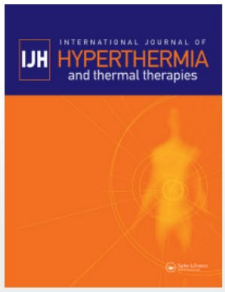
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International Journal of Hyperthermia

An open access journal

Publishes articles on various aspects of thermal energy and thermal therapy in clinical, biological or engineering studies involving human or animals.

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This Journal

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JCR Year 2024

INTERNATIONAL JOURNAL OF HYPERTHERMIA

Open Access since 2019

ISSN
0265-6736

EISSN
1464-5157

JCR ABBREVIATION
INT J HYPERTHER

ISO ABBREVIATION
Int. J. Hyperthermia

Journal information

EDITION
Science Citation Index Expanded (SCIE)

CATEGORY
RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING

ONCOLOGY

LANGUAGES
English

REGION
ENGLAND

1ST ELECTRONIC JCR YEAR
1997

Publisher information

PUBLISHER
TAYLOR & FRANCIS LTD

ADDRESS
2-4 PARK SQUARE, MILTON PARK, ABINGDON OR14 4RN, OXON, ENGLAND

PUBLICATION FREQUENCY
8 issues/year

Journal's performance

Journal Impact Factor

The Journal Impact Factor (JIF) is a journal-level metric calculated from data indexed in the Web of Science Core Collection. It should be used with careful attention to the many factors that influence citation rates, such as the volume of publication and citations characteristics of the subject area and type of journal. The Journal Impact Factor can complement expert opinion and informed peer review. In the case of academic evaluation for tenure, it is inappropriate to use a journal-level metric as a proxy measure for individual researchers, institutions, or articles. Learn more

2024 JOURNAL IMPACT FACTOR
3.0
View calculation

JOURNAL IMPACT FACTOR WITHOUT SELF CITATIONS
2.6
View calculation

Journal Impact Factor Trend 2024

Export

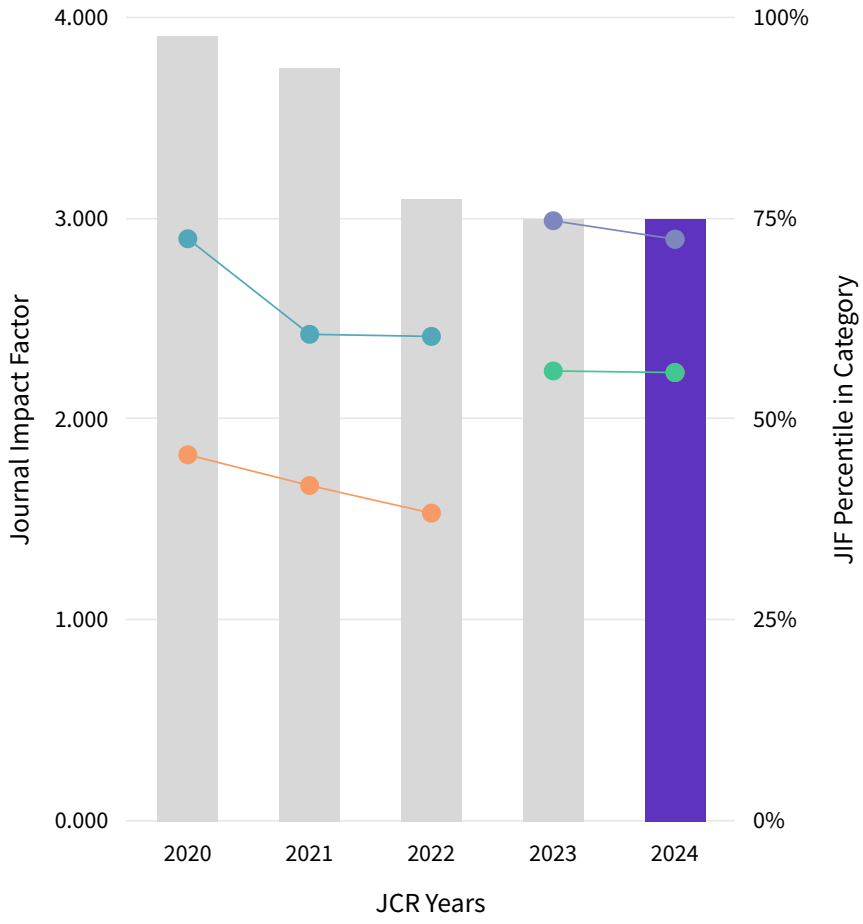
Journal Impact Factor contributing items

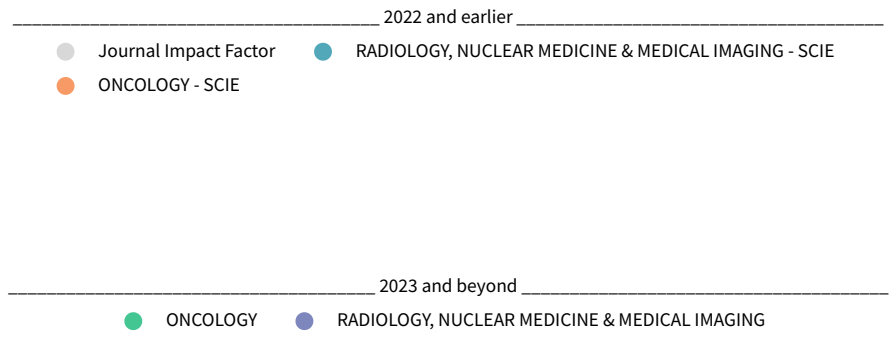
Export

Citable items (290) | Citing Sources (371)

TITLE	CITATION COUNT
First-in-man histotripsy of hepatic tumors: the THERESA trial, a feasibility…	37

15





View all years

SIRT1-mediated p53 deacetylation inhibits ferroptosis and alleviates heat…	29
Thermophysical and mechanical properties of biological tissues as a…	23
3D margin assessment predicts local tumor progression after ablation of…	14
The histotripsy spectrum: differences and similarities in techniques and…	13
Efficacy and safety of ultrasound-guided radiofrequency, microwave and laser…	12
Strong correlation between specific heat capacity and water content in human…	12
Comparison of efficacy, safety, and patient satisfaction between thermal…	11
Shaping the future of microwave tumor ablation: a new direction in precision a…	11
Radiomics analysis of ultrasound to predict recurrence of hepatocellular…	10

View All in Web of Science

Journal Citation Indicator (JCI)

Export

0.81

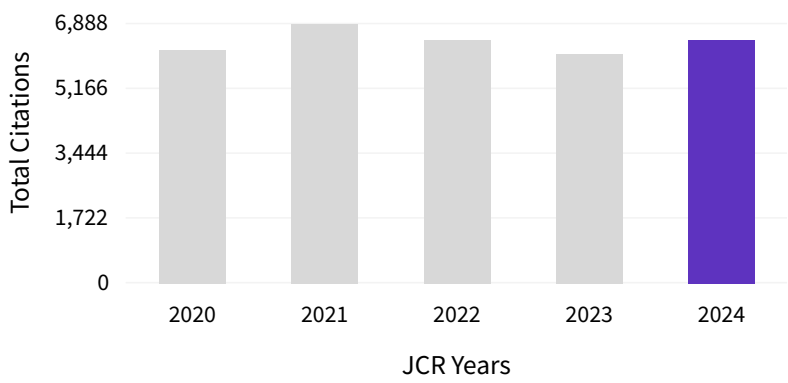
The Journal Citation Indicator (JCI) is the average Category Normalized Citation Impact (CNCI) of citable items (articles & reviews) published by a journal over a recent three year period. The average JCI in a category is 1. Journals with a JCI of 1.5 have 50% more citation impact than the average in that category. It may be used alongside other metrics to help you evaluate journals. Learn more

Total Citations

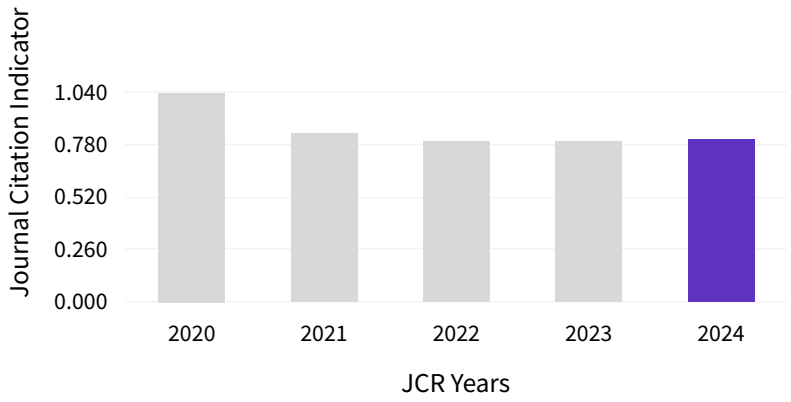
Export

6,446

The total number of times that a journal has been cited by all journals included in the database in the JCR year. Citations to journals listed in JCR are compiled annually from the JCR years combined database, regardless of which JCR edition lists the journal.



15



View all years

View all years

Citation distribution

Export

The Citation Distribution shows the frequency with which items published in the year or two years prior were cited in the JCR data year (i.e., the component of the calculation of the JIF). The graph has similar functionality as the JIF Trend graph, including hover-over data descriptions for each data point, and an interactive legend where each data element's legend can be used as a toggle. You can view Articles, Reviews, or Non-Citable (other) items to the JIF numerator. Learn more

ARTICLE CITATION MEDIAN

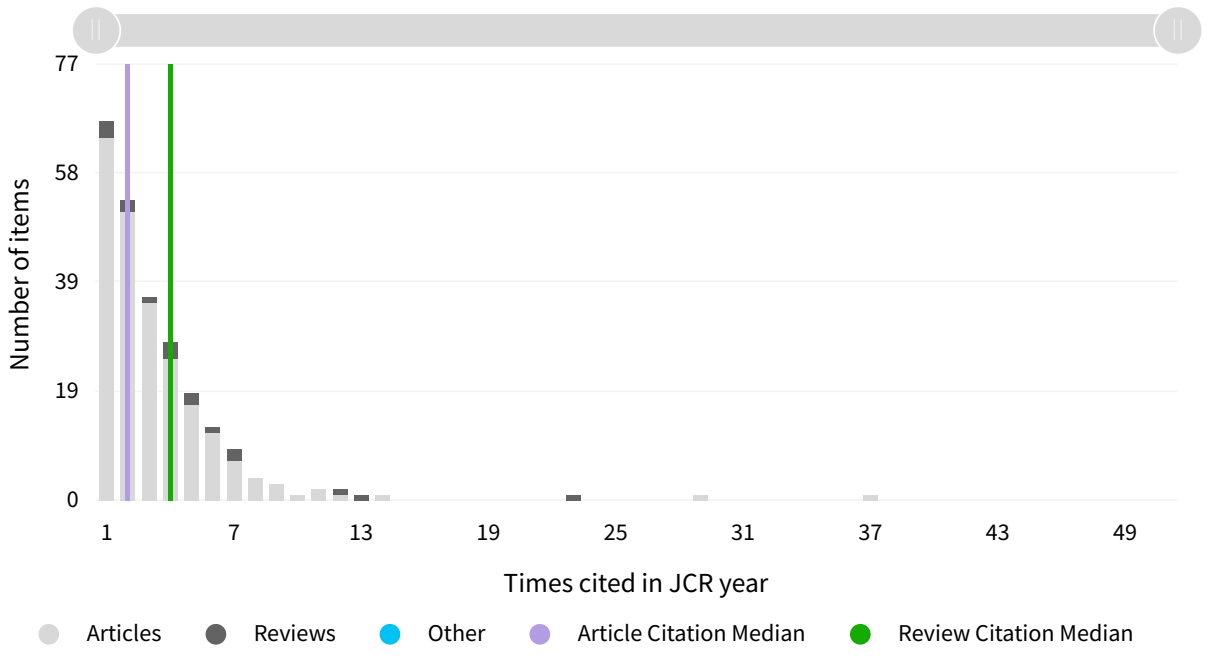
2

REVIEW CITATION MEDIAN

4

UNLINKED CITATIONS

4



TIMES CITED

0

ARTICLES

47

REVIEWS

1

OTHER

11

Open Access (OA)

Export

The data included in this tile summarizes the items published in the journal in the JCR data year and in the previous two years. This three-year set of published items is used to provide descriptive analysis of the content and community of the journal. Learn more

Items

TOTAL CITABLE	% OF CITABLE OA
411	99.51%

Citations*

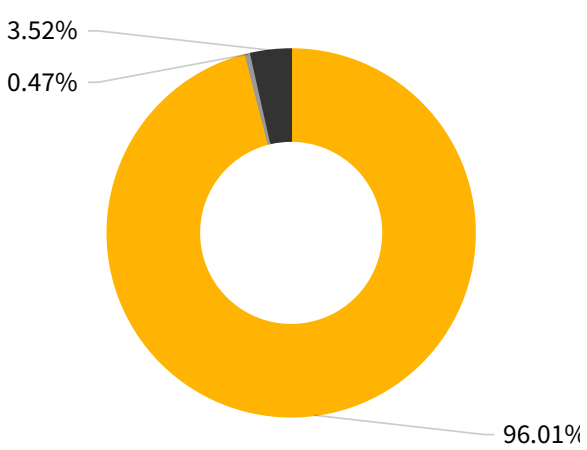
TOTAL CITABLE	% OF CITABLE OA
923	99.67%

15

CITABLE

GOLD OPEN ACCESS
409 / 96.01%

SUBSCRIPTION AND FREE TO READ
2 / 0.47%



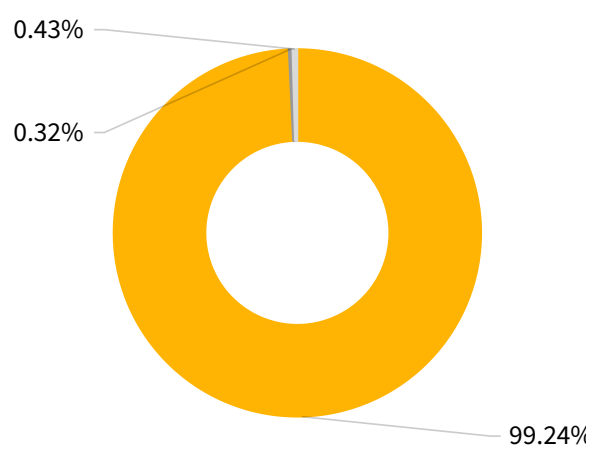
NON-CITABLE

OTHER (NON CITABLE ITEMS)
15 / 3.52%

CITABLE

GOLD OPEN ACCESS
920 / 99.24%

SUBSCRIPTION AND FREE TO READ
3 / 0.32%



NON-CITABLE

OTHER (NON CITABLE ITEMS)
0 / 0.00%

UNLINKED CITATIONS
4 / 0.43%

*Citations in 2024 to items published in [2022 - 2024]

Rank by Journal Impact Factor

Journals within a category are sorted in descending order by Journal Impact Factor (JIF) resulting in the Category Ranking below. A separate rank is shown for each category in which the journal is listed in JCR. Beginning in 2023, ranks are calculated by category.
Learn more

CATEGORY
ONCOLOGY

145/328

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2024	145/328	Q2	55.9
2023	142/322	Q2	56.1

Rank by JIF before 2023 for ONCOLOGY

EDITION
Science Citation Index Expanded (SCIE)

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2022	149/241	Q3	38.4
2021	143/245	Q3	41.84
2020	132/242	Q3	45.66
2019	103/244	Q2	57.99

CATEGORY
RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING

59/213

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2024	59/213	Q2	72.5
2023	52/204	Q2	74.8

Rank by JIF before 2023 for RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING

EDITION
Science Citation Index Expanded (SCIE)

JCR YEAR	JIF RANK	JIF QUARTILE	JIF PERCENTILE
2022	54/135	Q2	60.4
2021	54/136	Q2	60.66
2020	37/133	Q2	72.56

Rank by Journal Citation Indicator (JCI)

15

Journals within a category are sorted in descending order by Journal Citation Indicator (JCI) resulting in the Category Ranking below. A separate rank is shown for each category in which the journal is listed in JCR. Data for the most recent year is presented at the top of the list, with other years shown in reverse chronological order. Learn more

CATEGORY

ONCOLOGY

119/328

JCR YEAR	JCI RANK	JCI QUARTILE	JCI PERCENTILE
2024	119/328	Q2	63.87
2023	117/322	Q2	63.82
2022	116/318	Q2	63.68
2021	110/318	Q2	65.57
2020	81/310	Q2	74.03
2019	81/308	Q2	73.86
2018	76/302	Q2	75.00

CATEGORY

RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING

68/213

JCR YEAR	JCI RANK	JCI QUARTILE	JCI PERCENTILE
2024	68/213	Q2	68.31
2023	70/204	Q2	65.93
2022	71/203	Q2	65.27
2021	64/200	Q2	68.25
2020	32/186	Q1	83.06
2019	34/184	Q1	81.79

Citation network

Cited Half-life

6.6 years

The Cited Half-Life is the median age of the items in this journal that were cited in the JCR year. Half of a journal's cited items were published more recently than the cited half-life.

TOTAL NUMBER OF CITES

6,446

NON SELF-CITATIONS

5,988

SELF-CITATIONS

458

Citing Half-life

6.8 years

The Citing Half-Life is the median age of items in other publications cited by this journal in the JCR year.

TOTAL NUMBER OF CITES

4,841

NON SELF-CITATIONS

4,383

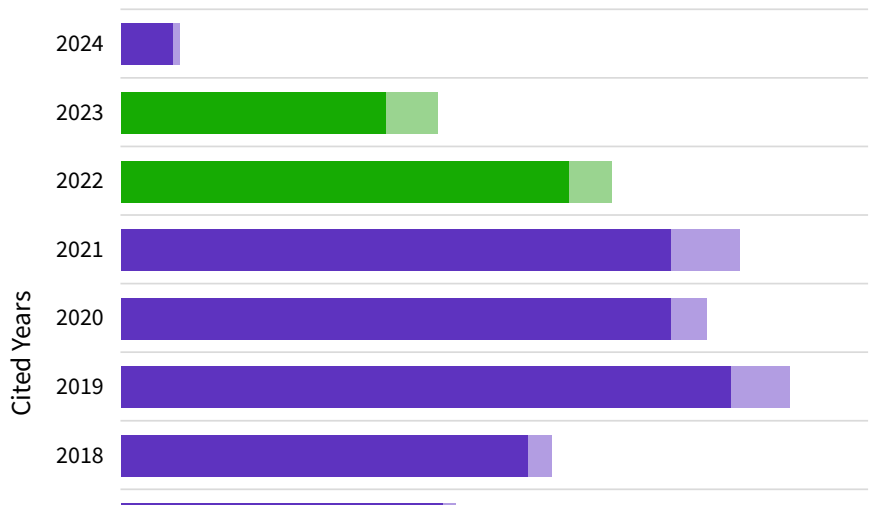
SELF-CITATIONS

458

Cited Half-life Data | Citing Half-life Data

Export

15

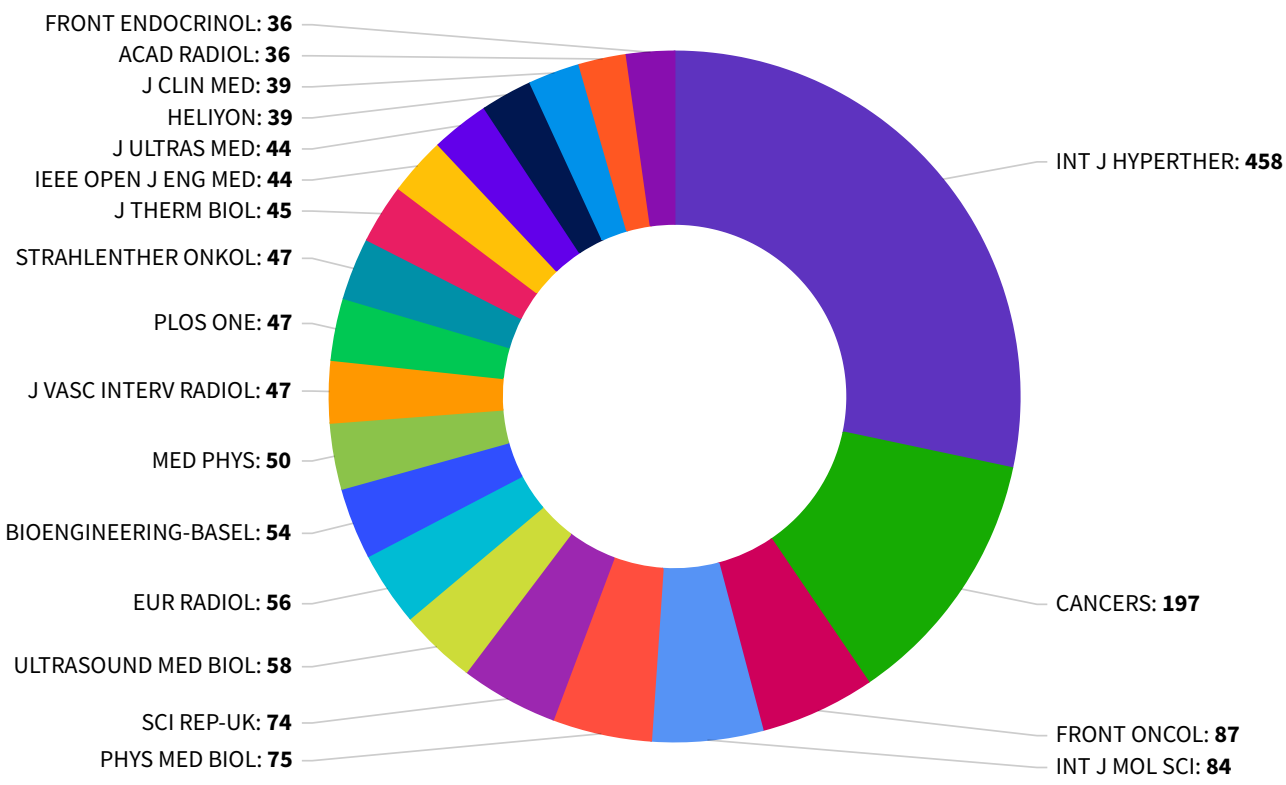


CITED YEAR	# OF CITES FROM 2024	CUMULATIVE %	# OF CITING SOURCES
All years	**6,446 citations**	**100.00%**	**1,349 sources**
2024	63 citations	0.98%	49 sources
2023	339 citations	6.24%	162 sources
2022	525 citations	14.38%	281 sources
2021	662 citations	24.65%	307 sources
2020	626 citations	34.36%	336 sources
2019	715 citations	45.45%	366 sources
2018	460 citations	52.59%	276 sources

Journal Citation Relationships

Cited Data | Citing Data

Top 20 journals citing INT J HYPERTHER by number of citations



Content metrics

Source data

This tile shows the breakdown of document types published by the journal. Citable Items are Articles and Reviews. For the purposes of calculating JIF, a JCR year considers the publications of that journal in the two prior years. Learn more

Average JIF Percentile

Export

The Average Journal Impact Factor Percentile takes the sum of the JIF Percentile rank for each category under consideration, then calculates the average of those values. Learn more

15

121 total citable items

	ARTICLES	REVIEWS	COMBINED(C)	OTHER DOCUMENT TYPES(O)	PERCENTAG
NUMBER IN JCR YEAR 2024 (A)	109	12	121	4	97%
NUMBER OF REFERENCES (B)	4,014	808	4,822	19	100%
RATIO (B/A)	36.8	67.3	39.9	4.8	

ALL CATEGORIES AVERAGE
64.2

ONCOLOGY
55.9

RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING
72.5

Contributions by organizations

Export

Organizations that have contributed the most papers to the journal in the most recent three-year period. Learn more

RANK	ORGANIZATION	COUNT
1	CHONGQING MEDICAL UNIVERSITY	58
2	SUN YAT SEN UNIVERSITY	22
3	CHINESE PEOPLE'S LIBERATION ARMY GENERAL HOSPITAL	19
4	CHONGQING HAIFU HOSP	18
5	ERASMUS UNIVERSITY ROTTERDAM	15

Contributions by country/region

Export

Countries or Regions that have contributed the most papers to the journal in the most recent three-year period. Learn more

RANK	COUNTRY / REGION	COUNT
1	CHINA MAINLAND	249
2	USA	70
3	GERMANY (FED REP GER)	24
-	NETHERLANDS	24
5	ITALY	13
6	SWITZERLAND	12
7	SPAIN	10
8	SWEDEN	9
	TAIWAN	9

Additional metrics

Eigenfactor Score

0.00523

The Eigenfactor Score is a reflection of the density of the network of citations around the journal using 5 years of cited content as cited by the Current Year. It considers both the number of citations and the source of those citations, so that highly cited sources will influence the network more than

Normalized Eigenfactor

1.17214

The Normalized Eigenfactor Score is the Eigenfactor score normalized, by rescaling the total number of journals in the JCR each year, so that the average journal has a score of 1. Journals can then be compared and influence measured by their score relative to 1. Learn more

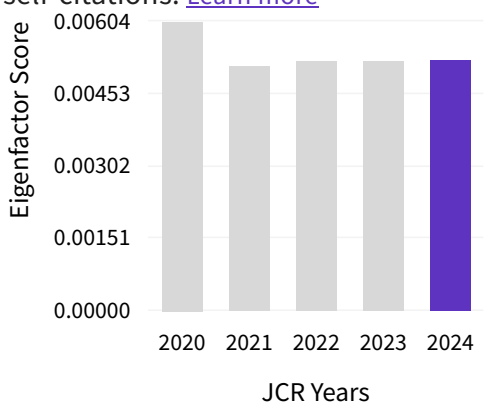
Article influence score

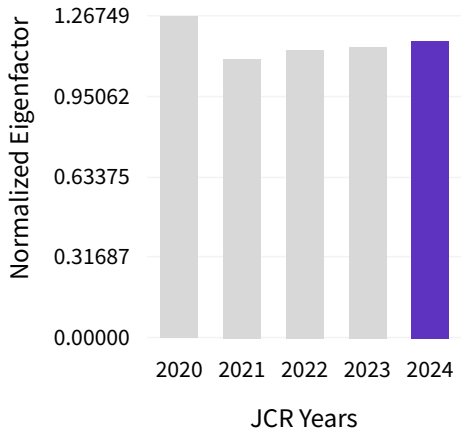
0.749

The Article Influence Score normalizes the Eigenfactor Score according to the cumulative size of the cited journal across the prior five years. The mean Article Influence Score for each article is 1.00. A score greater than 1.00

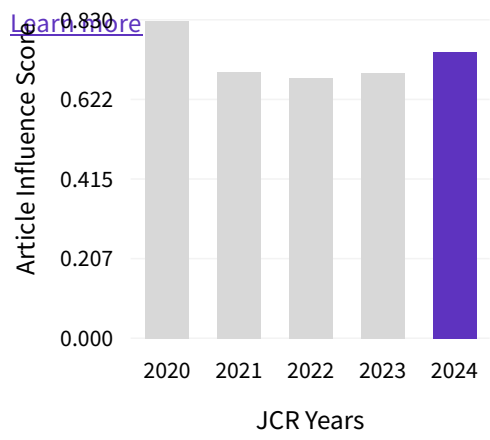
15

less cited sources. The Eigenfactor calculation does not include journal self-citations. Learn more





indicates that each article in the journal has above-average influence. Learn more

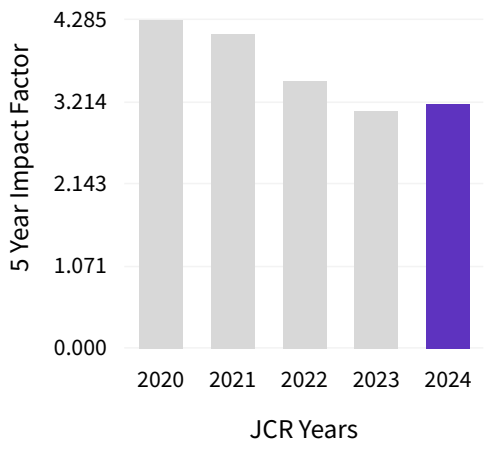


5 Year Impact Factor

3.2

View Calculation

The 5-year Impact Factor is the average number of times articles from the journal published in the past five years have been cited in the JCR year. It is calculated by dividing the number of citations in the JCR year by the total number of articles published in the five previous years. Learn more

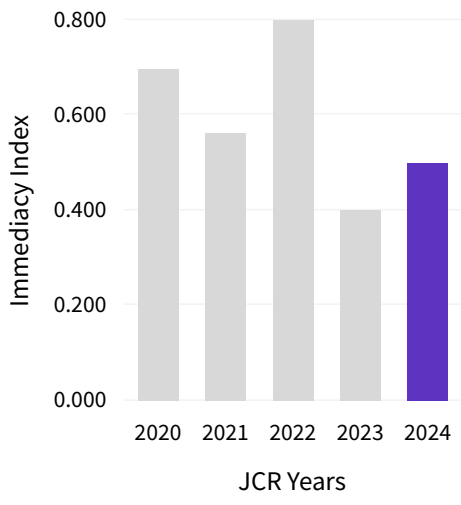


Immediacy Index

0.5

View Calculation

The Immediacy Index is the count of citations in the current year to the journal that reference content in this same year. Journals that have a consistently high Immediacy Index attract citations rapidly. Learn more



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15

International Journal of Hyperthermia

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Aims and scope

The ***International Journal of Hyperthermia*** is an Open Access, peer-reviewed journal publishing research and clinical studies on thermal energy based disease treatments. It is the official journal of the Society for Thermal Medicine, the European Society for Hyperthermic Oncology, and the Japanese Society for Thermal Medicine.

The journal's audience includes researchers and clinicians from all backgrounds as the journal publishes research related to the clinical studies, biological studies, and physics/engineering studies of therapeutic thermal therapies.

The journal has a special interest in the following topics:

- Clinical studies describing whole, regional or local treatment in humans or other animals covering the application of therapeutic thermal energy treatment alone or in combination with other clinical modalities
- Clinical outcomes on the physiological effects of heat or cold stress
- Clinical testing of methods related to thermal technologies
- Biological studies incorporating biochemical, anatomical or physiological studies of a basic or preclinical nature using basic biochemical, cell, animal, or computational models
- Research covering thermal tolerance, stress or shock, response and injury, immunological and physiological effects, toxicity and drug delivery, gene therapy, nanotechnology and nanomedicine
- The development of technologies and strategies for energy delivery and control, with an end goal to effect specific biologic responses leading to therapeutic outcomes
- Modalities and technology of therapy delivery, imaging, temperature management, and treatment monitoring and verification

International Journal of Hyperthermia

related technologies and systems

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Usage	Citation metrics	Speed/acceptance
• **748K** annual downloads/views	• **3.0 (2024)** Impact Factor • **Q2** Impact Factor Best Quartile • **3.2 (2024)** 5 year IF • **5.8 (2024)** CiteScore (Scopus) • **Q2** CiteScore Best Quartile • **0.998 (2024)** SNIP • **0.881 (2024)** SJR	• **10** days avg. from submission to first decision • **44** days avg. from submission to first post-review decision • **16** days avg. from acceptance to online publication • **30%** acceptance rate

Learn more about journal metrics and how to use them

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International Journal of Hyperthermia

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International Journal of Hyperthermia

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DOAJ; EBSCO Online; Index Medicus; MEDLINE; PubMed; Scopus; Sociedad Iberoamericana de Información Científica (SIIC); Science Citation Index.

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Calls for papers

- Heat-Sensitive Liposomal Drug Delivery

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Ultrasound-guided percutaneous microwave ablation for locoregional recurrence of medullary thyroid carcinoma

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ABSTRACT

Objective: Medullary thyroid carcinoma (MTC) is a rare, aggressive thyroid malignancy with frequent locoregional recurrence rate at 30–50%. Reoperative neck surgery is standard but challenging and risky. Ultrasound (US)-guided microwave ablation (MWA) offers minimally invasive alternatives, though evidence in recurrent MTC remains limited. This study evaluated the efficacy and safety of percutaneous US-guided MWA for treating recurrent MTC.

Methods: A retrospective review included 22 patients with biopsy-proven locoregional recurrent MTC treated by US-guided percutaneous MWA after prior total thyroidectomy. All were either poor surgical candidates or declined reoperation. Thirty-four lesions underwent single-session outpatient ablation. Tumor size, serum calcitonin and volume reduction ratio (VRR) were assessed at baseline, 1, 3, 6 and 12 months post-ablation. Imaging and biochemical responses determined treatment outcomes. Recurrence-free survival between recurrent and non-recurrent groups was compared.

Results: A total of 22 patients (median age 52 years; 14% hereditary) were included and MWA was successfully performed in all. Mean tumor diameter significantly reduced from 14.3 ± 11.6 mm to 2.6 ± 3.4 mm at 12 months ($p < .001$). Median serum calcitonin decreased significantly from 1165 pg/mL to 108 pg/mL at 12 months ($p < .001$). Treated lesions showed no regrowth; however, 50% developed new metastases elsewhere, correlating with higher initial metastatic burden ($p = .001$) and higher baseline calcitonin ($p = .037$).

Conclusion: US-guided MWA effectively reduces tumor volume and calcitonin levels in recurrent MTC with minimal morbidity, though close surveillance for new metastases remains essential.

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Medullary thyroid carcinoma; microwave ablation; thermal ablation; ultrasound-guided ablation; recurrent thyroid cancer

Introduction

Medullary thyroid carcinoma (MTC) is a malignant neuroendocrine tumor arising from calcitonin-secreting parafollicular C-cells, accounting for ~1–2% of all thyroid cancers [1]. MTC often behaves more aggressively than differentiated thyroid carcinoma, with early lymph node metastases and frequent biochemical persistence or recurrence, even after apparently adequate surgery [2]. The primary treatment for MTC is total thyroidectomy with cervical lymph node dissection, which can result in a cure for many patients with localized disease [3]. However, locoregional recurrence occurs in up to 30–50% of patients over long-term follow-up [3–5]. In the absence of distant metastasis, reoperative neck surgery is recommended for recurrent or persistent MTC as the only potential cure [3] but repeated neck surgeries carry higher risks of complications [5,6].

Ultrasound (US)-guided percutaneous ablation is well-established for recurrent papillary thyroid carcinoma (PTC), achieving disease control rates, with low morbidity [7–10], significantly better than that of

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repeat neck surgery [11–15]. Notably, there is scant literature on ablation therapy for MTC. MTC has traditionally been managed with surgery and, in advanced cases, systemic tyrosine kinase inhibitors [3], and only a few case reports have documented image-guided ablation in recurrent MTC [16]. To the best of our knowledge, no large clinical series of MWA for recurrent MTC has been published. In this study, we present a clinical evaluation of US-guided percutaneous MWA for recurrent MTC. The aim of this study is to evaluate the efficacy and safety of percutaneous ultrasound-guided MWA in achieving effective locoregional tumor control in patients with recurrent MTC.

Materials and methods

Study design and patient population

This retrospective study was approved by the Institutional Ethics Committee. All patients provided written informed consent before the ablation procedure. The requirement for informed consent for study inclusion was waived due to the retrospective anonymized nature of the study.

This study was a single-center, retrospective analysis of patients with recurrent MTC who underwent US-guided percutaneous MWA at our institution between 2018 and 2023. Patients included met the following criteria: (1) pathologically confirmed MTC relapse after prior total thyroidectomy, achieved through ultrasound-guided fine-needle aspiration cytology supported by calcitonin measurement in needle washout fluid; (2) imaging evidence of locoregional tumor recurrence in the neck confirmed by ^{68}Ga-DOTATATE PET-CT and ultrasound imaging (3); biochemical recurrence defined as serum calcitonin levels exceeding our institutional normal reference range (>18 pg/mL), indicative of active disease (4); patients who were either not candidates for further surgery (due to medical comorbidities or multiple prior operations) or who refused additional surgical intervention; and (5) a minimum follow-up duration of one year after ablation. Patients with unresected primary tumor or with widespread distant metastases requiring immediate systemic therapy were excluded.

Ablation procedure

All ablations were performed percutaneously under real-time US guidance by the same experienced interventional radiologist (İ.C.). Patients were positioned supine with neck extension under local anesthesia (1% lidocaine). Hydrodissection was performed by injecting sterile saline through a 21-gauge needle to achieve a minimum safety margin of 3 mm between the lesion and adjacent critical anatomical structures, including the trachea, recurrent laryngeal nerve and vascular structures. MWA was performed with a cooled MWA 17 gauge antenna (Intelligent basic type microwave ablation system, Nanjing ECO microwave system, Nanjing, China), The power was 30 W. A microwave ablation antenna was inserted into each targeted lesion under US visualization. Microwave energy was applied until the entire lesion was ablated, using multiple overlapping applications for larger lesions. The ablation was terminated when the target tumor had changed completely to a transient hyperechoic appearance and power Doppler ultrasound was performed immediately to confirm the absence of vascularity of the ablation area. All patients were managed in an outpatient setting, observed for 3–5 h post-procedure to monitor vital signs, vocal cord function and other complications, then discharged the same day.

Follow-up and assessments

Patients underwent follow-up evaluations at approximately 1, 3, 6 and 12 months and then annually thereafter. At each visit, neck US was performed to assess the ablation site and measure any residual or recurrent tumor size (largest diameter and volume). Serum calcitonin levels were obtained at the same intervals. Patients were scheduled for ^{68}Ga-DOTATATE PET-CT after one year except for cases in which calcitonin levels had increased during initial follow-up. Tumor volume reduction ratio (VRR) was calculated as: VRR = [(initial tumor volume – post-ablation volume)/initial volume] × 100%. Biochemical response was defined as a decrease in serum calcitonin level from the pre-ablation baseline level. Any procedure-related complication was recorded at each follow-up and classified as minor or major according to standard Society of Interventional Radiology criteria [17].

Recurrence is defined as the appearance of a new MTC lesion elsewhere following the post-ablation period without evidence of active disease in the ablation area. For the purposes of survival analysis, any new disease after MWA, either locoregional or distant, was considered a recurrence event. Recurrence-free survival (RFS) was calculated from the date of MWA to the date of first documented recurrence, or to the last follow-up if no recurrence occurred.

Statistical analysis

Continuous variables are presented as mean ± standard deviation (SD) or median and range. Categorical variables are given as counts and percentages. Pre- and post-ablation tumor metrics (size and volume) and serum calcitonin levels were compared using paired two-tailed Student's t-tests (or Wilcoxon signed-rank tests for non-normal distributions). Patients were divided into two groups based on outcome (recurrence vs. no recurrence during follow-up), and their baseline characteristics including age, sex, hereditary vs sporadic etiology, number and size of treated tumors, pre-ablation calcitonin level and interval since initial surgery, were compared using unpaired t-tests (or Mann–Whitney U tests) for continuous variables and chi-square or Fisher's exact tests for categorical variables. RFS after MWA was estimated with the Kaplan–Meier method, and the one-year RFS rate and median RFS (95% confidence interval) were determined.

Results

Patient characteristics and treatment details

In total, 22 patients, ten of whom were male with a median (range) age of 52 (30–74) years were included. Three patients (14%) had hereditary MTC (Multiple Endocrine Neoplasia type 2 A syndrome). All had undergone total thyroidectomy with lymph node dissection. The majority of patients had also undergone one or more repeat neck surgeries for recurrence before being considered for ablation: 18 patients (82%) had at least one prior reoperative cervical surgery (15 patients had one reoperation and 3 patients had two reoperations, in addition to the initial surgery). All patients had persistent or new locoregional disease amenable to targeted ablation. At the time of MWA, the median number of detectable tumor lesions per patient was 2 (1–4) with a total of 34 discrete lesions treated. Of the 34 treated lesions, 30 (88%) were in the cervical region (44% central compartment, 44% lateral neck) and 4 (12%) were in the superior mediastinum (Figure 1). Tumor size varied widely. The largest dimension of the recurrent lesions ranged from 4 mm to 60 mm, with a mean largest diameter of 14.3 mm. Seven patients had only small solitary metastatic lesions (<10 mm) at ablation, six patients had at least one dominant large lesion measuring ≥20 mm, and the remaining nine patients had intermediate-sized lesions between 10 and 20 mm. The mean pre-ablation tumor volume was approximately 2121 mm^3. Pretreatment serum calcitonin was markedly elevated (median 1165 pg/mL; mean 1126 pg/mL), >200 pg/mL in 85% of patients and exceeding 1000 pg/mL in 9 (41%), underscoring the substantial disease burden.

All but one patient (21/22) underwent MWA successfully with no immediate technical failures. Each tumor was successfully ablated as planned in a single treatment session for every patient. In one patient, despite performing hydrodissection, complete ablation was intentionally not performed because of the substantial size of the lesion (61 mm), proximity to the esophagus and dense surgical adhesions. This combination of factors prevented adequate separation from the esophagus. Approximately 90% of the lesion volume was ablated in a single treatment session (Figure 2). The mean procedure time was 21 ± 8 min.

Tumor response

All ablated tumors demonstrated significant shrinkage on follow-up US imaging. The mean largest tumor diameter had decreased from 14.3 mm pretreatment to 11.4 mm at 1 month, 9.3 mm at 3 months, 5.1 mm at 6 months and 2.6 mm at 12 months (all $p < .001$ compared to baseline). Tumor volume showed an even more dramatic response than diameter. The mean volume of the treated lesions shrank from approximately 2121 mm^3 before ablation to 889 mm^3 at 1 month, 442 mm^3 at 3 months, 42 mm^3 at 6 months and

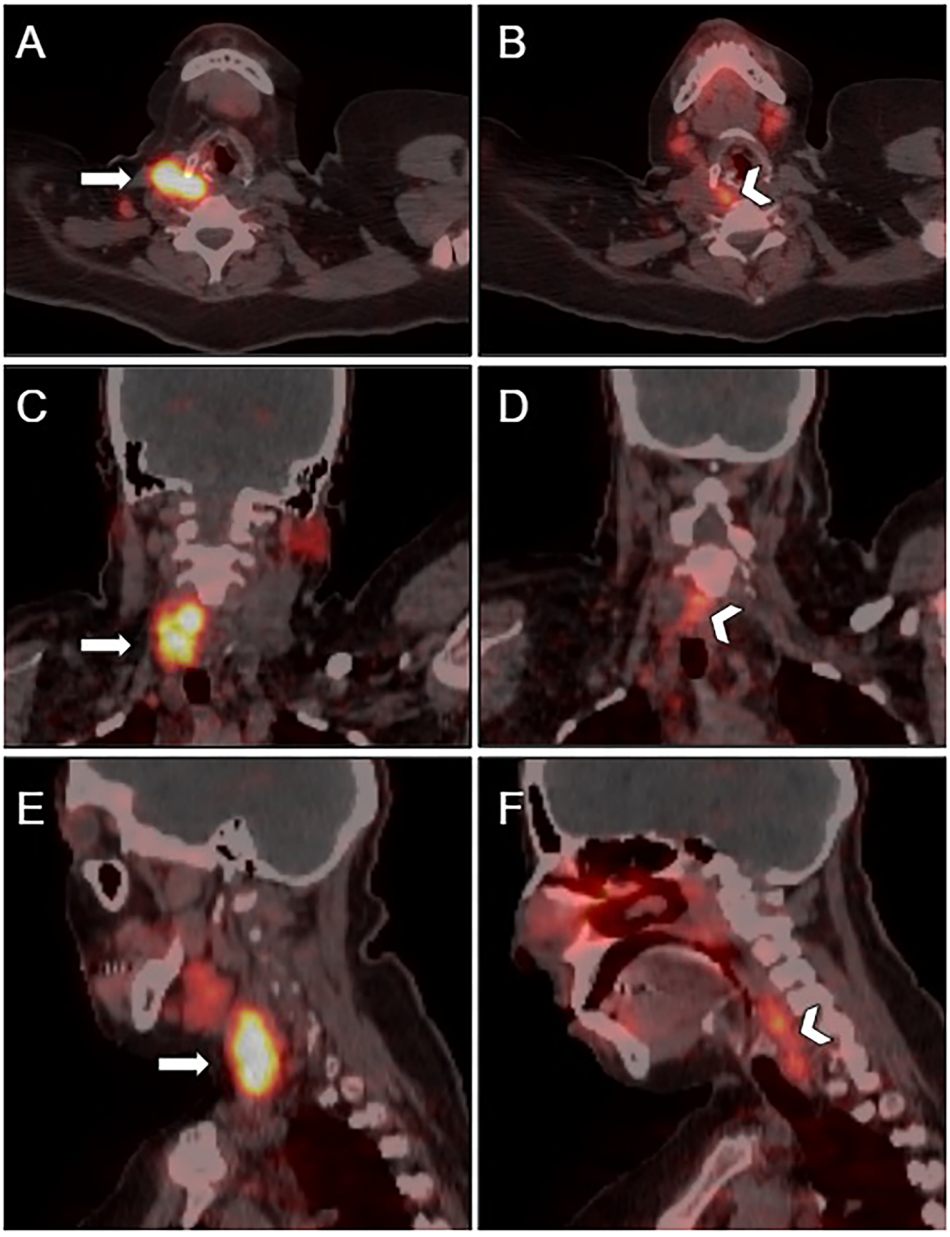


Figure 1. (A) ^{68}Ga-DOTATATE PET/CT fused axial view demonstrating intense uptake in the recurrent medullary thyroid carcinoma (MTC) located in the upper mediastinum, measuring 25 × 15 × 20 mm (arrows). (B–E) Ultrasound-guided hydrodissection of recurrent MTC (arrows) performed with saline (stars), effectively separating the lesion from the trachea, subclavian artery (SC) and common carotid artery (CCA). A microwave antenna was inserted into the lesion (curved arrow), and complete ablation was achieved (arrowheads). (F) Axial ^{68}Ga-DOTATATE PET/CT image at 12-month follow-up showing no uptake in the previously ablated area.

28 mm^3 at 12 months—a mean volume reduction of 98.4% (all $p < .001$ compared to baseline). Furthermore, 11 of 34 lesions (32.4%) had also completely disappeared on US and PET-CT imaging (Figure 3). On follow-up, there was no uptake of ^{68}Ga-DOTATATE on PET-CT imaging in 21 of 22 patients in the ablated area (Figure 4). In the one patient who did not undergo a total ablation ^{68}Ga-DOTATATE PET-CT images were positive in the region next to the esophagus, but no change was detected in this residual tumor during serial follow up (Figure 1).

Biochemical response

The median serum calcitonin level decreased from 1165 pg/mL pretreatment to 398 pg/mL at 1 month, 250 pg/mL at 3 months, 200 pg/mL at 6 months and 108 pg/mL at 12 months (all $p < .001$ compared to

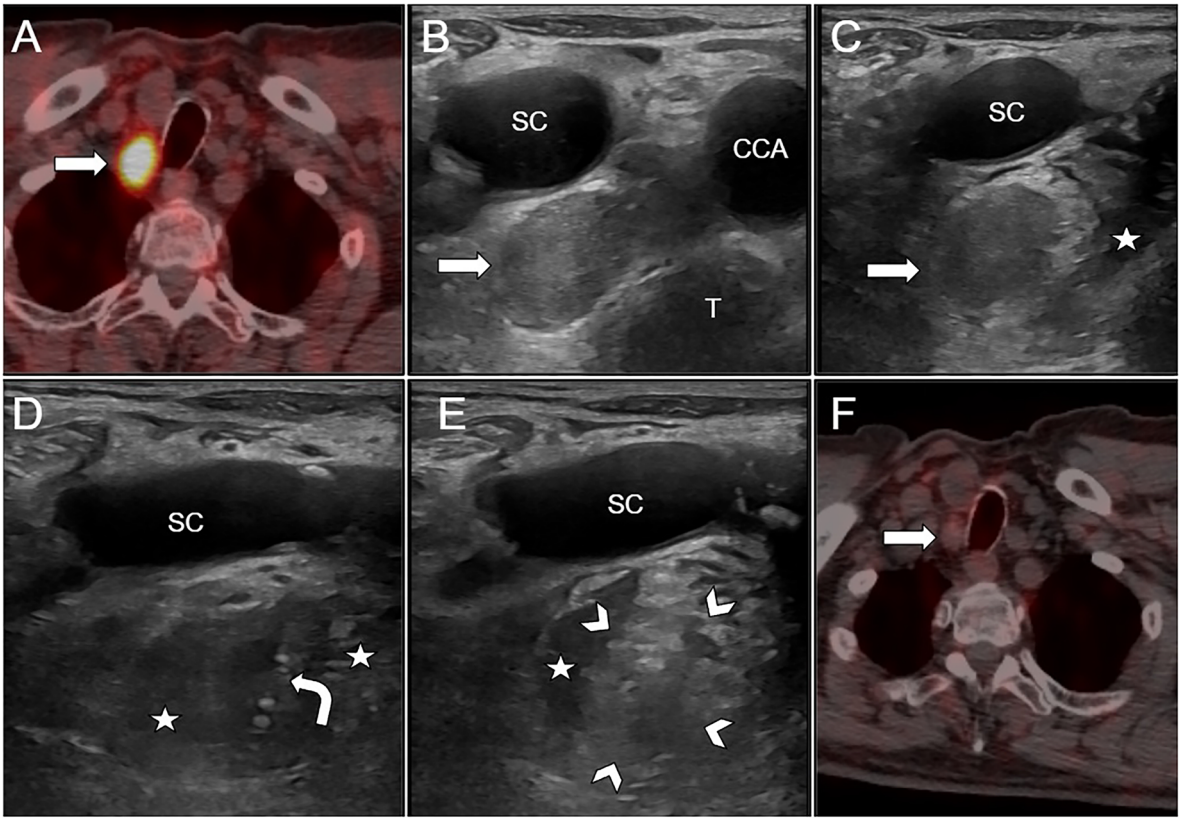


Figure 2. ^{68}Ga-DOTATATE PET/CT fused axial (A), coronal (C) and sagittal (E) views demonstrating intense uptake in recurrent MTC located in the right cervical region, measuring 61 × 34 × 20 mm (arrows). Microwave (MW) ablation was performed sparing only the tumor segments adjacent to the esophagus due to the risk of complications. Axial (B), coronal (D) and sagittal (F) ^{68}Ga-DOTATATE PET/CT images obtained at 12-month follow-up showing no uptake in the ablated areas (arrowheads), except for regions adjacent to the esophagus.

baseline). Moreover, 12 patients (55%) had achieved either normalization of calcitonin levels or $a > 80\%$ decrease from their respective pre-ablation level by 12 months; all of these patients remained recurrence-free during follow-up. An additional 6 (27%) experienced a partial biochemical response, with calcitonin decreasing by 30–80% from baseline but not reaching normal levels. The remaining 4 (18%) had little or no sustained calcitonin decline after ablation. Of note, all four of these patients developed early recurrence. Figure 5 depicts the trend of calcitonin levels before and after ablation for the cohort.

Recurrence outcomes

During a median follow-up of 24 months (range 12–48 months), 11 of the 22 patients (50%) developed tumor recurrence after MWA. Figure 6 shows the Kaplan–Meier curve for recurrence-free survival. The one-year RFS rate for the entire cohort was 50%, and the two-year RFS rate was approximately 34%. The median recurrence-free survival time was 12 months (95% confidence interval, 9–15 months). Among the 11 patients who experienced recurrence after ablation, 5 (45%) developed distant metastases indicative of hematogenous dissemination, specifically involving the liver ($n = 2$) or bone ($n = 3$). In the remaining six patients, recurrences were limited to regional cervical lymph nodes; four lesions appeared in lymph nodes within the same drainage territory as the initially treated lesions, while recurrence in two patients were identified in a lymph node from a different drainage territory. Importantly, no patient experienced regrowth of a previously ablated tumor, confirming durable local control of all ablated lesions. All recurrences were due to new disease in previously untreated locations. Consequently, none of the patients required repeat ablation of the same lesion, with subsequent interventions directed at the new disease sites. Among the patients with new neck lesions, four underwent additional ablation

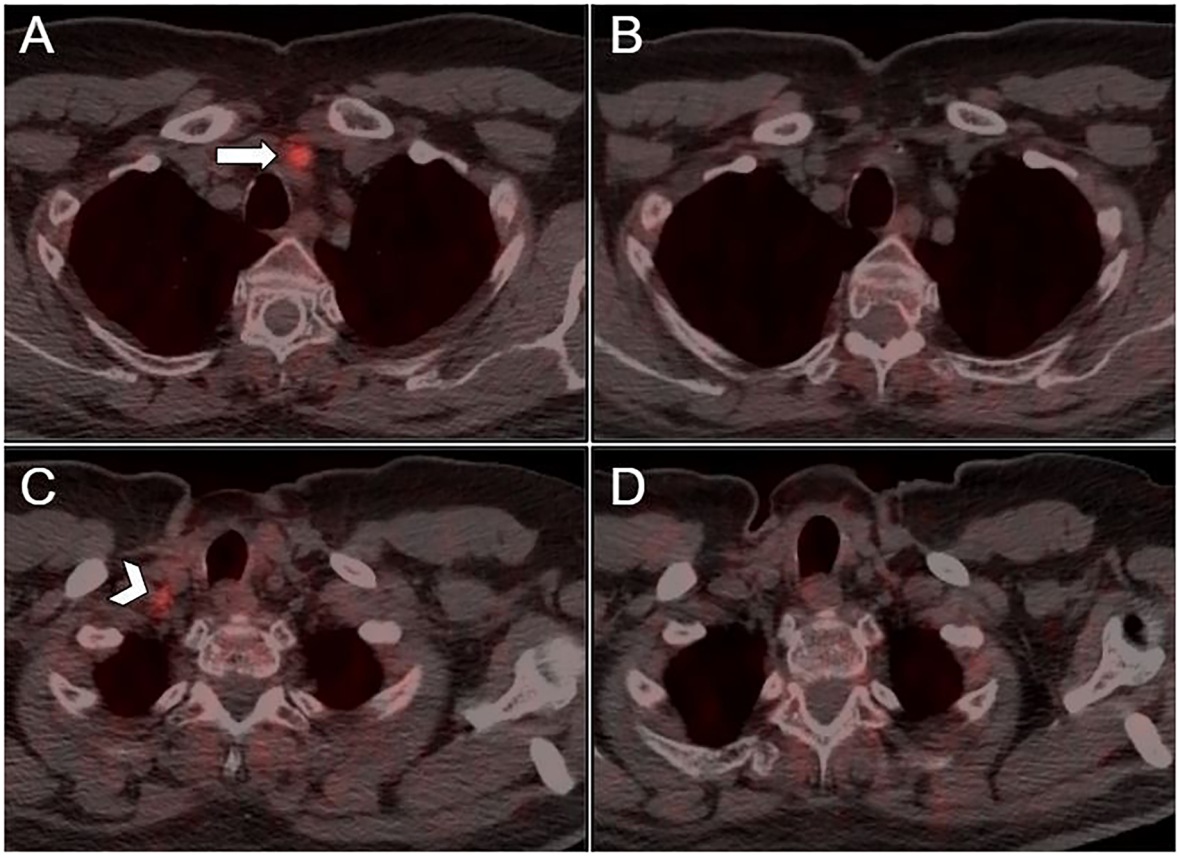


Figure 3. Ultrasound-guided hydrodissection performed using a 21-gauge needle (curved arrow) with saline (stars) to separate recurrent MTC (arrows) from the trachea and common carotid artery (CCA). A microwave antenna was positioned within the lesion, and complete ablation was achieved (arrowheads). (D) Ultrasound image at 12-month follow-up demonstrating complete disappearance of the lesion.

sessions to address the recurrent lesions. Among those with distant progression, seven patients started systemic therapy using tyrosine kinase inhibitor treatment due to progressive distant metastases.

Patients who experienced recurrence tended to have had a more extensive initial disease burden. Specifically, the patients with recurrence had a higher mean number of lesions treated at initial ablation (3.0 ± 1.2 nodes) compared to the non-recurrence group (1.2 ± 0.4 nodes, $p = .001$). The largest mean treated tumor size tended to be larger in the recurrence group (mean 17.3 mm vs. 11.2 mm in non-recurrence group, $p = .07$). Pre-ablation calcitonin was significantly higher in those who had recurrence (mean 1369 pg/mL vs. 884 pg/mL in those without recurrence, $p = .037$), reflecting a greater occult tumor burden. In contrast, patient-specific factors such as age, sex and hereditary status were not significantly different between the two groups with or without recurrence.

Safety and complications

No major complications occurred during or after the MWA procedures. All patients were managed in an outpatient setting and none required emergency surgery or prolonged hospitalization following ablation. Five patients (22%) developed transient voice hoarseness immediately after the procedure, despite hydrodissection. These patients had tumors located in the central compartment (Level VI), close to the recurrent laryngeal nerve (RLN). Although all cases resolved spontaneously within one to three months without further intervention, a comprehensive management strategy was in place to address potential RLN injury. This included intra-procedural injection of approximately 10–20 cc cold sterile saline (0–4 °C) around the nerve for immediate thermal protection, intravenous corticosteroids (prednisolone, 1 mg/kg) in case nerve injury was suspected post-procedure and prompt referral to the otolaryngology department for persistent vocal dysfunction. Management would further involve laryngoscopic assessment, oral

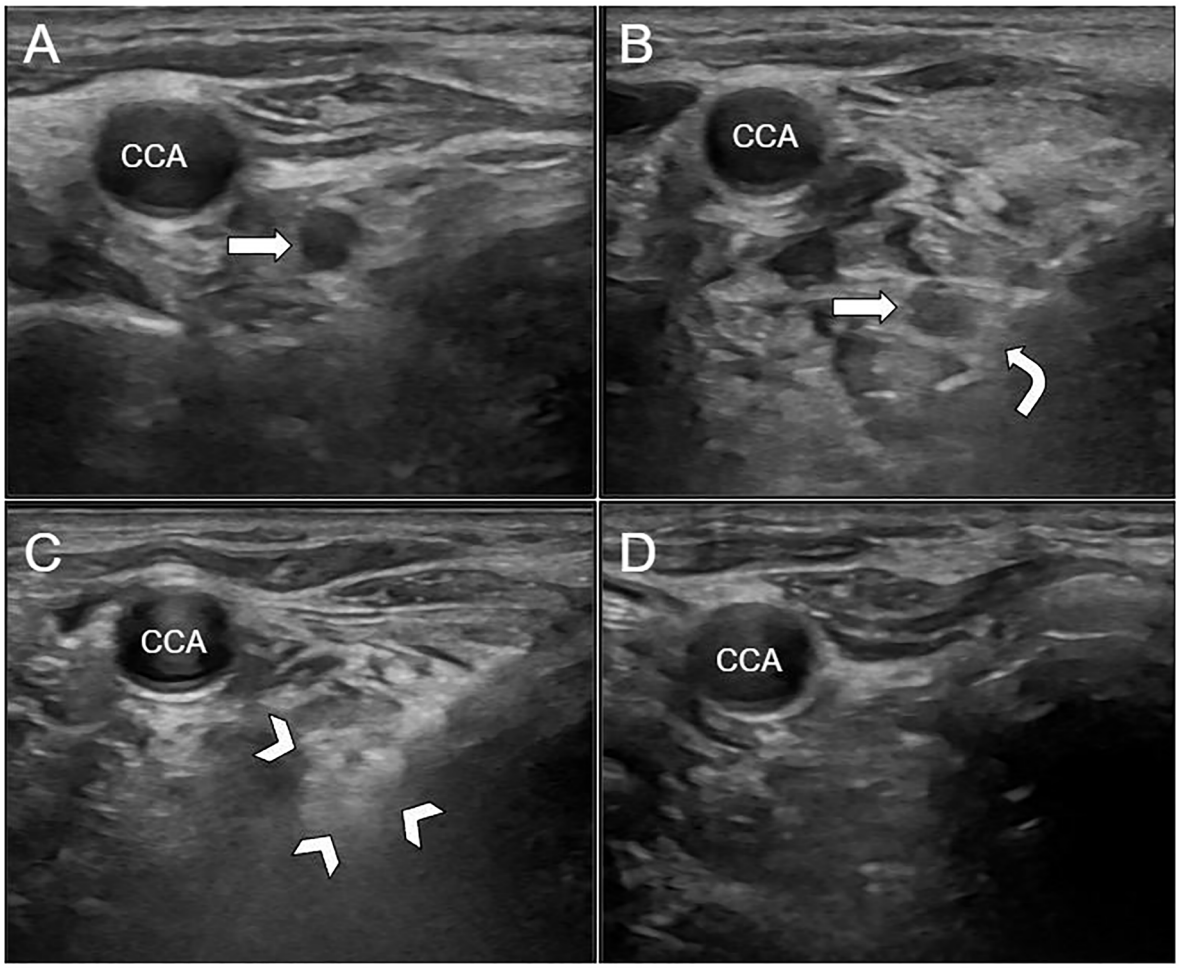


Figure 4. Axial ^{68}Ga-DOTATATE PET/CT fused images demonstrating uptake in the right cervical region at level IV (A) and in the upper mediastinum (B). (C–D) Axial ^{68}Ga-DOTATATE PET/CT images obtained at 12-month follow-up demonstrating no uptake in the previously ablated areas.

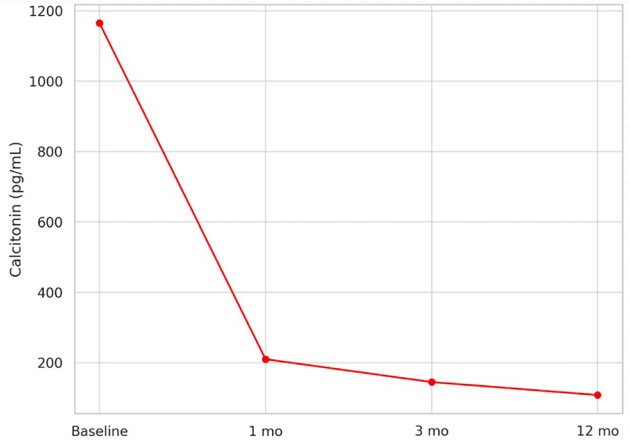


Figure 5. Trend of median calcitonin levels before and after ablation for the cohort.

corticosteroids (prednisolone) for two to three weeks and speech therapy rehabilitation, if clinically indicated. No patient experienced permanent vocal cord paralysis. Three patients (14%) developed minor hematoma that resolved within one week after the procedure. There were no infections of the ablation site or neck.

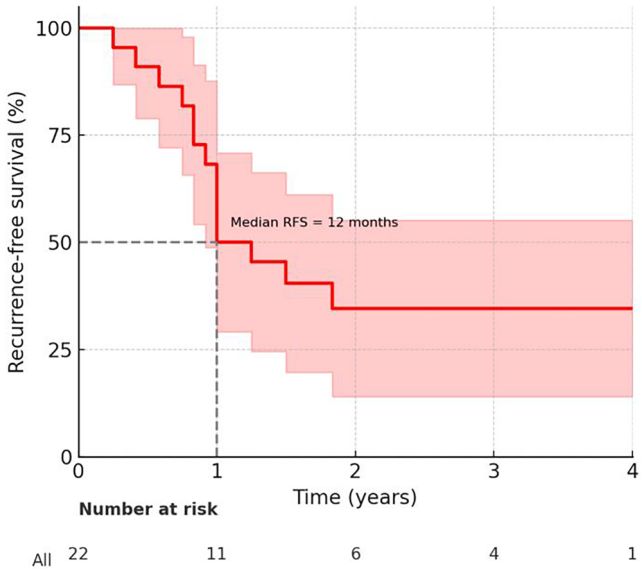


Figure 6. Kaplan–Meier curve for recurrence-free survival.

Discussion

Recurrent or persistent MTC in the neck poses a therapeutic challenge [18]. Complete surgical resection offers the best chance for cure [3], but reoperative neck surgery is technically difficult and carries high risk. Many patients have persistently elevated calcitonin due to microscopic residual disease and up to ~25% develop structural nodal recurrence over time, despite aggressive initial surgery [5]. Systemic therapy is a treatment option in advanced cases [19]. A few case reports have described US-guided ablation for recurrent MTC, resulting in significant tumor shrinkage and a dramatic calcitonin decline with no procedure-related complications [20–22]. A few small cohorts demonstrated successful ablation results using ethanol [21] or radiofrequency ablation (RFA) [23]. There is a clear need for less invasive, local therapies that can eradicate localized MTC foci while minimizing morbidity. Our results suggest that US-guided MWA may fill this therapeutic gap by achieving substantial tumor debulking and durable local disease control with minimal complications.

Our results demonstrated a mean volume reduction of approximately 98% in MTC tumor deposits one year after MWA. This magnitude of tumor shrinkage is comparable to outcomes reported for thermal ablation in recurrent PTC. Yue et al. achieved a 91% mean VRR at 18 months for recurrent PTC using MWA [14], and Kim et al. noted approximately 93% volume reduction at one year after RFA for recurrent thyroid cancers <2 cm [7]. Similarly, studies of RFA for metastatic lymph nodes have shown VRRs of the order of 88–98% after 6–12 months [10,24].

Importantly, no treated tumor in our series showed regrowth on imaging, indicating 100% sustained local control of ablated lesions in the intermediate term. This is noteworthy, given the aggressive nature of MTC. It suggests that when an MTC focus is completely ablated with adequate margins, the likelihood of that lesion recurring is very low, similar to the published experience with ablation of PTC.

MWA also led to marked biochemical improvement. Serum calcitonin levels fell significantly in all patients, reflecting reduced tumor burden. Our findings are in contrast with other published articles and we attribute the difference in the results to the small sample size in these previously published studies [21,25]. Over half of the patients achieved either calcitonin normalization or >80% reduction from baseline and, notably, these patients remained disease-free during follow-up. In contrast, the few patients who had little or no calcitonin decline after ablation developed early recurrence. This association suggests that a marked post-ablation calcitonin response may be a favorable prognostic indicator, whereas an inadequate biochemical response may signal residual disease, although this hypothesis requires more data to confirm.

Despite the excellent local control of treated sites, half of the patients developed disease recurrence during follow-up, corresponding to a one-year recurrence-free survival of 50% and a median RFS of about 12 months. These recurrences were due entirely to new metastases arising outside the treated

area. Again, it is notable that none of the recurrences involved regrowth of a previously ablated tumor, confirming persistent local control of all treated lesions. Patients with distant progression received systemic therapies, as previously described [19].

Patients who eventually experienced recurrent disease had a significantly higher number of metastatic lesions treated at ablation and they also had higher pre-ablation calcitonin levels, reflecting a greater overall disease burden.

The safety profile of MWA in this study was excellent. Percutaneous MWA proved to be a safe procedure with no major or permanent complications observed. Transient vocal changes were observed in a few cases. All transient recurrent laryngeal nerve palsies in our series resolved completely, indicating only temporary thermal irritation. This aligns with the literature in which thermal ablation in the thyroid/neck region has a low incidence of permanent nerve damage (~1% or less) [10,24]. Three patients developed a small, asymptomatic hematoma at the ablation site that resolved without intervention. Overall, this complication profile is comparable to that reported for RFA in recurrent thyroid carcinoma [10,26].

Although our sample size is limited compared to larger surgical series, we noted a complication profile with MWA that appears notably lower than rates reported for reoperative surgery, which most commonly involved recurrent laryngeal nerve palsy (8–15.5%), massive hemorrhage (5.8%) or hypoparathyroidism (16–25%) [1,27]. These findings indicate MWA appears to be an attractive therapeutic alternative, particularly suited for patients who are unsuitable for or prefer to avoid the higher risks associated with repeat surgical interventions.

When comparing MWA to RFA, both modalities appear highly effective for small thyroid cancer lesions [25]. There is no study that compared MWA to RFA in respect to treating recurrent thyroid cancer. However, there are some theoretical and practical considerations. MWA may create a larger ablation zone more quickly due to its thermal mechanism. In our experience, an average 1–1.5 cm MTC node was ablated. RFA typically takes longer for a similar sized nodule, but can achieve the same end result. The ability of MWA to rapidly heat tumor tissue, which is highly vascular in MTC, may theoretically be advantageous in overcoming cooling by blood flow [11]. Our zero incidence of permanent complications attests to the safety of a careful approach. A recent review noted that the overall complication profiles for RFA, laser ablation and MWA in thyroid nodules are similarly low when performed by experienced operators [24].

In the management of MTC, patients with widespread disease will require systemic therapy. In our series, five patients eventually had progression to distant metastases and went on to receive systemic treatment. For advanced metastatic MTC, targeted therapies, such as tyrosine kinase inhibitors, have shown improved progression-free survival in clinical trials [3,19,28].

The strengths of our study include uniform treatment, detailed volumetric and biochemical follow-up and the demonstration of therapeutic efficacy and safety in a challenging patient group with reoperative history and recurrent MTC. Our study has several limitations. The relatively small sample size, reflecting the rarity of MTC and the strict selection criteria for ablation candidates, limits the generalizability of our findings. The lack of routine histological confirmation after ablation might be considered a limitation. Future prospective studies should consider integrating scheduled repeat fine-needle aspiration or core needle biopsies of treated lesions to verify the absence of viable tumor cells, providing definitive evidence of complete ablation alongside imaging and biochemical follow-up. In addition, the absence of a direct comparator group prevents head-to-head comparisons of efficacy and safety outcomes with alternative therapies. Our relatively short follow-up might be insufficient to fully capture longer-term recurrence or complications. However, this series is relatively large in terms of the current literature. Moreover, it is one of only a few reports of the use of MWA for recurrent MTC.

Conclusion

This study indicated that US-guided percutaneous MWA was a highly effective and safe, minimally invasive option for treating locoregional recurrent MTC in appropriately selected patients. The procedure achieved marked tumor volume reduction, significant decline in serum calcitonin and sustained local tumor control of treated lesions in the medium term, with minimal morbidity. Close surveillance remains essential, as new metastatic disease may arise outside the treated areas. Larger studies with longer follow-up are warranted to confirm the long-term outcomes of MWA, to assess the recurrence risk factors suggested by this series and to further refine patient selection criteria for this therapy.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

The data in this work are available for scientific research with formal authorization. If required, please contact the corresponding author.

References

[1] Muñoz de Nova JL, Valdés de Anca Á, Torres Mínguez E, et al. Narrative review of neck reinterventions for medullary thyroid carcinoma: indications and outcomes. Ann Thyroid. 2021;6:11–11. doi: 10.21037/aot-21-12.
[2] Viola D, Elisei R. Management of medullary thyroid cancer. Endocrinol Metab Clin North Am. 2019;48(1):285–301. PMID: 30704998 doi: 10.1016/j.ecl.2018.11.006.
[3] Wells SAJr, Asa SL, Dralle H, et al. Revised American Thyroid Association guidelines for the management of medullary thyroid carcinoma. Thyroid. 2015;25(6):567–610. PMID: 25810047 doi: 10.1089/thy.2014.0335.
[4] Abou Azar S, Tobias J, Applewhite M, et al. Medullary thyroid cancer: single institute experience over 3 decades and risk factors for recurrence. J Clin Endocrinol Metab. 2024;109(11):2729–2734. PMID: 38651609 doi: 10.1210/clinem/dgae279.
[5] Kotwal A, Erickson D, Geske JR, et al. Predicting outcomes in sporadic and hereditary medullary thyroid carcinoma over two decades. Thyroid. 2021;31(4):616–626. PMID: 33174479 doi: 10.1089/thy.2020.0167.
[6] Orloff LA, Noel JE, Stack BCJr, et al. Radiofrequency ablation and related ultrasound-guided ablation technologies for treatment of benign and malignant thyroid disease: an international multidisciplinary consensus statement. Head Neck. 2022;44(3):633–660. PMID: 34967120 doi: 10.1002/hed.26960.
[7] Kim JH, Yoo WS, Park YJ, et al. Efficacy and safety of radiofrequency ablation for treatment of locally recurrent thyroid cancers <2 cm. Radiology. 2015;276(3):909–918. PMID: 26079490 doi: 10.1148/radiol.15140079.
[8] Chung SR, Baek JH, Choi YJ, et al. Longer-term outcomes of radiofrequency ablation for locally recurrent papillary thyroid cancer. Eur Radiol. 2019;29(9):4897–4903. PMID: 30887173) doi: 10.1007/s00330-019-06063-5.
[9] Choi YS, Jung SL, Bae JS, et al. Comparison of efficacy and complications between radiofrequency ablation and repeat surgery in the treatment of locally recurrent thyroid cancers: a single-center propensity score matching study. Int J Hyperthermia. 2019;36(1):359–367. PMID: 30836037 doi: 10.1080/02656736.2019.1571248.
[10] Kim C, Lee JH, Choi YJ, et al. Complications encountered in ultrasonography-guided radiofrequency ablation of benign thyroid nodules and recurrent thyroid cancers. Eur Radiol. 2017;27(8):3128–3137. PMID: 27878430 doi: 10.1007/s00330-016-4690-y.
[11] Feng B, Liang P, Cheng Z, et al. Ultrasound-guided percutaneous microwave ablation of benign thyroid nodules: experimental and clinical studies. Eur J Endocrinol. 2012;166(6):1031–1037. PMID: 22492558 doi: 10.1530/EJE-11-0966.
[12] Yue WW, Wang SR, Wang B, et al. Ultrasound guided percutaneous microwave ablation of benign thyroid nodules: safety and imaging follow-up in 222 patients. Eur J Radiol. 2013;82(1):e11–e16. PMID: 23099185 doi: 10.1016/j.ejrad.2012.07.020.
[13] Heck K, Happel C, Grünwald F, et al. Percutaneous microwave ablation of thyroid nodules: effects on thyroid function and antibodies. Int J Hyperthermia. 2015;31(5):560–567. PMID: 25933173 doi: 10.3109/02656736.2015.1032371.
[14] Yue W, Chen L, Wang S, et al. Locoregional control of recurrent papillary thyroid carcinoma by ultrasound-guided percutaneous microwave ablation: a prospective study. Int J Hyperthermia. 2015;31(4):403–408. PMID: 25815750 doi: 10.3109/02656736.2015.1014433.
[15] Zhao Z-L, Wang S-R, Dong G, et al. Microwave ablation versus surgical resection for US-detected multifocal T1N0M0 papillary thyroid carcinoma: a 10-center study. Radiology. 2024;311(1):e230459. doi: 10.1148/radiol.230459.
[16] Tong MY, Li HS, Che Y. Recurrent medullary thyroid carcinoma treated with percutaneous ultrasound-guided radiofrequency ablation: a case report. World J Clin Cases. 2021;9(4):864–870. PMID: 33585633 doi: 10.12998/wjcc.v9.i4.864.
[17] Khalilzadeh O, Baerlocher MO, Shyn PB, et al. Proposal of a new adverse event classification by the Society of Interventional Radiology Standards of Practice Committee. J Vasc Interv Radiol. 2017;28(10):1432.e3–1437.e3. PMID: 28757285 doi: 10.1016/j.jvir.2017.06.019.

[18] Pelizzo MR, Mazza EI, Mian C, et al. Medullary thyroid carcinoma. Expert Rev Anticancer Ther. 2023;23(9):943–957. PMID: 37646181 doi: 10.1080/14737140.2023.2247566.
[19] Gild ML, Clifton-Bligh RJ, Wirth LJ, et al. Medullary thyroid cancer: updates and challenges. Endocr Rev. 2023;44(5):934–946. PMID: 37204852 doi: 10.1210/endrev/bnad013.
[20] Persichetti A, Bizzarri G, Guglielmi R, et al. Ultrasound-guided laser ablation for local control of neck recurrences of medullary thyroid cancer. A feasibility study. Int J Hyperthermia. 2018;35(1):480–492. PMID: 30204004 doi: 10.1080/02656736.2018.1508759.
[21] Yamashita TS, Rogers RT, Foster TR, et al. Ultrasound-guided percutaneous ethanol ablation for local regional recurrence of medullary thyroid cancer. Am Surg. 2021;87(9):1396–1399. PMID: 34461779 doi: 10.1177/00031348211041563.
[22] Biamonte E, Solbiati L, Ierace T, et al. Medullary thyroid carcinoma treated with percutaneous ultrasound-guided radiofrequency ablation. Endocrine. 2019;65(3):515–519. PMID: 31273680 doi: 10.1007/s12020-019-01995-w.
[23] Dupuy DE, Monchik JM, Decrea C, et al. Radiofrequency ablation of regional recurrence from well-differentiated thyroid malignancy. Surgery. 2001;130(6):971–977. PMID: 11742325 doi: 10.1067/msy.2001.118708.
[24] Chung SR, Suh CH, Baek JH, et al. Safety of radiofrequency ablation of benign thyroid nodules and recurrent thyroid cancers: a systematic review and meta-analysis. Int J Hyperthermia. 2017;33(8):920–930. PMID: 28803434 doi: 10.1080/02656736.2017.1337936.
[25] Tong M, Li S, Li Y, et al. Efficacy and safety of radiofrequency, microwave and laser ablation for treating papillary thyroid microcarcinoma: a systematic review and meta-analysis. Int J Hyperthermia. 2019;36(1):1278–1286. PMID: 31826684 doi: 10.1080/02656736.2019.1700559.
[26] Xiao X, Chen X, Li J, et al. Microwave ablation for lymph node metastasis in thyroid cancer: the impact of lymph node diameter. Front Endocrinol. 2024;15:1430693. PMID: 37687964 doi: 10.3389/fendo.2024.1430693.
[27] Wierzbicka M, Gurgul E, Wasniewska-Okupniak E, et al. The feasibility and efficacy of secondary neck dissections in thyroid cancer metastases. Eur Arch Otorhinolaryngol. 2014;271(4):795–799. doi: 10.1007/s00405-013-2588-8.
[28] Elisei R, Schlumberger M, Müller S, et al. Cabozantinib in progressive medullary thyroid cancer. J Clin Oncol. 2013;31(29):3639–3646. PMID: 24002501 doi: 10.1200/JCO.2012.48.4659.