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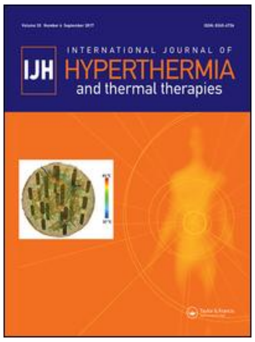

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A comparative study of short-term efficacy and safety for thyroid micropapillary carcinoma patients after microwave ablation or surgery

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ABSTRACT

Background: Although papillary thyroid microcarcinoma (PTMC) has a high incidence and excellent clinical outcome, debate continues as to the therapeutic approach that would be most appropriate after confirming the diagnosis.

Methods: We retrospectively analyzed the medical records of 311 patients with T1aN0M0 PTMC between January 2013 and September 2018. In all, 168 underwent microwave ablation (MWA), and 143 underwent surgery. MWA was performed using extensive ablation with hydrodissection. The surgery comprised thyroid lobectomy (TL) with unilateral central lymph node dissection (CND). We examined clinical outcomes during mean follow-up periods of 824 ± 452 days for the TL group and 753 ± 520 days for the MWA group.

Results: Postprocedural follow-up revealed that, in the MWA group, the tumors had completely disappeared in 34 patients, and the remainder were reduced to necrotic or carbonized tissue. The incidence of transient hypoparathyroidism was significantly lower in the MWA group than in the TL group ($p < .001$). In addition, during the follow-up, we found no statistically significant differences between the two groups (TL *vs* MWA) for PTMC recurrence (1 *vs* 2 cases), lymph node metastasis (5 *vs* 5 cases), or disease-free survival [2001 days (5.5 years) *vs* 1702 days (4.7 years)] ($p = .659$, $p = .795$, and $p = .974$, respectively).

Conclusions: If low-risk thyroid carcinoma (i.e., T1N0M0 PTMC) is accurately diagnosed early, MWA could be a minimally invasive alternative to surgery based on our short-term follow-up regarding recurrence and the low rates of complications and disease-free survival.

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Papillary thyroid microcarcinoma; microwaves; thyroidectomy; recurrence; complications

Introduction

The recorded incidence of papillary thyroid microcarcinoma (PTMC) has recently increased following widespread screening and technical improvements in thyroid ultrasonography (US) and fine-needle aspiration biopsy (FNAC) [1–3]. Despite this increased incidence, the mortality rate remains unchanged at 0.5 deaths per 100 000, although the long-term prognosis is usually excellent, with 10-year survival rates of up to 98% [4–6]. The American Thyroid Association (ATA) guidelines [7] recommend active surveillance, but many patients refuse this approach because of the possibility of lymph node and distant metastases. Currently, thyroid lobectomy (TL) is commonly used to treat PTMC [8]. A disadvantage of traditional surgery is the high rate of severe complications, with morbidity exceeding that of the disease itself [8]. Hence, the ideal PTMC treatment is still controversial [9].

With advances in medical technology, thermal ablation has emerged as a new strategy. The thyroid radiofrequency ablation guideline [10] reported that radiofrequency ablation, microwave ablation (MWA), and laser ablation effectively ablate local PTMCs over the short term and after a 4-year follow-up period. MWA provides a high intratumoral temperature, allows ablation of large volumes, and has a rapid ablation speed. It may also be far less invasive than surgery [11,12]. Many studies have confirmed that MWA treats solitary T1aN0M0 PTMCs effectively [13,14]. We also confirmed the effectiveness of MWA in an earlier study of thermal ablation versus surgery for PTMC [15].

The present study aimed to compare follow-up outcomes for MWA versus surgery, focusing on lymph node metastasis, recurrence, and postoperative complications.

Materials and methods

Patients

The institutional review board of the Beijing Friendship Hospital at Capital Medical University approved the study, and informed consent was obtained from all patients before surgery or MWA.

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Altogether, 220 PTMC patients were treated with US-guided MWA between January 2013 and September 2018. Among them, 52 patients were excluded (32 were lost to follow-up, and 20 had incomplete information). The remaining 168 patients were enrolled in this study as group A (the MWA group). We also selected 143 patients without clinical or US evidence of neck lymph node metastasis (cN0) in chronological order for the surgical group (group B).

All enrolled patients fulfilled the following criteria: (1) solitary PTMC confirmed by US-guided FNAC; (2) presence of a solitary tumor measuring ≤10 mm along its greatest dimension; (3) tumor did not contact or distort the thyroid capsule; (4) no extra-thyroidal spread (to the trachea or esophagus); (5) no lymph node involvement identified on imaging or biopsy evaluation; (6) no history of neck irradiation. The MWA patients (group A) were ineligible for, or refused to undergo, surgery because they were either considered at too-high risk for thyroid surgery or for other reasons. The group B patients had requested surgery because of physical or psychological discomfort or neck extension disorders that made MWA intolerable. The exclusion criteria were (1) biopsy confirmation of a different carcinoma or a coexisting thyroid malignancy such as medullary carcinoma; (2) imaging examinations or biopsy that revealed lymph node or distant metastasis; (3) pregnancy; (4) presence of severe heart, respiratory, liver, or renal failure; (5) presence of a coagulation disorder associated with a severe bleeding tendency (Figure 1).

Preoperative assessment for all patients

All included patients underwent a preoperative physical examination that involved high-resolution neck US examination of suspicious tumors or lymph nodes to confirm the number of lesions (single or multiple) (≥TI-RADS 4a) [16] in the thyroid gland, followed by FNAC. All patients were forbidden to take antiplatelet or anticoagulant medications for at least 1 week before surgery.

Exclusion and diagnostic standards of lymph node metastasis

US findings of lymph node metastasis were as follows: round shape (length/short diameter ratio <2:1); unclear division of cortex and medulla; absent hilus; irregular margins; fusion tendency; peripheral halo; high-echo, low-echo, or cortical calcification [17]. Two doctors (LQ, XH) with more than 10 years of experience assessed the lymph node status. When more than two US images exhibited features of lymph node metastasis, we defined the lymph node as "suspicious," which was then confirmed by FNAC.

MWA instruments and procedures

Before the MWA procedure, each group A patient underwent US and contrast-enhanced US (CEUS) to determine the site, vascularity, and size of the tumor [18]. Two doctors (LQ, YL), each with more than 5 years of experience, performed the MWA using HI VISION Ascendus (Hitachi, Tokyo, Japan) equipped with a 5- to 12-MHz linear-array transducer. The patient was placed supine with the neck fully exposed and with continuous electrocardiographic, respiratory, and blood pressure monitoring. Routine sterile skin preparation was performed with 1% lidocaine as topical anesthesia. A mixture of 1% lidocaine and physiological saline solution was carefully injected into the thyroid capsule as hydrodissection to protect major structures (carotid vessels, trachea, recurrent laryngeal nerve, esophagus) from thermal injury [19].

MWA was performed using the moving-shot technique for multipoint and multidimensional ablation from the tumor's

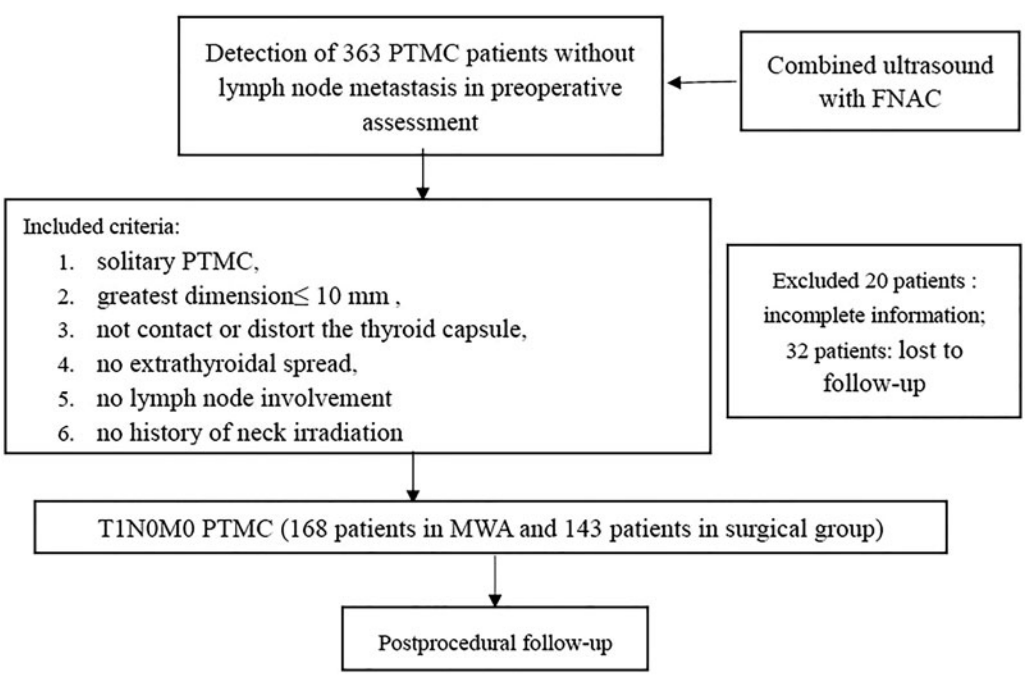

Figure 1. Flow chart of the management of papillary thyroid carcinoma (PTMC) using microwave ablation (MWA) or surgery. FNAC, fine-needle aspiration biopsy.

lower pole to its upper pole [15]. A 17-gauge ablation needle was inserted into the tumor's lower pole under US guidance. The tumor and adjacent thyroid gland were included in the ablated zone (5 mm) to prevent marginal recurrence. A power output of 30 W at 2450 MHz for 20–120 s was routinely used, inducing coagulation necrosis in the tumor. The therapy was sustained until the entire tumor was hyperechoic. When withdrawing the antenna, the needle track was coagulated to prevent tumor cell seeding. We spoke with the patients intermittently during the entire procedure to monitor their vocal status. At 1 h after MWA completion, CEUS was repeated to evaluate the ablated area.

Surgical procedures

Surgery for group B patients, performed under general anesthesia, was undertaken by general surgeons with 10 years of clinical experience. The surgical procedure comprised TL (143 patients) with unilateral CND, according to ATA guidelines [16].

Postprocedural follow-up

In the MWA group, the size, volume, vascularity, and characteristics of each tumor were carefully evaluated 1 h after ablation, at each follow-up point (1, 3, 6, 9, and 12 months), and over the years thereafter. Thus, all patients in all groups underwent neck US every 3–6 months postoperatively.

We defined locoregional recurrence as recurrence in thyroid tissue. Lymph node recurrence was defined as either cytological evidence of disease in the central or lateral neck compartment or evidence of disease on US. A diagnosis of recurrent PTMC was based on evidence of disease in the ablated area of the thyroid bed confirmed by FNAC and/or US. Distant metastasis was defined as evidence of disease outside the neck. Complications—transient or persistent hypoparathyroidism confirmed by serum calcium levels <8.5 mg/dl (2.12 mmol/l); symptoms of hypocalcemia; transient or persistent recurrent laryngeal nerve injury (presenting as voice change, hoarseness)—were carefully monitored after the procedures and at each follow-up assessment. If suspected, recurrent laryngeal nerve injury was confirmed by laryngoscopy.

Disease-free survival

Disease-free survival (DFS) following PTMC was defined as the duration of time from treatment until the lack of disease and/or recurrence was confirmed postoperatively [20]. Event occurrence was defined as postoperative lymph node metastasis and/or tumor recurrence [21].

Statistical analysis

Quantitative data measurements are described as means ± standard deviation (SD) and range. We compared data for the two groups using Student's unpaired t test. Categorical data comparisons were performed using the χ^2 test or Fisher's exact test. Comparisons of changes in the mean diameter of each tumor before MWA and at each follow-up were evaluated using the analysis of variance repeated-measures test. DFS curves were determined using the Kaplan–Meier estimation and survival curves using the log-rank test. All analyses were performed with SPSS statistical software (version 19; IBM, Armonk, NY, USA). $p < .05$ was considered to indicate statistical significance.

Results

Postprocedural follow-up findings

The patients' characteristics are shown in Table 1. There were no statistically significant differences in age or sex between groups A and B ($p = .185$ and $p = .804$, respectively).

Therapeutic effect of MWA

At the time of this writing, 89.3% (150/168) of the MWA patients had undergone more than 1 year of follow-up. During that time, the tumors in 34 patients had completely disappeared. One patient's tumor disappeared as early as 3 months after treatment, with the others having completely disappeared at 6 months (eight patients), 9 months (seven patients), and 1 year (18 patients). The remaining patients' tumors were obviously unchanged 1 year later. CEUS confirmed no enhancement, and FNAC showed necrosis. Changes in the mean diameters after MWA at 1 h and 1, 3, 6, 9, and 12 months after MWA are shown in Table 2.

Complications

Transient hypoparathyroidism was recorded in 10 patients in the surgical group (7%). In contrast, no patients who underwent MWA developed permanent or transient hypoparathyroidism. Transient recurrent laryngeal nerve palsy was reported in 6 (4.2%) patients and permanent laryngeal nerve damage in 1 (0.7%) in the surgical group. The rates of transient and permanent recurrent laryngeal nerve injury in the MWA group were 3.6% and 0.6%, respectively. Hence, the complication rate was significantly lower after MWA than

Table 1. Patients' characteristics and follow-up duration, by treatment.

	MWA	Surgery	p value
Number of patients	168	143	–
Mean age (range)	47.36 ± 10.75 (24–75)	49.18 ± 11.41 (26–76)	.185
Sex (M:F)	36:132	29:114	.804
Mean follow-up days (range)	753 ± 520 (79–1787)	824 ± 452 (46–2235)	.069

M: male; F: female; MWA: microwave ablation.

after surgery ($p < .001$). In addition, all patients in the surgical group required thyroid replacement therapy, whereas none of the patients in the MWA group did so (Table 3).

Table 2. Changes in mean tumor volume at each follow-up after microwave ablation.

Time	Mean ± SD	p value
Before treatment	81.60 ± 9.99	
1 hour	828.86 ± 63.09	<.001[a]
1 month	454.19 ± 45.86	<.001[a]
3 month	221.11 ± 26.27	<.001[a]
6 month	84.70 ± 12.90	<.001[a]
9 month	37.47 ± 6.51	<.001[a]
12 month	21.41 ± 4.02	<.001[a]

[a]Statistically significant.

Table 3. Recurrence, lymph node metastasis, and complications following thyroid lobectomy versus microwave ablation.

	MWA	Surgery	p value
Complications	7/168 (4.2%)	17/143 (11.9%)	<.001
Transient hypoparathyroidism	0	10/143 (7%)	<.001
Persistent hypoparathyroidism	0	0	NA
Transient voice change	6/168 (3.6%)	6/143 (4.2%)	.776
Persistent voice change	1/168 (0.6%)	1/143 (0.7%)	.909
Recurrence (%)			
PTMC	2/168 (1.2%)	1/143 (0.7%)	.659
LNM (%)	5/168 (3.0%)	5/143 (3.5%)	.795
Total (%)	7/168 (4.2%)	6/143 (4.2%)	.990
Distance metastasis (%)	0	0	NA
Disease-specific mortality	0	0	NA

PTMC: papillary thyroid microcarcinoma; LNM: lymph node metastasis; NA: not applicable.

Recurrence and DFS

Among the 161 patients with PTMC treated with MWA, there were five lymph node metastatic recurrences [at 180–1326 days (0.5–3.6 years) of follow-up] and two PTMC recurrences [at 1078–1328 days (3.0–3.7 years) of follow-up]. Thus, during 1–5 years of follow-up, 95.8% (161/168) of patients in the MWA group experienced no recurrence. For the 143 PTMC patients who underwent surgery, there were five lymph node metastatic recurrences [at 382–1696 days (1.0–4.6 years) of follow-up] and one PTMC recurrence [at a follow-up of 1348 days (3.7 years)]. The remaining 95.8% (137/143) of patients experienced no recurrence following surgery. Finally, in the MWA group, two patients with PTMC recurrence and three with lymph node metastatic recurrence underwent a second MWA, and two with lymph node metastatic recurrence required surgery. In the surgical group, one patient with PTMC recurrence and one with lymph node metastatic recurrence required reoperation, and four patients with lymph node metastatic recurrence underwent MWA.

The mean DFS was 1702 days (range 79–1787 days; 4.7 years) in the MWA group compared with 2001 days (range 46–2235 days; 5.5 years) in the surgical group. There was no statistically significant difference in the 5-year DFS between group A (95.8%) and group B (95.5%) ($p = .974$). The Kaplan–Meier survival plots are shown in Figure 2 and Table 4.

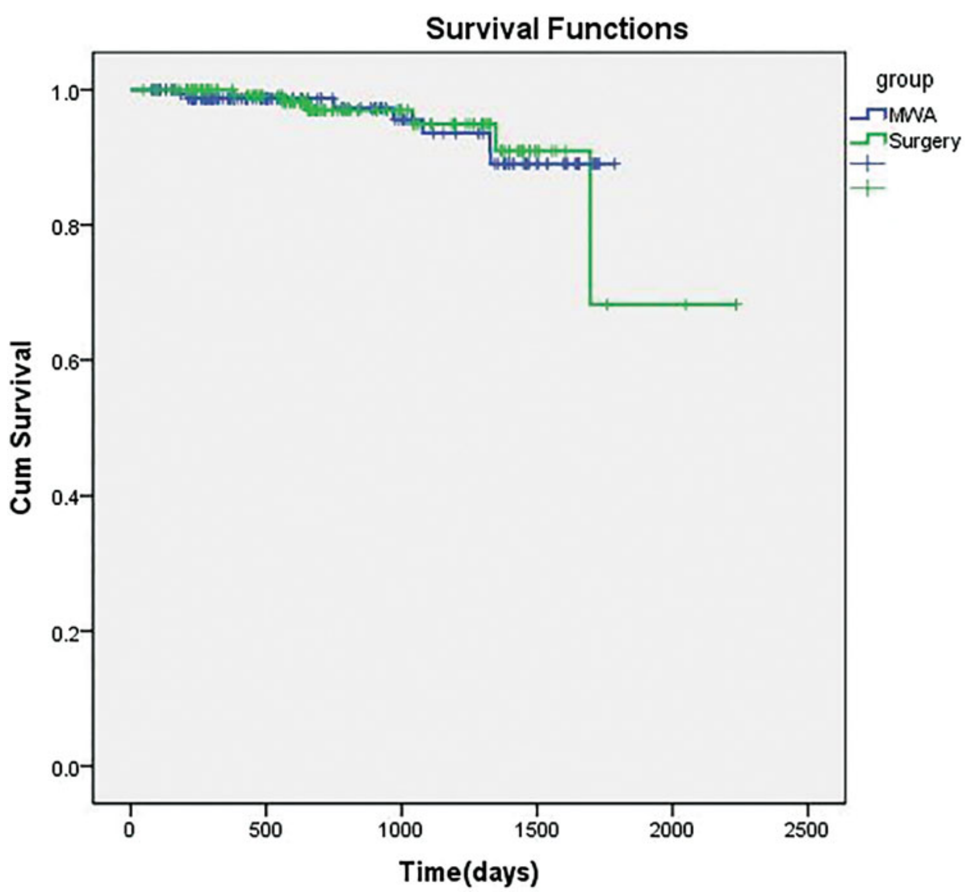

Figure 2. Disease-free survival curves show no statistically significant differences between the microwave ablation (MWA) and surgical groups during follow-up. Cum, cumulative.

Table 4. Number of remaining patients in the study groups throughout the 5+ year follow-up.

Group	Follow-up (years) <1	1–2	2–3	3–4	4–5	5+	Total
MWA	18	59	34	33	24	0	168
Surgery	25	49	27	30	10	2	143

MWA: microwave ablation.

Discussion

Thyroid carcinoma exhibits an interesting phenomenon in that, despite an increasing disease incidence, the associated morbidity and mortality rates remain stable. Thyroid cancer also generates much controversy regarding over-diagnosis and over-treatment. The ATA guidelines [16] support active surveillance of patients with low-risk PTMC, especially those who are at high surgical risk and/or are projected to have a short lifespan. Nevertheless, most patients considered to have maintained a stabilized condition prefer to eliminate the cancer. Along with active surveillance, surgery is therefore the most common, traditional treatment, and MWA is an emerging, minimally invasive approach.

During the period 2008–2017, laser ablation [22–24], radiofrequency ablation [18], and MWA [13] were reported as treatments for low-risk PTMC. MWA is more effective than other ablation techniques because of its good therapeutic effect and rapid rate of temperature increase [11, 19, 25]. We reported a significant reduction in the mean lesion volume (from 81.60 ± 9.99 to $21.41 \pm 4.02\,mm^3$) and complete disappearance of the ablation zones (22.7%, 34/150) during follow-up, indicating that MWA is an effective "local" treatment for PTMC.

In contrast, TL is a relatively "complete" surgical procedure for PTMC with the advantage of low recurrence, but it also carries a risk of injury to recurrent laryngeal nerves or parathyroid glands. Many patients experience postoperative hoarseness and hypoparathyroidism, thus requiring lifelong thyroid hormone replacement therapy. In contrast, MWA minimizes recurrent laryngeal nerve and parathyroid injury rates because of real-time US guidance and the use of the hydrodissection technique [19]. Our experience confirms the reported high rates (7%) of transient hypoparathyroidism after surgery (TL + unilateral CND). With zero incidence of transient hypoparathyroidism in the MWA group, the difference between groups was statistically significant ($p < .001$). We found no statistically significant difference in recurrent laryngeal nerve injury between the two groups ($p = .527$), although the rate was somewhat lower in the MWA group. Compared with RFA and PLA, MWA has the features of thermal conductivity, a faster rate of temperature increase, and powerful thermal injury [11,25]. Zhang et al. [18] reported 5.43% (5/92) as the overall RFA complication rate. In an MWA study, the rates of transient and permanent hoarseness (3.6% and 0.6%) were higher in the present study than the hoarseness rate (2.7%) reported by Teng et al. [26] but lower than the 19% rate found by Yue et al. [13]. Korkusuz et al. [27] reported median pain scores of 3 and 4 points during RFA and MWA, respectively, and their rates of mild hematoma after RFA and MWA treatment were 47.3% (26/55) and 44.7% (21/47), respectively. The complications in the present study were similar to those in other studies [27,28].

Recurrence is of greater concern than postoperative complications in patients with thyroid carcinoma. US is the most frequently recommended imaging modality for both preoperative and postoperative evaluations of the thyroid gland and lymph nodes [29]. All patients in our study underwent preoperative and postoperative follow-up US evaluations, with FNAC added to address suspicious lesions (to confirm recurrent disease).

The present study found that 4.2% (7/168) and 4.2% (6/143) of patients in the MWA and surgical groups, respectively, developed lymph node metastasis and PTMC recurrence, with similar rates of neck recurrence in the two groups. We speculated that it resulted from an antitumor immune response activated by thermal ablation [30]. Some studies have suggested that thermal ablation can induce a so-called abscopal effect—i.e., spontaneous regression of a remote, non-targeted tumor [31,32]. In our study, recurrent tumors found after MWA or surgery were successfully treated by repeat MWA. Repeated operations are usually challenging for recurrent carcinoma in the thyroid bed and cervical lymph nodes because of distortion of normal tissue planes and fibrosis caused by scar tissue. Thus, the 2017 Thyroid Ablation Guideline [10] recommends ablation to avoid complications. Some studies [33,34] had reported use of MWA to treat recurrent thyroid carcinoma or metastatic lymph nodes.

Given the high disease-specific survival and lack of disease-specific mortality among the treatment groups, the need to perform more radical neck surgery remains controversial [1,8,35]. In our study, there was no disease-specific mortality or distant metastasis in either treatment group. Therefore, when considering the short-term survival status and lack of complications, simply eliminating the tumor may be the better approach. Based on our results and previous reports [11,12,14,15,19], MWA appears to be a good alternative to surgery in low-risk patients (i.e., those with T1N0M0 PTMCs).

Our study has several limitations. First, the sensitivity of US to detect lymph node metastases is relatively low (23–72%), although its specificity is 69–92% [29,36,37]. The main reason is that region VI is a blind area for US [38]. Second, five patients in the surgical group had multifocal disease according to the final pathology, which showed small (1–2 mm) and occult (<2 mm) carcinomas that could easily be missed by US [39]. Thus, the conventional examinations (US, FNAC) could not evaluate a solitary tumor with great validity. Finally, the follow-up time is short (1.0–3.5 years), and the number of cases is small.

In conclusion, MWA is superior to surgery in terms of the appearance of complications and its minimal invasiveness. As a technique that could accurately assess lymph node and lesion status preoperatively, and on the basis of our short-term follow-up for recurrence and the DFS rates, MWA may be considered an alternative to surgery for low-risk patients with a PTMC. Above all, the most appropriate treatment for PTMC has yet to be determined.

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Disclosure statement

All authors report no conflicts of interest.

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References

[1] Jegerlehner S, Bulliard JL, Aujesky D, et al. Overdiagnosis and overtreatment of thyroid cancer: A population-based temporal trend study. PloS One. 2017;12:e0179387.
[2] Jung KW, Won YJ, Oh CM, et al. Prediction of cancer incidence and mortality in Korea, 2017. Cancer Res Treat. 2017;49:306–312.
[3] Munim H, Deen KMB, Amanda J, Janis C. Cancers of the thyroid: overview and statistics in the United States and Oklahoma. J Okla State Med Assoc. 2016;109:7–8.
[4] Gartland RM, Lubitz CC. Impact of extent of surgery on tumor recurrence and survival for papillary thyroid cancer patients. Ann Surg Oncol. 2018;25:2520–2525.
[5] Adam MA, Pura J, Goffredo P, et al. Impact of extent of surgery on survival for papillary thyroid cancer patients younger than 45 years. J Clin Endocrinol Metab. 2015;100:115–121.
[6] Davies L, Welch HG. Current thyroid cancer trends in the United States. JAMA Otolaryngol Head Neck Surg. 2014;140:317–322.
[7] Yeh MW, Bauer AJ, Bernet VA, et al. American thyroid association statement on preoperative imaging for thyroid cancer surgery. Thyroid. 2015;25:3–14.
[8] Dobrinja C, Pastoricchio M, Troian M, et al. Partial thyroidectomy for papillary thyroid microcarcinoma: Is completion total thyroidectomy indicated? Int J Surg. 2017;41 Suppl 1:S34–S39.
[9] McLeod DSA, Sawka AM, Cooper DS. Controversies in primary treatment of low-risk papillary thyroid cancer. Lancet. 2013;381:1046–1057.
[10] Kim JH, Baek JH, Lim HK, et al. 2017 Thyroid radiofrequency ablation guideline: Korean society of thyroid radiology. Korean J Radiol. 2018;19:632–655.
[11] Lubner MG, Brace CL, Hinshaw JL, et al. Microwave tumor ablation: mechanism of action, clinical results, and devices. J Vasc Interv Radiol. 2010;21:S192–S203.
[12] Carrafiello G, Lagana D, Mangini M, et al. Microwave tumors ablation: principles, clinical applications and review of preliminary experiences. Int J Surg. 2008; 6:S65–S9.
[13] Yue W, Wang S, Yu S, et al. Ultrasound-guided percutaneous microwave ablation of solitary T1N0M0 papillary thyroid microcarcinoma: Initial experience. Int J Hyperthermia. 2014;30:150–157.
[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;31:403–408.
[15] Li J, Liu Y, Liu J, et al. Ultrasound-guided percutaneous microwave ablation versus surgery for papillary thyroid microcarcinoma. Int J Hyperthermia. 2018;34:653–659.
[16] Haugen BR, Alexander EK, Bible KC, et al. 2015 american thyroid association management guidelines for adult patients with thyroid nodules and differentiated thyroid cancer: the American thyroid association guidelines task force on thyroid nodules and differentiated thyroid cancer. Thyroid. 2016;26:1–133.
[17] Khanna R, Sharma AD, Khanna S, et al. Usefulness of ultrasonography for the evaluation of cervical lymphadenopathy. World J Surg Oncol. 2011;9:29.
[18] Zhang M, Luo Y, Zhang Y, et al. Efficacy and safety of ultrasound-guided radiofrequency ablation for treating low-risk papillary thyroid microcarcinoma: a prospective study. Thyroid. 2016;26:1581–1587.
[19] Morelli F, Sacrini A, Pompili G, et al. Microwave ablation for thyroid nodules: a new string to the bow for percutaneous treatments?. Gland Surg. 2016;5:553–558.
[20] Oluic B, Paunovic I, Loncar Z, et al. Survival and prognostic factors for survival, cancer specific survival and disease free interval in 239 patients with Hurthle cell carcinoma: a single center experience. BMC Cancer. 2017;17:371.
[21] Cabanillas ME, McFadden DG, Durante C. Thyroid cancer. Lancet. 2016;388:2783–2795.
[22] Papini E, Bizzarri G, Pacella CM. Percutaneous laser ablation of benign and malignant thyroid nodules. Curr Opin Endocrinol Diabetes Obesity. 2008;15:434–439.
[23] Zhou W, Jiang S, Zhan W, et al. Ultrasound-guided percutaneous laser ablation of unifocal T1N0M0 papillary thyroid microcarcinoma: preliminary results. Eur Radiol. 2017;27:2934–2940.
[24] Papini E, Guglielmi R, Gharib H, et al. Ultrasound-guided laser ablation of incidental papillary thyroid microcarcinoma: a potential therapeutic approach in patients at surgical risk. Thyroid. 2011;21:917–920.
[25] Yu J, Liang P, Yu X, et al. A comparison of microwave ablation and bipolar radiofrequency ablation both with an internally cooled probe: results in *ex vivo* and *in vivo* porcine livers. Eur J Radiol. 2011;79:124–130.
[26] Teng DK, Li HQ, Sui GQ, et al. Preliminary report of microwave ablation for the primary papillary thyroid microcarcinoma: a large-cohort of 185 patients feasibility study. Endocrine. 2019;64:109–117.
[27] Korkusuz Y, Groner D, Raczynski N, et al. Thermal ablation of thyroid nodules: are radiofrequency ablation, microwave ablation and high intensity focused ultrasound equally safe and effective methods? Eur Radiol. 2018;28:929–935.
[28] Mainini AP, Monaco C, Pescatori LC, et al. Image-guided thermal ablation of benign thyroid nodules. J Ultrasound. 2017;20:11–22.
[29] Liu Z, Zeng W, Liu C, et al. Diagnostic accuracy of ultrasonographic features for lymph node metastasis in papillary thyroid microcarcinoma: a single-center retrospective study. World J Surg Oncol. 2017;15:32.
[30] Takaki H, Cornelis F, Kako Y, et al. Thermal ablation and immunomodulation: from preclinical experiments to clinical trials. Diagn Interv Imaging. 2017;98:651–659.
[31] Rao P, Escudier B, de Baere T. Spontaneous regression of multiple pulmonary metastases after radiofrequency ablation of a single metastasis. Cardiovasc Intervent Radiol. 2011;34:424–430.
[32] Kim H, Park BK, Kim CK. Spontaneous regression of pulmonary and adrenal metastases following percutaneous radiofrequency ablation of a recurrent renal cell carcinoma. Korean J Radiol. 2008;9:470–472.
[33] Teng D, Ding L, Wang Y, et al. Safety and efficiency of ultrasound-guided low power microwave ablation in the treatment of cervical metastatic lymph node from papillary thyroid carcinoma: a mean of 32 months follow-up study. Endocrine. 2018;62:648–654.
[34] Zhou W, Chen Y, Zhang L, et al. Percutaneous microwave ablation of metastatic lymph nodes from papillary thyroid carcinoma: preliminary results. World J Surg. 2019;43:1029–1037.

[35] Welch HG, Doherty GM. Saving thyroids–overtreatment of small papillary cancers. N Engl J Med. 2018;379:310–312.

[36] Kim E, Park JS, Son KR, et al. Preoperative diagnosis of cervical metastatic lymph nodes in papillary thyroid carcinoma: comparison of ultrasound, computed tomography, and combined ultrasound with computed tomography. Thyroid. 2008;18:411–418.

[37] Xiang D, Hong Y, Zhang B, et al. Contrast-enhanced ultrasound (CEUS) facilitated US in detecting lateral neck lymph node metastasis of thyroid cancer patients: diagnosis value and enhancement patterns of malignant lymph nodes. Eur Radiol. 2014;24:2513–2519.

[38] Hall CM, Snyder SK, Maldonado YM, et al. Routine central lymph node dissection with total thyroidectomy for papillary thyroid cancer potentially minimizes level VI recurrence. Surgery. 2016; 160:1049–1058.

[39] Park SY, Jung YS, Ryu CH, et al. Identification of occult tumors by whole-specimen mapping in solitary papillary thyroid carcinoma. Endocrine-Related Cancer. 2015;22:679–686.