the patient was diagnosed with after ablation of thyroid cancer.

Treatment

We performed cervical lymph node biopsy, frozen pathology during surgery showed: (Left cervical lymph nodes) papillary carcinoma (Fig. 7), then we performed the total thyroidectomy with right central node dissection for right-sided thyroid cancer. The postoperative pathology showed that papillary thyroid carcinoma (right and isthmus thyroid), and lymph node metastasis in the central area and anterior laryngeal tissue (4/22), AJCC-p TNM stage: T1aN1bMx (Fig. 8).

Outcome and follow-up

The patient underwent one dose of iodine-131 treatment postoperatively, and then underwent regular endocrine suppression therapy, and at present, 100ug levothyroxine sodium tablets were taken orally every day, and thyroid function and thyroid ultrasound were monitored dynamically, and there was no sign of recurrence [10].

Discussion

In recent years, with the improvement of socio-economic level, people's awareness of physical examination has also been significantly improved, which has led to a rapid increase in the incidence of thyroid nodules [1, 2, 10]. Studies have shown that the onset of thyroid nodules may be related to childhood radiation exposure, bad mood, endocrine disorders, etc. Thyroid nodules include benign thyroid nodules and malignant thyroid nodules, and benign nodules include thyroid cysts, thyroid adenomas, nodular goiters, etc. Observation, medication, and surgery are the traditional forms of routine treatment [2].

The boom in ablation technology has given the thyroid nodule treatment an option. Benign thyroid nodule ablation has been developed for more than 20 years, and its treatment effect is good, and the patient experience

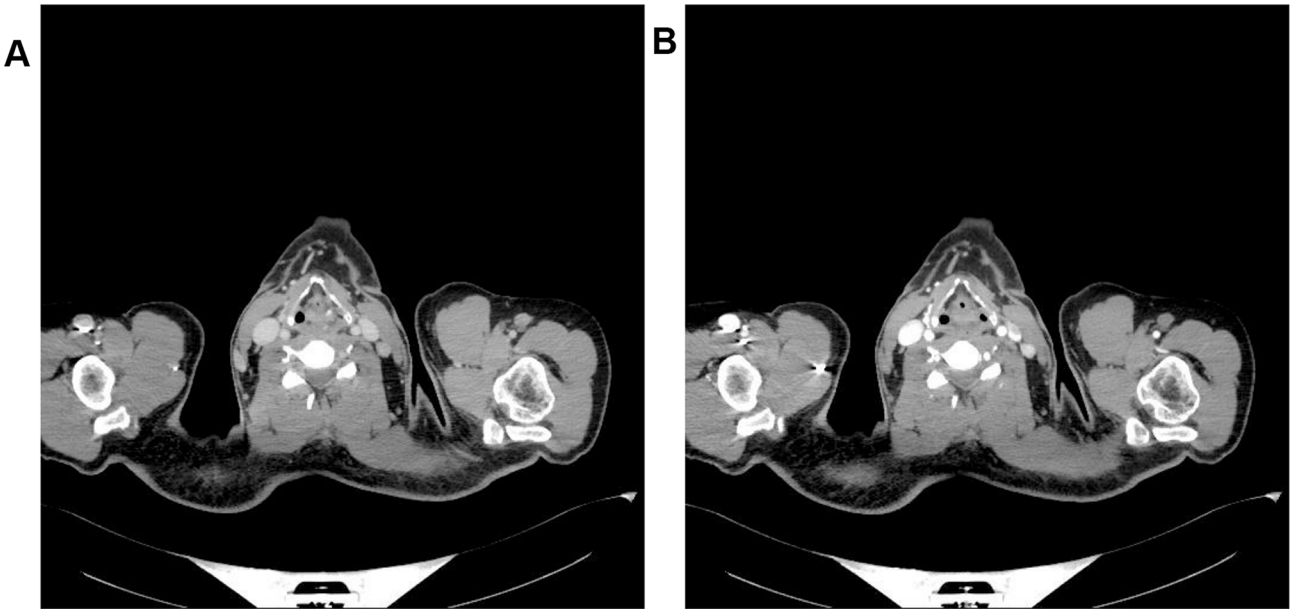

Fig. 6 Computerized Tomography (CT) imaging showed multiple swollen lymph nodes on the left side of the neck, partially enhanced during the enhancement phase

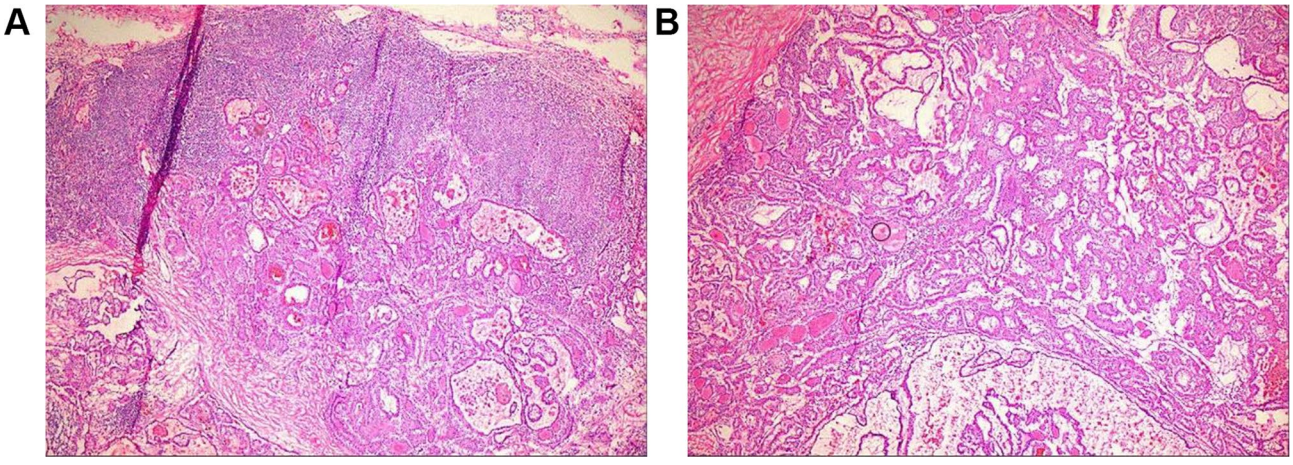

Fig. 7 Intraoperative frozen pathology showed metastatic papillary carcinoma (lymph nodes in the left neck zone 4)

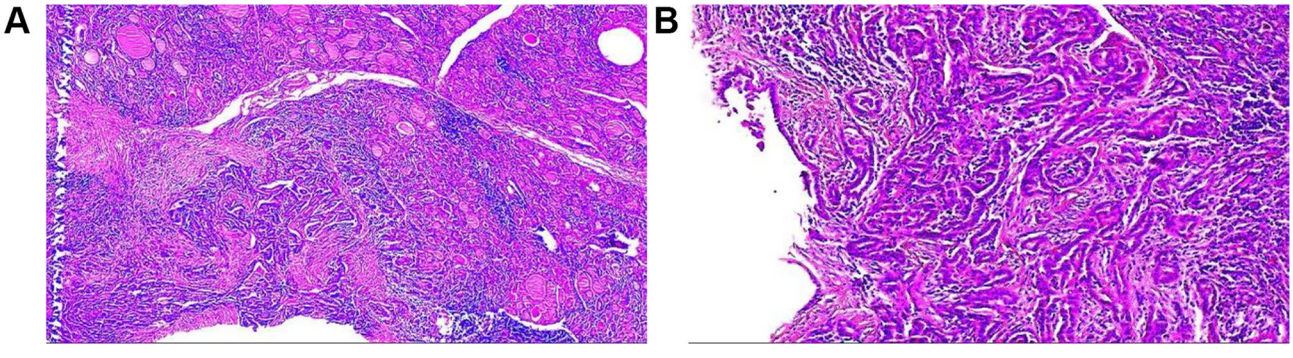

Fig. 8 Immunohistochemistry (IHC) showed that the right thyroid gland was papillary carcinoma, and the left cervical lymph node had multiple metastases

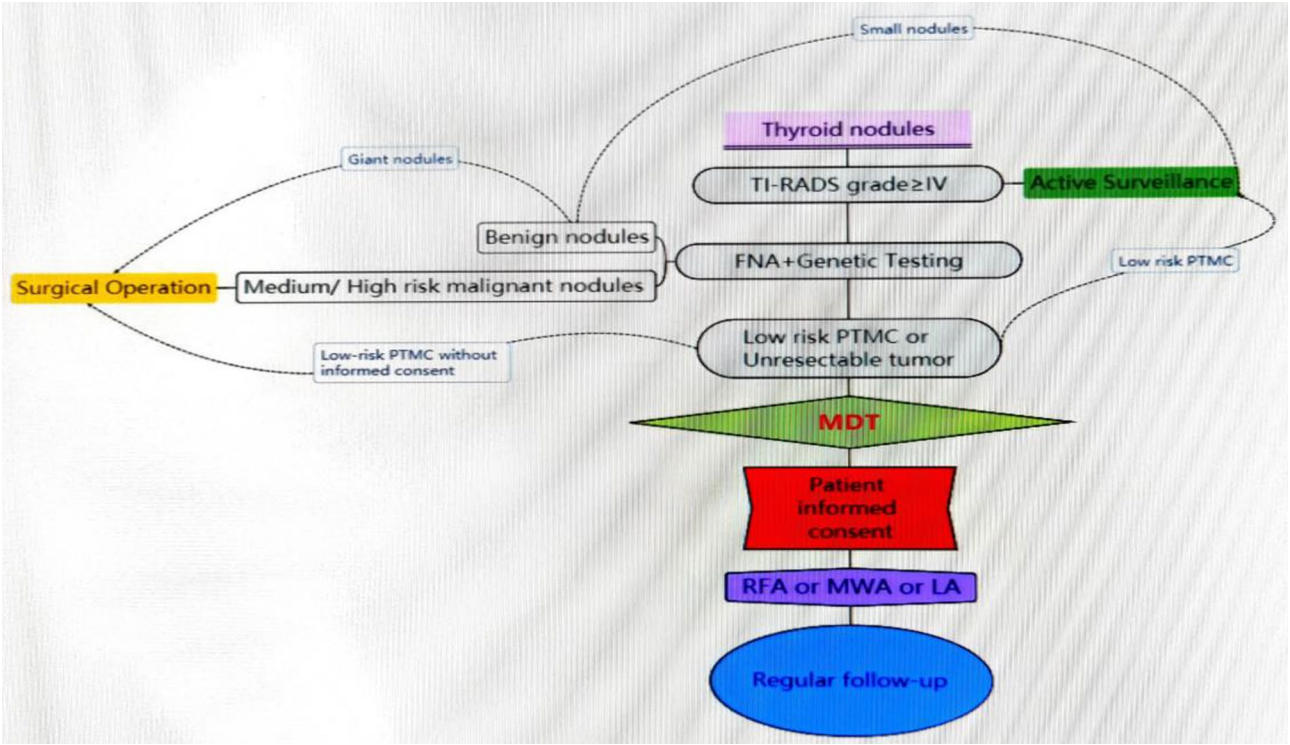

Fig. 9 Flow chart of ablation treatment of thyroid nodules. PTMC, papillary thyroid microcarcinoma; FNA, fine needle aspiration; MDT, multi-disciplinary treatment; RFA, radiofrequency ablation; MWA, microwave ablation; LA, laser ablation

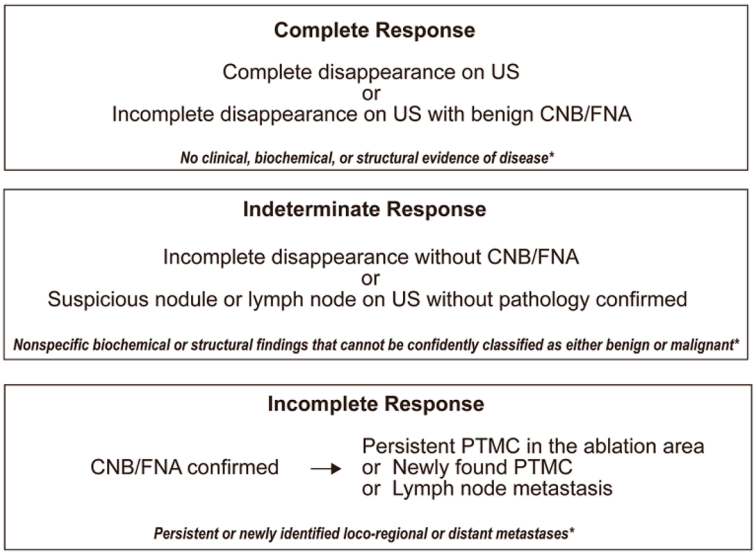

Fig. 10 Definitions of the response-to-ablation system at 1-year follow-up [31]. PTMC, papillary thyroid microcarcinoma; CNB, core needle biopsy; FNA, fine needle aspiration

is good [11–14]. In view of the successful application of ablation technology in benign nodules, some researchers have begun to try to apply this technique to the treatment of malignant thyroid nodules [14]. Many studies have shown that ablation can also be effective in the treatment of malignant thyroid nodules [15, 16]. However, incomplete ablation of malignant nodules and recurrence after ablation still plague medical workers and discourage many patients [9, 17].

We reported two patients with incomplete ablation, one of whom underwent FNA during ablation treatment, and the pathology after ablation showed papillary carcinoma. Another patient also underwent FNA at the time of ablation, and the pathology showed papillary carcinoma and

then underwent the total thyroidectomy with central node dissection surgery, but unfortunately, abnormal lymph nodes in the left neck and high-risk nodules on the right thyroid gland were found in the reexamination six months after surgery, and the left cervical lymph node was confirmed to be metastatic papillary carcinoma after puncture, and the postoperative pathology also showed that the right nodule was also papillary carcinoma. Such cases make us doubt the application of ablation in the treatment of thyroid cancer nodules. A proverb says: know yourself and know your enemy, and win all battles. To better understand the causes of incomplete ablation, we reviewed and analyzed literatures that is relevant to it.

It is important to choose the right patient. At present, there is some consensus that it is recommended to choose patients with low-risk papillary carcinoma nodules or unresectable cancer nodules and strong desire for ablation [5, 18]. However, none of the patients reported in this article had pre-ablation FNA to determine the nature of the nodule and tumor risk stratification. It seems a bit arbitrary, ablation should be carried out under the guidance of a multidisciplinary team with the participation of experts from endocrinology, thyroid surgery, ultrasound, radiology, and radiotherapy [19]. Pathology classification and patient informed information are important [20]. Genetic testing also has a good guiding effect on pathological analysis and patient treatment effect [21]. When BRAF, RAS, TERT, PIK3CA, TP53 genes mutated, the malignant possibility and aggressiveness of thyroid nodules are significantly increased, and ablation treatment should be carried out cautiously when the pathology suggests the presence of one or more of the above gene mutations after puncture. At present, there is no risk stratification model that integrates multiple genes and pathological types. In practice, it is necessary to continuously accumulate experience, and ablation technology should be used cautiously for patients with suspected multifocal cancer nodules and newly diagnosed cervical lymph node metastasis [22, 23]Machine and deep learning may play a key role in the risk stratification of thyroid nodules [24].

The commonly used techniques for thyroid cancer ablation are microwave ablation and radiofrequency ablation. The former forms a microwave electromagnetic field in the ablation area, and a high temperature is formed locally for a short time, resulting in coagulative necrosis of cells [25], and the latter sends a radiofrequency current locally, causing necrosis of the lesion [26]. Its characteristics of action determine that it can only treat local lesions, and it will affect the tissues around the lesions. Therefore, ablation therapy is limited for malignant thyroid nodules close to the back membrane of the thyroid gland, especially the dorsal membrane, adjacent to the recurrent laryngeal nerve, arteries and veins, etc [4, 17].

For high-risk nodules under ultrasound, FNA and genetic testing are recommended to assess the risk of malignancy of the nodules. For low-risk PTMC and unresectable thyroid cancer, patients should be informed in detail about the condition and the advantages and disadvantages of ablation therapy, and ablation therapy can be considered after obtaining the patient's consent. MDT should guide the entire course of treatment (Fig. 9).

There have been a lot of studies that have tried to protect the normal tissue around the nodules, and the results are encouraging [27, 28]. Preoperative localization of thyroid nodules and evaluation of possible efficacy with appropriate evaluation models [29]. After ablation, appropriate evaluation indicators are used to determine the risk of incomplete ablation and recurrence in advance, post-ablation stimulated thyroglobulin (>20.2 ng/mL) was a valuable predictor of disease persistence/recurrence in DTC patients with biochemical incomplete response [30]. A post-ablation response evaluation system consisting of ultrasound results and post-FNA pathological results was defined in one study and validated in practical applications(Fig. 10) [31].

Thermal ablation may produce sublethal thermal stress, it may increase clonogenicity, migration, and invasion of thyroid cancer cells [32],and also can promote proliferation and invasion of breast cancer cells and caused gene alterations in cancer and immune system [33]. One study suggested that the VEGR and AKT pathways and related genes may be activated after radiofrequency ablation, resulting in incomplete ablation and recurrence [34]. It is worth paying attention to in future studies.

Conclusion

Ablation of thyroid cancer nodules is currently facing many challenges, and incomplete ablation is one of the important challenges. There are many factors such as social economy, operation technology, and diagnosis and treatment standards. We need to study these factors in depth, make friends with our enemies, and use the most appropriate technology to treat the most suitable patients, so as to improve the level of diagnosis and treatment of thyroid nodules and provide patients with a better medical experience.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12902-024-01659-5.

Supplementary Material 1

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Author contributions
Yang Z, Ma LB and Pan XH performed the experiments and image acquisition; Yang Z, Ma LB, Pan XH , and Zhao YX designed the study and wrote the manuscript; Ma LB, Yang Z, and Han HT edited the manuscript.

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Data availability
No underlying data was collected or produced in this study.

Declarations

Ethical approval and consent to participate
This study was approved by the Ethics Committee of the First Hospital of Lanzhou University. The patient was not required to provide informed consent, as the analysis used anonymized clinical data, obtained after obtaining written consent to treatment.

Consent for publication
Written informed consent for publication of their clinical details and/or clinical images was obtained from the patients."

CARE checklist (2016) statement
The authors have read the CARE Checklist (2016) and the manuscript was prepared and revised according to the CARE Checklist (2016).

Conflict of interest
The authors declare that there is no conflict of interest regarding the publication of this article.

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References

1. Boucai L, Zafereo M, Cabanillas ME. Thyroid Cancer: a review. JAMA. 2024;331(5):425–35.
2. Chen DW, Lang BHH, McLeod DSA, Newbold K, Haymart MR. Thyroid cancer. Lancet (London England). 2023;401(10387):1531–44.
3. Díez JJ, Parente P, Durán-Poveda M. Surgical management of low-risk papillary thyroid cancer in real life in Spain: a nationwide survey of endocrine neck surgeons and endocrinologists. *Endocrine* 2023.
4. Papini E, Crescenzi A, D'Amore A, Deandrea M, De Benedictis A, Frasoldati A, et al. Italian guidelines for the management of Non-functioning Benign and locally symptomatic thyroid nodules. Endocr Metab Immune Disord Drug Targets. 2023;23(6):876–85.
5. Ben Hamou A, Ghanassia E, Muller A, Ladsous M, Paladino NC, Brunaud L, et al. SFE-AFCE-SFMN 2022 consensus on the management of thyroid nodules: thermal ablation. Ann Endocrinol (Paris). 2022;83(6):423–30.
6. Yan L, Zhen Y, Li Y, Li X, Xiao J, Jing H et al. Five-year Outcome between Radiofrequency ablation vs. surgery for unilateral multifocal papillary thyroid microcarcinoma. J Clin Endocrinol Metab 2023.
7. Ayoub NF, Balakrishnan K, Orloff LA, Noel JE. Time-Driven activity-based cost comparison of thyroid lobectomy and radiofrequency ablation. Otolaryngology–head neck Surgery: Official J Am Acad Otolaryngology-Head Neck Surg 2023.
8. 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.
9. Yue W, Wang S, Xu H. Thermal ablation for papillary thyroid microcarcinoma: some clarity amid controversies. J Interv Med. 2022;5(4):171–2.
10. Davies L, Hoang JK. Thyroid cancer in the USA: current trends and outstanding questions. Lancet Diabetes Endocrinol. 2021;9(1):11–2.
11. Che Y, Jin S, Shi C, Wang L, Zhang X, Li Y, et al. Treatment of Benign thyroid nodules: comparison of surgery with Radiofrequency ablation. AJNR Am J Neuroradiol. 2015;36(7):1321–5.
12. Khoo TK. Ethanol ablation of cystic thyroid nodules. Mayo Clin Proc. 2019;94(1):171.
13. Yan L, Luo Y, Song Q, Li N, Xiao J, Zhang Y, et al. Inter-observer reliability in ultrasound measurement of benign thyroid nodules in the follow-up of radiofrequency ablation: a retrospective study. Int J Hyperth. 2020;37(1):1336–44.
14. Papini E, Guglielmi R, Gharib H, Misischi I, Graziano F, Chianelli M, et al. Ultrasound-guided laser ablation of incidental papillary thyroid microcarcinoma: a potential therapeutic approach in patients at surgical risk. Thyroid. 2011;21(8):917–20.
15. Cho SJ, Baek SM, Na DG, Lee KD, Shong YK, Baek JH. Five-year follow-up results of thermal ablation for low-risk papillary thyroid microcarcinomas: systematic review and meta-analysis. Eur Radiol. 2021;31(9):6446–56.
16. Cao XJ, Liu J, Zhu YL, Qi L, Liu G, Wang HL, et al. Efficacy and safety of thermal ablation for Solitary T1bN0M0 papillary thyroid carcinoma: a Multicenter Study. J Clin Endocrinol Metab. 2021;106(2):e573–81.
17. Lim JY, Kuo JH. Thyroid nodule Radiofrequency ablation: complications and clinical follow up. Tech Vasc Interv Radiol. 2022;25(2):100824.
18. Navin PJ, Thompson SM, Kurup AN, Lee RA, Callstrom MR, Castro MR, et al. Radiofrequency ablation of Benign and malignant thyroid nodules. Radiographics: Rev Publication Radiological Soc North Am Inc. 2022;42 6:1812–28.
19. Orloff LA, Noel JE, Stack BC Jr., Russell MD, Angelos P, Baek JH, et al. Radiofrequency ablation and related ultrasound-guided ablation technologies for treatment of benign and malignant thyroid disease: an international multidisciplinary consensus statement of the American Head and Neck Society Endocrine Surgery Section with the Asia Pacific Society of thyroid surgery, Associazione Medici Endocrinologi, British Association of Endocrine and thyroid surgeons, European Thyroid Association, Italian Society of endocrine surgery units, Korean Society of Thyroid Radiology, latin American thyroid Society, and Thyroid Nodules Therapies Association. Head Neck. 2022;44(3):633–60.
20. Tuttle RM, Li D, Ridouani F. Percutaneous ablation of low-risk papillary thyroid cancer. Endocr Relat Cancer 2023; 30(3).
21. Landa I, Cabanillas ME. Genomic alterations in thyroid cancer: biological and clinical insights. Nat Rev Endocrinol. 2024;20(2):93–110.
22. Wei X, Wang X, Xiong J, Li C, Liao Y, Zhu Y et al. Risk and Prognostic Factors for BRAF(V600E) Mutations in Papillary Thyroid Carcinoma. *Biomed Res Int* 2022; 2022:9959649.
23. Cui L, Feng D, Zhu C, Li Q, Li W, Liu B. Clinical outcomes of multifocal papillary thyroid cancer: a systematic review and meta-analysis. Laryngoscope Investig Otolaryngol. 2022;7(4):1224–34.
24. Slabaugh G, Beltran L, Rizvi H, Deloukas P, Marouli E. Applications of machine and deep learning to thyroid cytology and histopathology: a review. Front Oncol. 2023;13:958310.
25. Dong P, Wu XL, Sui GQ, Luo Q, Du JR, Wang H, et al. The efficacy and safety of microwave ablation versus lobectomy for the treatment of benign thyroid nodules greater than 4 cm. Endocrine. 2021;71(1):113–21.
26. Guo DM, Chen Z, Zhai YX, Su HH. Comparison of radiofrequency ablation and microwave ablation for benign thyroid nodules: a systematic review and meta-analysis. Clin Endocrinol (Oxf). 2021;95(1):187–96.
27. Huang L, Yang S, Bai M, Lin Y, Chen X, Li G, et al. Thermal shielding performance of self-healing hydrogel in tumor thermal ablation. Colloids Surf B Biointerfaces. 2022;213:112382.
28. Zheng B, Zhang P, Lv Q, Wu T, Liu Y, Tang J, et al. Development and preclinical evaluation of multifunctional hydrogel for precise thermal protection during thermal ablation. Bioact Mater. 2024;31:119–35.
29. Sinclair CF, Baek JH, Hands KE, Hodak SP, Huber TC, Hussain I, et al. General principles for the safe performance, training, and adoption of ablation techniques for benign thyroid nodules: an American thyroid Association Statement. Thyroid. 2023;33(10):1150–70.
30. Wang Y, Wu J, Jiang L, Zhang X, Liu B. Prognostic value of post-ablation stimulated thyroglobulin in differentiated thyroid cancer patients with biochemical incomplete response: a bi-center observational study. Endocrine. 2022;76(1):109–15.
31. Li X, Yan L, Xiao J, Li Y, Yang Z, Zhang M, et al. Follow-up strategy of radiofrequency ablation for papillary thyroid microcarcinoma: defining a response-to-ablation system. Eur Radiol. 2023;34(2):761–9.
32. Kuo CY, Tsai CH, Wu JK, Cheng SP. Sublethal thermal stress promotes migration and invasion of thyroid cancer cells. PLoS ONE. 2024;19(2):e0298903.

33. Xia S, Li X, Xu S, Ni X, Zhan W, Zhou W. Sublethal heat treatment promotes breast cancer metastasis and its molecular mechanism revealed by quantitative proteomic analysis. Aging. 2022;14(3):1389–406.
34. Mueller LE, Issa PP, Hussein MH, Elshazli RM, Haidari M, Errami Y, et al. Clinical outcomes and tumor microenvironment response to radiofrequency ablation therapy: a systematic review and meta-analysis. Gland Surg. 2024;13(1):4–18.

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