# US-guided Microwave Ablation of Hyperplastic Parathyroid Glands: Safety and Efficacy in Patients with End-Stage Renal Disease—A Pilot Study[1]

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**Purpose:** To evaluate the safety and efficacy of microwave ablation (MWA) in patients with end-stage renal disease and secondary hyperparathyroidism.

**Materials and Methods:** The study protocol was approved by the human ethics review committee. Between March 1, 2014, and June 30, 2015, 51 patients (25 men, 26 women; mean age ± standard deviation, 53.1 years ± 12.9) were enrolled. All patients had at least one enlarged parathyroid gland and secondary symptomatic hyperparathyroidism, which was treated with ultrasonographically (US) guided MWA. The levels of intact parathyroid hormone, serum calcium, phosphorus, and alkaline phosphatase were compared before and after MWA. Paired-sample *t* tests and paired-sample Wilcoxon signed-rank tests were used to compare treatment outcomes before and after MWA.

**Results:** Complete ablation was achieved in all 96 glands in 51 of 120 patients with severe secondary hyperparathyroidism. The mean follow-up time was 11.1 months ± 3.3. The maximum diameter of the glands ranged from 0.5 cm to 4.8 cm (mean, 1.5 cm ± 0.6). The ablation time for each gland was 216.1 seconds ± 130.1. The mean serum intact parathyroid hormone, calcium, and phosphorus levels after MWA (400 pg/mL [400 ng/L; range, 151.3–629.0 ng/L], 2.33 mmol/L ± 0.23, and 1.54 mmol/L ± 0.43, respectively) were significantly lower than those before MWA (1203 pg/mL [1203 ng/L; range, 854.7–1694.5 ng/L], 2.53 mmol/L ± 0.24, and 1.97 mmol/L ± 0.50, respectively; $P < .01$), while the alkaline phosphatase levels did not change with MWA ($P > .05$). Ipsilateral recurrent laryngeal nerve injury was seen in one patient (2%). A hematoma developed during one procedure in one patient (2%) and was treated successfully with injection of thrombin.

**Conclusion:** US-guided MWA is safe and effective for destroying parathyroid gland tissue in patients with end-stage renal disease and severe secondary hyperparathyroidism. Further experience with the technique is clearly necessary.



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Secondary hyperparathyroidism (SHPT) is a frequently encountered problem in the treatment of patients with end-stage renal disease (ESRD) (1,2), affecting approximately one in three patients undergoing long-term dialysis (3,4). Its serious clinical complications include renal osteodystrophy, calcific uremic arteriolopathy (a syndrome of vascular calcification, thrombosis, and skin necrosis), and vascular calcification. Uncontrolled SHPT is associated with increased risk of fractures and mortality (5,6). Although disease progression can be managed by using medical therapy, such as orally active vitamin D sterols (7,8), intravenous vitamin D analogs (9,10), and cinacalcet (Sensipar; Amgen, Thousand Oaks, Calif) (11,12), parathyroidectomy may still be necessary in patients with severe SHPT (13,14). Surgical parathyroidectomy has risks such as those of anesthesia and permanent hypoparathyroidism (15). A minimally invasive alternative is desirable and would have potential advantages, such as reduced risks compared with classic surgical treatment, faster recovery, reduced side effects, and, ideally, lower cost.

In recent years, various percutaneous ablation modalities have been developed for use in patients with locally treatable causes of hyperparathyroidism, such as ethanol injection (16,17), acetic acid injection (18), laser ablation (19), high-intensity focused ultrasound treatment (20), and radiofrequency ablation (21–23). Microwave ablation (MWA) has also been used successfully to treat benign thyroid nodules (24–26). Therefore, we considered MWA a viable alternative therapeutic option for hyperparathyroidism. However, the use of ultrasonographically (US) guided percutaneous MWA has not been reported for this condition. The purpose of our study was to evaluate the safety and efficacy of MWA in patients with SHPT.

## Materials and Methods

### Patient Population

The study protocol was approved by the Human Ethics Review Committee of the China-Japan Friendship Hospital. Written informed consent was obtained from all patients before they underwent MWA. Of the 120 patients with severe SHPT seen in the Nephrology Department between March 1, 2014, and June 30, 2015, 51 met the inclusion criteria for ablation of a hyperplastic parathyroid gland. The baseline clinical characteristics of the enrolled patients were recorded and analyzed by five authors (L.Z., Y.M.Z., Z.H.X., G.M.Z., and X.W., with 12, 22, 16, 13, and 10 years of experience, respectively). Recurrent SHPT was defined as a normalized intact parathyroid hormone (PTH) level (<300 pg/mL [<300 ng/L]) within 6 months after total parathyroidectomy, followed by an elevated level more than 6 months after surgery, and persistent SHPT was defined as intact PTH levels higher than the upper limit of normal (300 pg/mL [300 ng/L]) for 6 months (27).

The inclusion and exclusion criteria are shown in Figure 1. The inclusion criteria were *(a)* ESRD with SHPT and intolerance to medication (uncontrolled SHPT with adequate medical therapy); *(b)* intact PTH level greater than or equal to 600 pg/mL (600 ng/L), which is associated with higher cardiovascular mortality (hazard ratio, 1.23; 95% confidence interval: 1.12, 1.34) and all-cause and cardiovascular hospitalization (1); *(c)* at least one enlarged SHPT gland accessible for MWA treatment (ie, no important structures such as a large blood vessel in the puncture path); *(d)* increased $^{99m}$Tc-sestamibi accumulation in the gland in both the early and delayed phases; *(e)* prothrombin time less than or equal to 25 seconds, prothrombin activity greater than or equal to 40%, and platelet count greater than or equal to 100 × 109/L; and *(f)* no intractable complication such as cardiac insufficiency or hypertension that could not be controlled with drugs. Exclusion criteria were *(a)* intact PTH level less than 600 pg/mL (600 ng/L); *(b)* medication effectiveness (controlled SHPT with adequate medical therapy); *(c)* US

### Advances in Knowledge

- By using US-guided microwave ablation (MWA), complete ablation was achieved in all 96 glands (51 patients) treated.
- US-guided MWA could be an option for treating secondary hyperparathyroidism in patients with end-stage renal disease.
- The levels of intact parathyroid hormone, serum calcium, phosphorus (400 pg/mL [400 ng/L; range, 151.3–629.0 ng/L], 2.33 mmol/L ± 0.23, and 1.54 mmol/L ± 0.43, respectively) after MWA (mean follow-up time, 11.1 months ± 3.3) were acceptable, and no major complication was encountered.

### Implication for Patient Care

- MWA is a potentially feasible, safe treatment modality for patients with secondary hyperparathyroidism and is associated with broader inclusion criteria and more rapid postoperative recovery compared with surgery.

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**Abbreviations:**
ALP = alkaline phosphatase
ESRD = end-stage renal disease
MWA = microwave ablation
PTH = parathyroid hormone
SHPT = secondary hyperparathyroidism

**Author contributions:**
Guarantors of integrity of entire study, L.Z., L.L.P., Y.M.Z., Z.H.X., G.M.Z., X.W., W.G.L., M.A.Y.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; agrees to ensure any questions related to the work are appropriately resolved, all authors; literature research, L.Z., L.L.P., Y.M.Z., G.M.Z., X.W., W.G.L., M.A.Y.; clinical studies, all authors; experimental studies, L.Z., L.L.P., Y.M.Z., G.M.Z., X.W., W.G.L., M.A.Y.; statistical analysis, L.Z., L.L.P., Y.M.Z., G.M.Z., X.W., W.G.L., M.A.Y.; and manuscript editing, L.Z., L.L.P., Y.M.Z., G.M.Z., X.W., W.G.L., M.A.Y.

Conflicts of interest are listed at the end of this article.

**Figure 1**

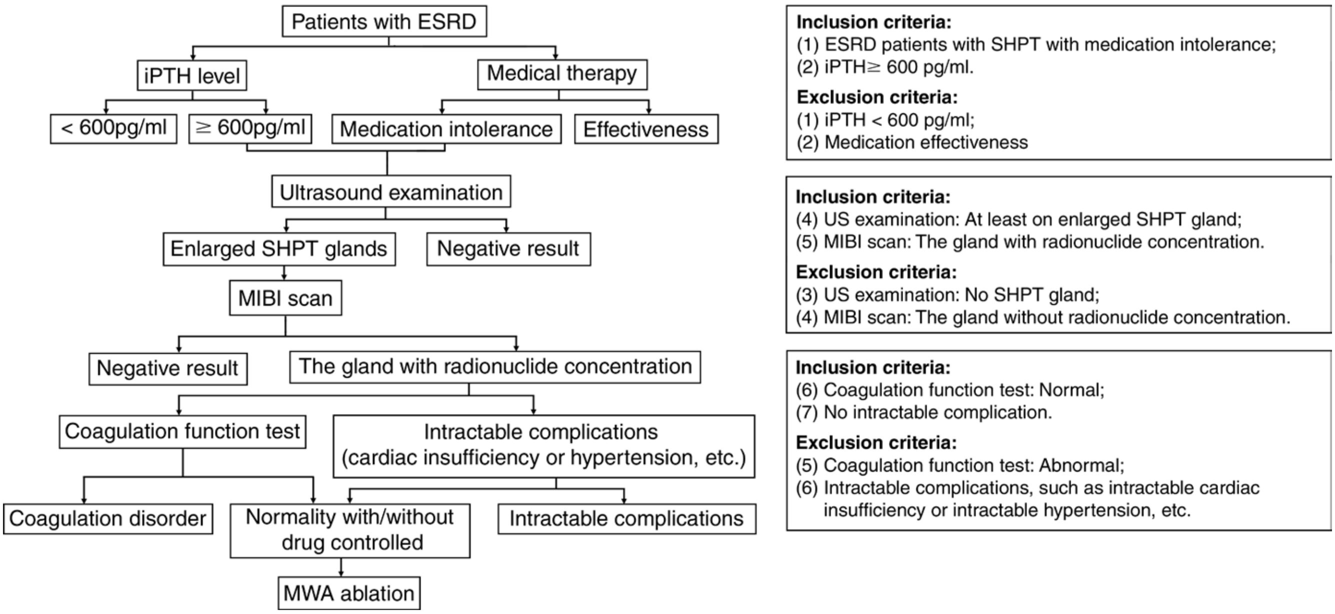


**Figure 1:** Flow chart shows patient selection criteria. iPTH = intact PTH, MIBI = technetium 99m ($^{99m}$Tc) sestamibi.

examination showing no hyperplastic parathyroid glands; *(d)* $^{99m}$Tc sestamibi imaging radionuclide concentration in the gland; *(e)* abnormal coagulation function tests, such as prothrombin time greater than 25 seconds, prothrombin activity of less than 40%, and platelet count less than 100 × 109/L; or *(f)* intractable complications such as cardiac insufficiency or hypertension that could not be controlled with drugs. If a patient did not meet these criteria, MWA was delayed until the abnormal results were corrected. Typically, the SHPT glands are located posterolateral to the thyroid gland, although ectopic SHPT glands can be located in the submandibular region, suprasternal fossae, or anterior mediastinum.

### Percutaneous MWA Procedure

MWA was performed in patients by one of the authors (M.Y., with 10 years of experience with MWA of hepatocellular carcinoma, thyroid nodules, and hyperplastic parathyroid nodules). The US characteristics of the affected parathyroid glands, including the echo features at US, maximum diameter, position, and contrast material enhancement, were evaluated by three authors (M.A.Y. and L.L.P. and M.D.L., with 3 and 32 years of experience, respectively). Before MWA was performed, intravenous access was obtained by means of an antecubital vein. The patients were in the supine position with the neck extended. All patients were given minimal to moderate sedation with midazolam (Roche Laboratories, Nutley, NJ) and fentanyl (Cephalon, Frazer, Pa) before MWA. After cleaning and draping the surgical site on the neck, we injected local anesthesia with 2% lidocaine (Synera, Salt Lake City, Utah) at the puncture site. Then, lidocaine in normal saline solution (1:3, lidocaine concentration 0.5%) was injected in the area 0.5 cm around the hyperplastic gland capsule to provide heat insulation and induce further local anesthesia by means of its effects on the recurrent laryngeal and vagal nerves (21). A microwave generator and 17-gauge internally cooled antenna with a 0.4-cm tip (Intelligent Basic Type Microwave Tumor Ablation System, Nanjing ECO Microwave System, Nanjing, China) were used for the MWA procedures. The antenna was inserted freehand into the parathyroid gland under US guidance with a 10-MHz linear probe for glands in the neck and a 3.5-MHz convex array probe for glands in the suprasternal fossa or supra-anterior mediastinum (Aplio 500; Toshiba Medical Systems, Tokyo, Japan). The approach was lateral for glands in the neck and suprasternal fossa and cranio-caudal for glands in the supra-anterior mediastinum to avoid the clavicle (28). Before each ablation, the needle tip location in the gland was confirmed by means of US. The power for ablation was 25 W for each microwave application. The needle tip was held in a quiescent state for 15–25 seconds, because SHPT glands are usually small, with a maximum diameter of approximately 1 cm, and this was repeated two to four times at intervals of 5 seconds to prevent heat injury to surrounding critical structures (29).

After ablation in one area (one ablation unit), the antenna was repositioned and guided with US to continue the ablation. The power was stopped when patients could not tolerate the pain during ablation. Ablation was terminated when transient hyperechoic echotexture was seen throughout the gland. After ablation, contrast-enhanced US (SonoVue; Bracco, Milan, Italy) was used to evaluate the extent of ablation of the parathyroid gland (30). If the nonenhanced zone at contrast-enhanced US covered the ablated gland, the ablation was considered complete. If there was nodular enhancement inside a gland, an additional ablation was performed immediately. After complete ablation on one side, the procedure was continued on the other side. If the patient experienced persistent dysphonia for more than 1 hour after ablation on one side, laryngoscopy was performed by an otorhinolaryngologist to identify whether a recurrent laryngeal nerve injury had occurred. On the basis of the laryngoscopic results, contralateral ablation was continued if there was no injury or was canceled if there was a nerve injury. During the procedure, an anesthesiologist was present to assist the radiologist in cases of pain, vasovagal reactions, or uncontrollable hematoma pressing on the trachea. At the end of the procedure, mild compression was applied to the site of the needle insertion for 20 minutes and patients remained under observation for 2 hours.

### Clinical Data Collection and Follow-up

Clinical data were collected for all patients by five authors (L.Z., Y.M.Z., Z.H.Y., G.M.Z., and X.W.). The clinical data collected included the intact PTH, serum calcium, phosphate, and alkaline phosphatase (ALP) levels before ablation, 1 and 7 days after ablation, and at the end of follow-up (June 30, 2015). All of the data were obtained in the same laboratory at the China-Japan Friendship Hospital. US was performed and evaluated by two authors (M.A.Y. and M.D.L.) at 2 and 24 hours after ablation to identify hematomas or other complications, and a final examination was performed at the end of follow-up (June 30, 2015). Major and minor complications were defined according to the criteria of the Society of Interventional Radiology. A major complication was an event that led to substantial morbidity and disability, increased the level of care, or resulted in hospital admission or a substantially lengthened hospital stay. All other complications were considered minor (31,32).

### Statistical Analysis

Statistical analyses were performed by using software (SPSS version 17.0 for Windows; IBM, Armonk, NY) by one of the authors (W.G.L.). Continuous data were presented as means ± standard deviation or medians and interquartile ranges. Continuous variables were analyzed by using the Student $t$ test or the Wilcoxon rank-sum test, as applicable. Paired-sample $t$ tests and paired-sample Wilcoxon signed-rank tests were used to compare pre- and postablation treatment outcomes. The relationships between two variables were calculated by using Spearman rank correlation analysis. $P$ values of less than .05 were considered to indicate a significant difference.

## Results

### Patient Demographics and Clinical Characteristics

Table 1 shows the baseline clinical characteristics of the enrolled patients. In total, 51 patients (25 men, 26 women; median age, 53.1 years; range, 19–78 years) underwent US-guided MWA from March 1, 2014, to June 30, 2015, in our center. All patients had ESRD. Of those, 44 patients had been undergoing hemodialysis for 8.2 years ± 5.3, while two had been undergoing peritoneal dialysis for 7.5 years ± 2.5, four had been undergoing hemodialysis and peritoneal dialysis successively for 6.0 years ± 0.7, and one was not undergoing dialysis (estimated glomerular filtration rate, 12.6 mL/min per 1.73 m$^2$). All patients had high serum intact PTH levels; intact PTH is the main bioactive product of PTH, and the intact PTH level shows the best correlation with the production and biologic activity of the hormone (614.5–6800 pg/mL [614.5–6800 ng/L]; normal value, 15–88 pg/mL [15–88 ng/L]). These patients were associated with high serum phosphorus (1.66–3.62 mmol/L; normal value, 0.97–1.62 mmol/L) and normal to high total calcium (2.10–3.24 mmol/L; normal value, 2.03–2.54 mmol/L) levels. All patients were undergoing long-term treatment with various doses of oral calcitriol (0.125–0.5 μg/day; average, 0.25 μg/day ± 0.13) and/or calcium carbonate (600–4000 mg/day; average, 2093.8 mg/day ± 900.2). Fifteen patients had undergone renal transplantations, one of them twice, for a total of 16 renal transplantations. The 51 patients with SHPT included 38 with persistent disease and 13 with recurrent disease after resection. Twenty-three patients had one hyperplastic parathyroid gland, 14 had two, 11 had three, and three had four glands. Complete ablation was achieved in all 96 glands. Of those, 84 glands were in normal locations (37 behind the left thyroid lobe and 47 behind the right thyroid lobe) and 12 were ectopic (one submandibular, eight in the suprasternal fossae, and three in the anterior mediastinum). The maximum diameter of glands ranged from 0.5 cm to 4.8 cm (mean, 1.5 cm ± 0.6).

### Technical Outcomes after MWA

All 96 glands in 51 patients were treated with MWA in a single treatment session. The ablation time was 63–705 seconds (mean, 216.1 seconds ± 130.1) for a single gland, and the puncture site gave access to two-to-nine ablation units (mean number of ablation units, 5.2 ± 1.7). All 96 glands showed hyperenhancement in the arterial phase, including 33 that showed uniform hyperenhancement in the whole hyperplastic gland and 63 that showed nonuniform enhancement inside the gland but hyperenhancement in most parts of the gland and were isoechoic in the late phase at preablation contrast-enhanced US. This enhancement mode was consistent with high parathyroid function. After MWA, all glands showed nonenhancement at contrast-enhanced US, which indicated complete ablation. Figure 2 shows a percutaneous MWA procedure.

### Laboratory Analysis

As of June 30, 2015, the mean follow-up time was 11.1 months ± 3.3. Two

**Table 1**

**Baseline Clinical Characteristics of Patients with SHPT at the Time of MWA**

| Characteristic | Data |
|---|---|
| Patients | |
| Mean age (y)* | 53.1 ± 12.9 |
| Sex | |
| Male | 25 |
| Female | 26 |
| No. of patients who underwent dialysis | |
| Hemodialysis | 44 |
| Peritoneal dialysis | 2 |
| Successive hemodialysis and peritoneal dialysis | 4 |
| Mean duration of dialysis (y)* | |
| Hemodialysis | 8.2 ± 5.3 |
| Peritoneal dialysis | 7.5 ± 2.5 |
| Successive hemodialysis and peritoneal dialysis | 6.0 ± 0.7 |
| No. of patients who did not undergo dialysis | 1 |
| Estimated glomerular filtration rate (mL/min per 1.73 $m^2$) | 12.6 |
| No. of transplantations | 16 |
| No. of patients who received transplants | 15 |
| Incipient | 38 |
| Recurrent | 13 |
| Nodules | |
| No. of glands with nodules | |
| One nodule | 23 |
| Two nodules | 14 |
| Three nodules | 11 |
| Four nodules | 3 |
| Total no. of nodules | 96 |
| Location of nodules | |
| Normal location | 84 |
| Back of left lobe of thyroid | 37 |
| Back of right lobe of thyroid | 47 |
| Ectopic location | 12 |
| Submandibular | 1 |
| Suprasternal fossae | 8 |
| Anterior mediastinum | 3 |
| Hyperenhancement at contrast-enhanced US in arterial phase | |
| Uniform hyperenhancement | 33 |
| Nonuniform hyperenhancement | 63 |
| Maximum diameter of gland (cm)† | 0.5–4.8 (1.5 ± 0.6) |
| Ablation time for nodule (sec)† | 63–705 (216.1 ± 130.1) |
| No. of puncture sites per nodule† | 2–9 (5.2 ± 1.7) |

Note.—Unless otherwise indicated, data are number of patients, glands, or nodules.

* Data are means ± standard deviation.

† Data the range, with means ± standard deviation in parentheses.

patients died, one of gastric cancer and the other of a pulmonary infection. Four other patients were lost to follow-up. On postablation days 1 and 7 and at the end of follow-up, the intact PTH and calcium levels were significantly lower than they were before MWA (both, $P < .01$), as was the serum phosphorus level on postablation day 7 and at the end of follow-up ($P < .01$). However, the total ALP level remained essentially unchanged (Table 2). At the same time, paired-sample $t$ tests showed that calcium and phosphate were significantly decreased after MWA, and the paired-sample Wilcoxon signed-rank test showed that intact PTH and ALP were decreased. ALP at baseline was correlated with ALP at the end of follow-up ($r = 0.912$, $P < .001$), but not with ALP 1 day or 1 week after MWA ($P > .05$). There was no significant correlation between pre- and post-MWA intact PTH, calcium, and phosphate levels ($P > .05$). Spearman rank correlation analysis of the clinical characteristics at baseline and after MWA treatment showed no significant correlations ($P > .05$).

### Complications

All ablation-related adverse events showed spontaneous remission without medical intervention. Adverse events included mild subcutaneous edema, which disappeared 2–4 days after MWA, in six patients; prolonged vocal cord mobility impairment, which improved 2–3 months after MWA, in three patients; and slightly bucking (mild cough) on swallowing water in six patients, all of whom recovered 3–7 days after MWA.

A hemirecurrent laryngeal nerve injury verified at laryngoscopy was seen in one (2%) patient during MWA; this patient had dysphonia and tonality after MWA and during the follow-up period. A hematoma, which was the result of MWA of an ectopic gland in the anterior superior mediastinum, was encountered during one procedure. The hematoma was treated successfully by means of thrombin injection (Fig 3), and there were no other complications reported at 1-week follow-up.

## Discussion

If severe SHPT fails to respond to dietary restriction of phosphate, treatment with dialysis, drugs, or parathyroidectomy should be performed. Parathyroidectomy is also recommended in the Kidney Disease: Improving Global Outcomes (KDIGO) guidelines for chronic kidney disease–related mineral and bone disorder (33). Although parathyroidectomy is very effective for patients with severe SHPT, the surgeon may

**Figure 2**

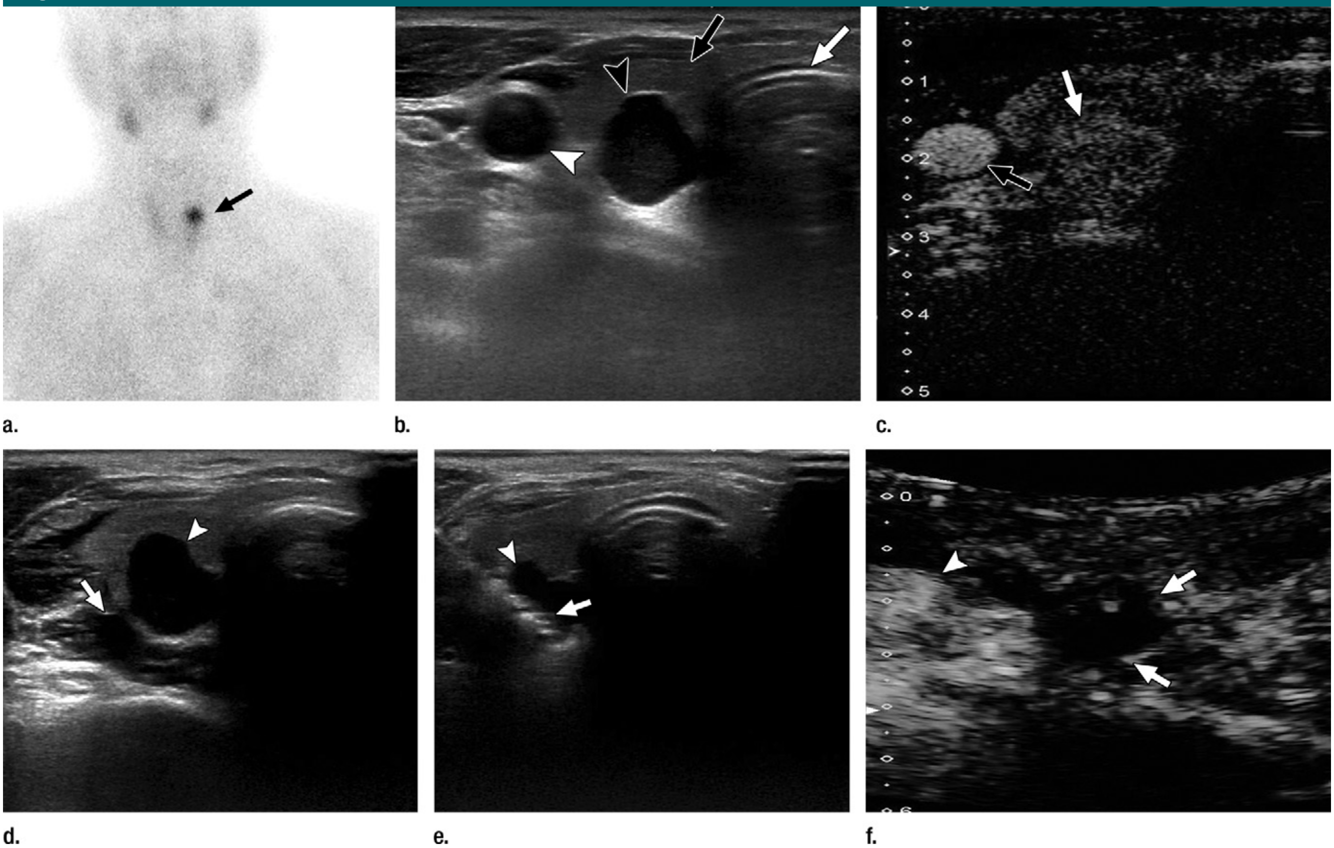


Figure 2: Images show MWA of SHPT nodule. **(a)** Coronal image shows that nodule has concentration of radioactivity (arrow) in late phase of $^{99m}$Tc-sestamibi sequence. **(b)** Axial US image shows SHPT hypoechoic nodule with sharp boundary (black arrowhead) behind lateral lobe of thyroid (black arrow) and between carotid artery (white arrowhead) and trachea (white arrow) before MWA. **(c)** Contrast-enhanced axial US image shows uniform hyperenhancement of nodule (white arrow) beside carotid artery (black arrow) before MWA. **(d)** Axial US image shows injection of spacer fluid (arrow) behind SHPT nodule (arrowhead) before MWA. **(e)** Axial US image shows hyperechoic area (arrow) emerging inside nodule (arrowhead) during MWA. **(f)** Axial contrast-enhanced US image shows nonenhancing area covering nodule (arrows) beside carotid artery (arrowhead) after MWA, which suggests that complete ablation was achieved with MWA.

**Table 2**

**Laboratory Data of Patients with SHPT before or after MWA**

| Laboratory Test | Before MWA ($n = 51$) | After MWA (day 1) ($n = 51$) | After MWA (day 7) ($n = 51$) | End of Follow-up ($n = 45$)* |
|---|---|---|---|---|
| Intact PTH (pg/mL)† | 1203 (854.7–1694.5) | 283 (135.8–432.0)‡ | 322 (165.0–552.5)‡ | 400 (151.3–629.0)‡ |
| Calcium (mmol/L) | 2.53 ± 0.24 | 2.19 ± 0.31‡ | 2.31 ± 0.21‡§ | 2.33 ± 0.23†§ |
| Phosphorus (mmol/L) | 1.97 ± 0.50 | 1.77 ± 0.48 | 1.59 ± 0.31‡ | 1.54 ± 0.43‡ |
| ALP (U/L) | 180 (98.5–467.0) | 161 (92.0–418.0) | 175 (89.0–394.0) | 152 (85.0–392.5) |

Note.—Intact PTH and ALP values are medians, with interquartile range in parentheses. All other data are means ± standard deviation.

* End of follow-up was June 30, 2015. Mean follow-up time was 11.1 months ± 3.3. Two patients died of gastric cancer and pulmonary infection, and four patients were lost to follow-up.

† To convert to Systéme International units (nanograms per liter) multiply by 1.

‡ $P < .01$ vs before MWA.

§ $P < .01$ vs after MWA (day 1).

fail to detect all of the glands requiring reoperation (34). The surgical and anesthetic risks also may be elevated because some patients with SHPT have skeletal deformities, short necks (neck shortening due to bone deformation), and internal environmental disorders (electrolyte abnormalities such as hyper- or hyponatremia, hyper- or

**Figure 3**

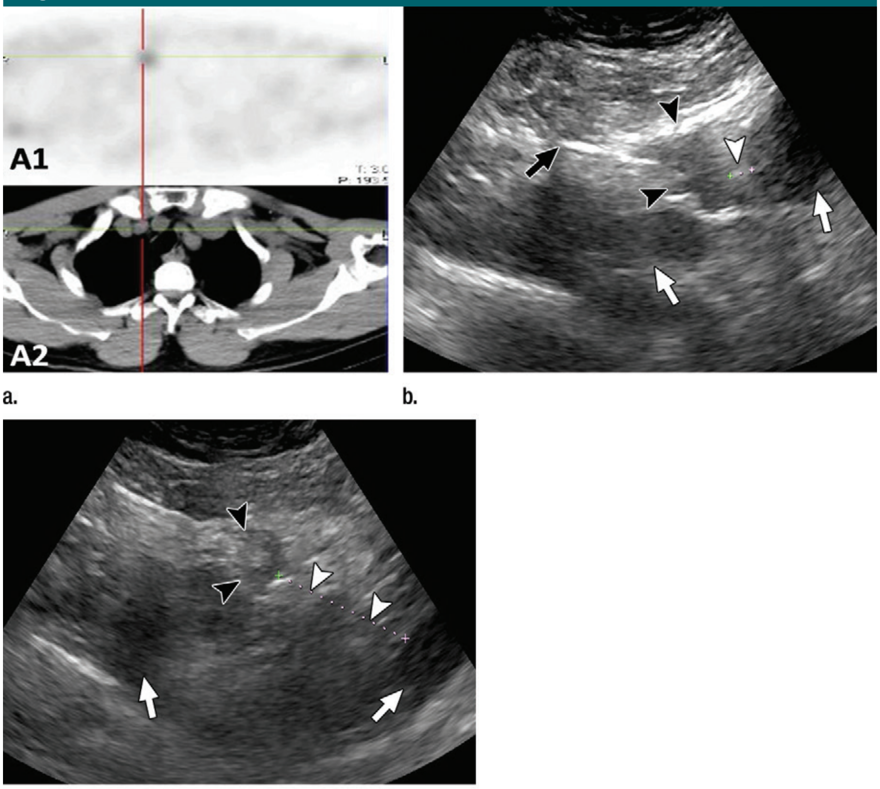


**Figure 3:** Images show hematoma encountered during MWA of ectopic SHPT nodule in anterior superior mediastinum. **(a)** Axial $^{99m}$Tc-sestamibi sequence image *(A1)* and corresponding axial CT image *(A2)* before MWA show nodule with radioactivity concentration, located behind sternum (intersection of vertical red line and horizontal yellow line) in a 61-year-old woman. **(b)** Oblique US image shows microwave antenna (black arrow) inserted into ectopic SHPT nodule (black arrowheads), next to carotid artery (white arrows) with an interval of 0.4 cm (white arrowhead) before MWA. **(c)** Oblique US image shows that interval between nodule (black arrowheads) and carotid artery (arrows) was widened (white arrowheads) to 2.4 cm during MWA, which suggests hematoma.

hypokalemia, hyper- or hypocalcemia, hyper- or hypomagnesemia, hyper- or hypochloremia, and hyper- or hypophosphatemia). Nonsurgical methods are often preferable for the physical destruction of hyperplastic parathyroid glands. As shown in this study, US-guided MWA effectively reduced the serum intact PTH, calcium, and phosphorus levels of patients with ESRD and severe SHPT and caused less trauma and fewer complications, with a faster recovery.

Compared with other treatments for SHPT, MWA has unique advantages. Subtotal and total parathyroidectomy offers higher cure rates for SHPT, although 17% of patients still have PTH levels higher than the KDIGO guidelines range (35). The overall mortality (1%) and morbidity (3.5%) of parathyroidectomy are higher than those in our study (36). After performing percutaneous ethanol injection therapy as a minimally invasive treatment for recurrent and persistent SHPT, a promising result was seen in 91.8% of patients, with an intact PTH level of less than 300 pg/mL (300 ng/L). Although that is better than our result, the percutaneous ethanol injection therapy procedure is more complicated than is MWA because it requires three to five injections at 7-day intervals for each gland (27). Regarding drug therapy with cinacalcet, the most promising drug to manage SHPT, the median intact PTH level decreased from 611 pg/mL to 251 pg/mL (611–251 ng/L) at 12-month follow-up (37), which was equal to our results with MWA.

Our pilot study of 51 patients with SHPT represents an early experience with MWA in patients with ESRD. Our report shows the potential benefits and limitations of this strategy in patients with SHPT. A marked decrease in serum intact PTH level was observed after MWA, and the serum calcium and phosphorus levels also improved. However, total ALP remained essentially unchanged. Authors of previous studies have shown (38,39) that bone resorption markers decrease significantly within 24 hours, while bone formation markers are unchanged after parathyroidectomy. This suggests that osteoclast activity becomes decoupled from osteoblast activity in the immediate postoperative period, perhaps because of the acute decrease in PTH. Because ALP is a marker of bone formation, this process likely does not change significantly after MWA.

In our study, serum intact PTH decreased significantly after MWA, which suggests that MWA can inactivate hyperplastic glands. For patients with ESRD, the National Kidney Foundation Kidney Disease Outcomes Quality Initiative recommended that intact PTH levels be below 300 pg/mL (300 ng/L) (40). Because of variability in PTH measurement, the target was modified in 2009 to suggest maintaining intact PTH levels in the range of approximately two to nine times the upper normal limit for the assay (33). However, the importance of intact PTH is still debated (41).

The use of MWA could be a reasonable alternative to surgery, as was shown recently in patients with benign thyroid nodules (24–26). Given its favorable safety profile, MWA also may be useful in patients with ESRD and SHPT. MWA devices create a uniform electromagnetic field surrounding the antenna that causes rapid volume tissue heating by means of the oscillation of polar water molecules. Tissue temperatures can increase markedly, because MWA does not rely on the conduction of an electrical current and is not limited by charring. This may translate into larger, faster, and more consistent ablation zones than those possible with radiofrequency ablative techniques (42,43).

There is no uniform standard for evaluating the efficacy of MWA, which presently differs from SHPT resection. Surgical resection is intended to remove all parathyroid gland tissue as thoroughly as possible to avoid recurrent glands, because a secondary resection of recurrent SHPT is usually more challenging due to adhesions. In comparison, MWA could be used to treat larger, hyperplastic, recurrent SHPT glands. Thus, any criteria for evaluation of the efficacy of MWA of SHPT should be more flexible because of the relative simplicity and safety of a secondary ablation, if needed. Such minimally invasive treatments call for formulation of new uniform evaluation criteria.

Apart from one hematoma encountered during MWA in one patient, there were no complications during MWA or within the follow-up period. This suggests that US-guided percutaneous MWA is safe for patients with ESRD.

There were several limitations to this study. First, relatively few patients were enrolled, and more patients are needed for a confident conclusion. Second, $^{99m}$Tc-sestamibi sequence was not repeated after treatment to show the reduction or disappearance of the activity. Third, a longer term follow-up is needed to determine the recurrence rate after MWA.

In conclusion, our pilot study provides initial evidence that US-guided MWA is safe and effective for managing SHPT glands. It may represent a nonsurgical alternative for patients with refractory drug-resistant SHPT or for patients with SHPT who refuse or are not able to undergo parathyroidectomy.

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