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ORIGINAL ARTICLE

Clinical application of ultrasound-guided percutaneous microwave ablation in the treatment of T1aN0M0 stage renal carcinoma

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Abstract

Purpose Evaluation of clinical application of ultrasound-guided percutaneous microwave ablation treatment for T1a renal carcinoma.

Methods Analysis of the clinical data from 31 patients with T1aN0M0 stage renal carcinoma who underwent ultrasound-guided percutaneous microwave ablation in the Department of Ultrasound of China-Japan Union Hospital of Jilin University between March 2010 and June 2014.

Results All of the 31 patients were treated with ablation only once: 96.8% (30/31) of patients had no local recurrence or distant metastasis after ablation. One (3.2%) patient had local tumor recurrence 6 months after surgery and underwent a second microwave ablation. According to the results of 2 years of follow-up re-examinations, no further recurrence or distant metastasis was found. Moreover, 90.3% (28/31) of the patients had no complications with normal ranges of preoperative and postoperative serum creatinine and urea nitrogen levels. Complications were found in 9.7% (3/31) of the patients: one case of transient hematuria, one case of perirenal hematoma, and one case of cholecystitis; the symptoms were resolved with symptomatic treatment.

Conclusion Ultrasound-guided percutaneous microwave ablation is a safe and effective micro-invasive therapy for T1a renal cancer patients.

Keywords Ultrasound-guided · Microwave · Ablation · Kidney cancer

Introduction

Kidney cancer is one of the most common tumors in the urinary system with one of the highest degrees of malignancy, ranking second only to bladder cancer and accounting for approximately 1.6% (66.8/4291.6) of the malignancy incidence in China and 0.8% (23.4/2814.2) of the mortality rate [1]. The five-year survival rates of early kidney cancer, advanced kidney cancer, and renal metastasis with distant metastases in the kidney are 92, 65, and 12%, respectively [2].

With the increase of the incidence of kidney tumors, the continuous improvement of modern imaging diagnostic techniques, and the enhancement of people's health awareness, more kidney cancers can be detected early. The average maximum diameter of new kidney cancer has dropped to within 4 cm [3]. ATM staging affects the prognosis of renal cancer [4]. About 75% of kidney cancer is T1. At present, the treatment of kidney cancer is still based on surgery. Surgical methods of radical nephrectomy are gradually changing to those that preserve the nephrons. Study results show that patients who undergo nephron-sparing surgical treatment have higher survival rates and fewer complications [5]. One kind of nephron-sparing surgery, partial nephrectomy, has become a standard treatment for patients with stage I disease [6]. In recent years, tumor thermal ablation technology has been widely used in the clinical treatment of solid tumors such as liver cancer, lung cancer, thyroid cancer, and breast cancer [7]. Microwave ablation is gradually being applied to the micro-invasive treatment of renal tumors, and it is a safe and effective micro-invasive treatment for T1a renal cancer patients. Its clinical effect is nearly as good as that of partial nephrectomy [8]. Considering its advantages, it is a preferred treatment especially for weak elderly patients, patients with multiple diseases who cannot undergo surgery

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[9], and patients with isolated renal kidney cancer [10] or renal insufficiency [11]. This report will describe the clinical effect of ultrasound (US)-guided percutaneous microwave ablation for T1a renal cancer.

Materials and methods

Subjects

Thirty-one patients with T1aN0M0 stage renal cancer who underwent US-guided percutaneous microwave ablation in the Department of Ultrasound of China-Japan Union Hospital of Jilin University between March 2010 and June 2014 were selected: 19 males and 12 females; age 51–82 years, average of 62.1 ± 11.5 years old; nephrectomy tumor recurrence in 2 cases; left kidney tumor in 17 cases and right kidney tumor in 14 cases; 13 cases in the upper pole of the kidney, 11 cases in the mid pole, and 7 in the lower pole. All distances from the lesion margins to the renal pelvis were > 0.3 cm. The maximum diameter of the tumor was 1.5–3.2 cm, with an average of 1.92 ± 0.67 cm. Table 1 shows the age, sex, location, size, and type of tumor of patients.

Table 1 Patients' background

Age	Sex	Position	Size	Tumor
62.1 ± 11.5	M (19)	Left (17)	1.92 ± 0.67	Clear cell carcinoma (29)
(51–82)	F (12)	Right (14)	(1.5–3.2)	Papillary cell carcinoma (1)
				Mixed cell carcinoma (1)

Data are mean ± standard deviation, and data in parentheses are the range

Operation process

All patients underwent US (Fig. 1a, Fig. 2a), contrast-enhanced US (CEUS) (Fig. 1b, Fig. 2b), computed tomography (CT), or magnetic resonance imaging (MRI) examination and pathological diagnosis of renal cell carcinoma confirmed by means of preoperative US-guided biopsy. The patient's lying position allowed the US to clearly show the lesion and the needle path through it. The left or right lateral decubitus position was usually chosen with a pillow of appropriate height under the waist. When

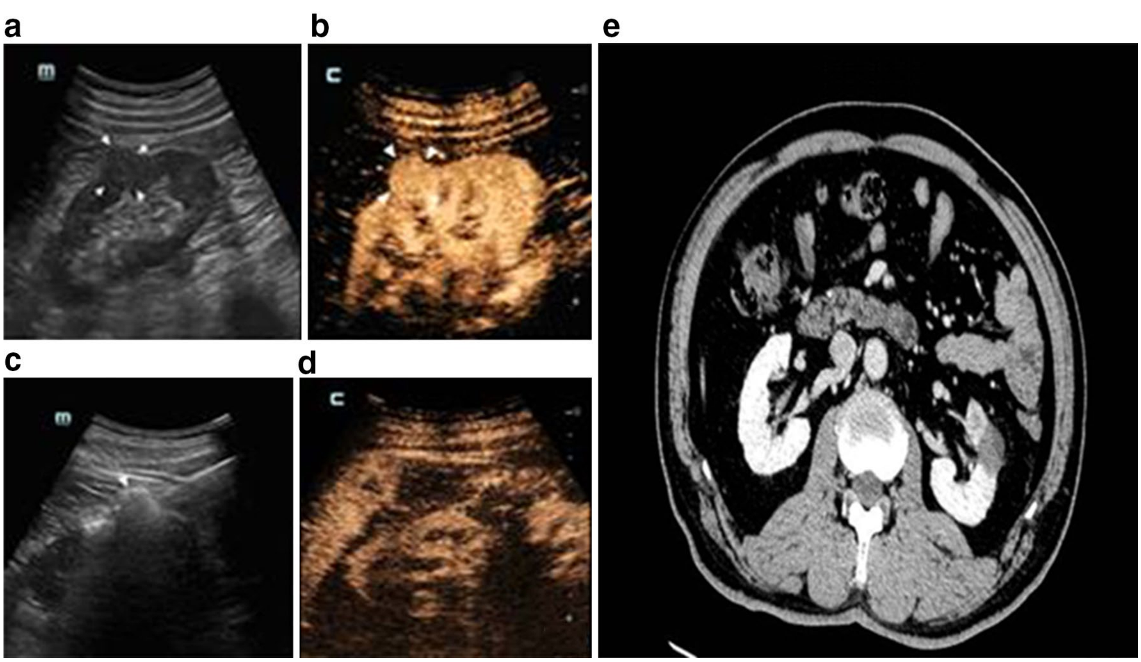

Fig. 1 **a** Preoperative two-dimensional US findings: evenly low echo in the middle and outer renal parenchyma of the right kidney, clear boundaries, and pseudocapsules. **b** After injection of SonoVue, CEUS showed that the lesion was uniformly high and enhanced, and the boundary with the surrounding renal parenchyma was more pronounced. It was confined to the kidney envelope, and there was no invasion of perirenal fat and pelvis. **c** Ablation: with ablation power of 60 w and ablation time of 3 min, low echogenic gasification in the tumor area formed a strong gas echo, followed by acoustic shadow. **d** US imaging at 10 min after ablation: no significant contrast agent filling was observed in the tumor area, and the range exceeded the tumor boundary by 0.5 cm, suggesting complete tumor. **e** Postoperative review of enhanced CT 3 months later: no obvious enhancement was seen in tumors and surrounding soft tissues, suggesting that tumor ablation was complete

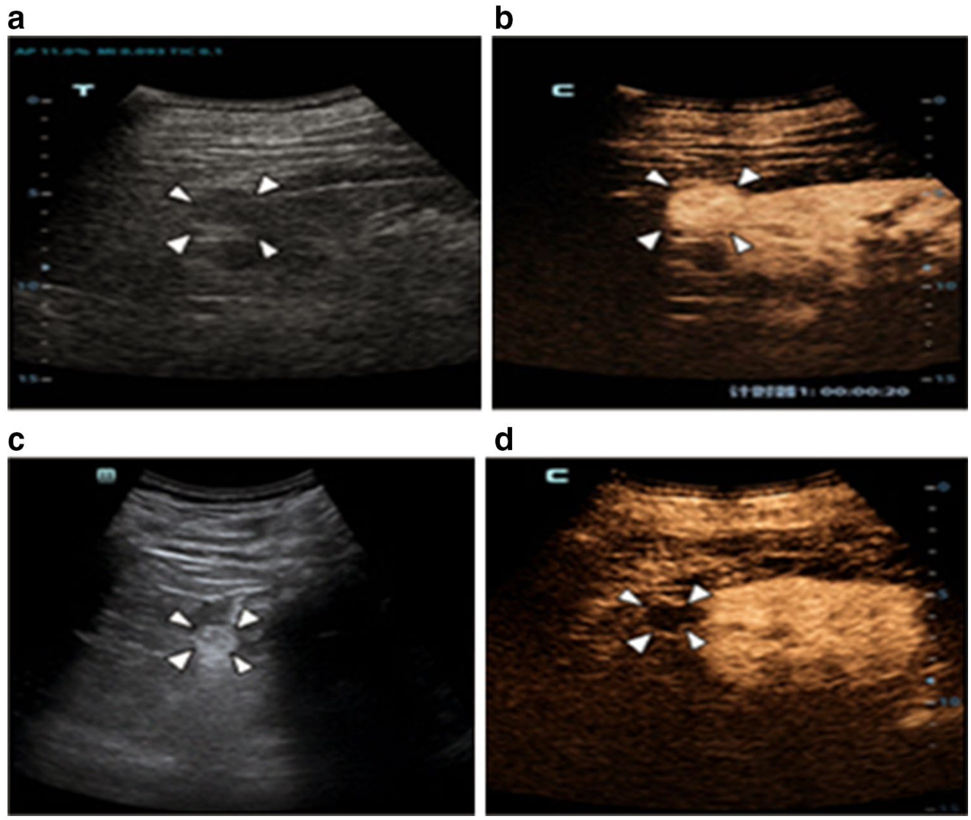

Fig. 2 **a** Preoperative two-dimensional US findings: the left kidney superior renal parenchyma uniform hypoechoic, clear boundary, pseudocapsules. **b** After injection of SonoVue, CEUS showed that the lesion was uniformly high and enhanced, and the boundary with the surrounding renal parenchyma was more pronounced. It was confined to the kidney envelope, and there was no invasion of perirenal fat and pelvis. **c** Ablation: with ablation power of 60 w and ablation time of 3 min, low echogenic gasification in the tumor area formed a strong gas echo, followed by acoustic shadow. **d** US imaging at 10 min after ablation: No significant contrast agent filling was observed in the tumor area, and the range exceeded the tumor boundary by 0.5 cm, suggesting complete tumor

routine sterilization was finished and intravenous anesthesia took effect, an 18G biopsy needle was used to take two to three lesion specimens for pathological examination under real-time US guidance (MINDRAY® DC-8Exp color Doppler US system with 5C1 convex array probe (frequency 3.5 MHz); Shenzhen, China). We performed rapid pathology on the puncture and performed microwave ablation after pathological diagnosis. When the biopsy was completed, the ablation needle was immediately punctured into the center of the tumor and the microwave instrument (Nanjing YI GAO billion high microwave ablation instrument, using I8 model ablation needle and 60 W output power during treatment) was started for treatment (Figs. 1c, 2c). At the end of treatment, the needle path was solidified before taking out the ablation needle, to reduce the risk of bleeding and planting. If the tumor was large, multipoint ablation could be used. Bleeding and other complications could be found in time using US examination after surgery. After observation for 10 min, the CEUS examination was performed (Figs. 1d, 2d). The scope of the treatment needed to completely cover the tumor and reach the safety perimeter of the tumor by 0.5–1.0 cm. If the ablation range was insufficient, supplementary ablation could be performed. Conformal ablation was needed for tumors adjacent to the renal pelvis.

Inclusion criteria

Patients with T1a stage renal cancers who met one of the following conditions: (1) patients with isolated renal kidney cancer and with renal insufficiency; (2) patients with recurrent renal cell carcinoma; (3) weak elderly patients with multiple diseases who cannot undergo surgery; and (4) patients who intend to receive micro-invasive treatment. This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Jilin University. Written informed consent was obtained from all participants.

Preoperative evaluation

Preoperative routine examinations were performed such as US, CEUS, CT, or MRI. With the detected information on the position, size, shape, envelope, blood supply, and peripheral adjacencies of the lesion, the appropriate puncture route and proper model of the ablation needle could be selected and a more detailed surgical plan could be drafted. Also, reasonable safety measures such as artificial ascites technology could be taken for possible injury of important organs during surgery [12].

Postoperative follow-up

The color change of the first urine after surgery was observed. On the first day, US, hematuria, renal function, and other findings were reviewed to observe the complications of patients and records were taken down. According to the standardized criteria for image-guided ablation therapy terminology and reporting [13], serious complications were defined as unintended events such as increased care grades, longer hospitalization, or unrecoverable adverse consequences. For other minor complications, patients underwent intensive image examinations 1, 3, and 6 months after surgery and every 6 months thereafter (Fig. 1e).

Results

Pathological results

The diagnosis of renal cell carcinoma was confirmed by means of preoperative US-guided biopsy. The diagnosis results were as follows: 29 cases of clear cell carcinoma (93.5%), one case of papillary cell carcinoma (3.2%), and one case of mixed cell carcinoma (3.2%).

Microwave ablation results

All of the 31 patients were treated with ablation only once. Each lesion was punctured with one to four needles, averaging 2.20 ± 0.62 needles; the microwave power for each lesion was 40 to 60 W, averaging 50.5 ± 2.13 W; the ablation time was 180–900 s, averaging 328.4 ± 175.6 s; the ablation energy was 12–49 kJ, averaging 24.2 ± 9.56 kJ. Hospitalization time was 1–3 days, with an average of 1.51 ± 0.32 days; the review time after surgery was 12–36 months after surgery, with an average of 20.2 ± 9.2 months. Also, 96.8% (30/31) of patients had no local recurrence or distant metastasis after ablation. Figure 1 shows the US and CEUS or enhanced CT findings before and after US-guided microwave ablation on one patient. Figure 2 shows the results of US and CEUS in one patient before, during, and after surgery.

Clinical characteristics

Thirty-one patients with T1aN0M0 stage renal cancer: 19 males and 12 females; age 51–82 years, average of 62.1 ± 11.5 years old; nephrectomy tumor recurrence in 2 cases; left kidney tumor in 17 cases and right kidney tumor in 14 cases; 13 cases in the upper pole of the kidney, 11 cases in the mid pole, and 7 in the lower pole. All distances from the lesion margins to the renal pelvis were > 0.3 cm.

Complications and side effects

One (3.2%) patient had local tumor recurrence 6 months after surgery. Enhanced CT results showed small nodular abnormalities at the edge of the original ablation area. A second microwave ablation was performed. After 2 years of follow-up, no further recurrence or distant metastasis was found. Complications were found in three patients (9.7%): one case of transient hematuria, which resolved after symptomatic treatment; one case of perirenal hematoma with a thickness of 1.3 cm, treated with hemostasis, symptomatic treatment, and follow-up observation that led to hematoma absorption after 1 month; and one case of cholecystitis, which resolved after symptomatic treatment. No serious complications such as intestinal fistula were found. Moreover, 90.3% (28/31) of patients had no complications, with normal ranges of preoperative and postoperative serum creatinine and urea nitrogen levels. Table 2 shows ablation efficacy and adverse events: one case of transient hematuria, one case of perirenal hematoma, one case of local tumor recurrence, and one case of cholecystitis. However, after long-term follow-up, there were no complications or recurrence.

Discussion

Kidney cancer is one of the most common tumors in the urinary system with one of the highest degrees of malignancy. With the increase of the incidence of kidney tumors, the continuous improvement of modern imaging diagnostic techniques, and the enhancement of people's health awareness,

Table 2 Ablation efficacy and adverse events

Postoperative outcome (complication)	Immediately after MWA	1 month later	6 months later	36 months later
No metastasis and relapse	30 (96.8)	29 (93.1)	30 (96.8)	31 (100.0)
Hematuria	1 (3.2)			
Perirenal hematoma		1 (3.2)		
Cholecystitis		1 (3.2)		
Local recurrence			1 (3.2)	

Data in parentheses are percentages

many kidney cancers can be detected early and the treatment methods have changed. Compared to radical nephrectomy, nephron-sparing surgery (NSS) does not increase the risk of recurrence or metastasis [14]. Also, clinical data show that middle-term and long-term survival rates for this treatment are comparable to those for radical resection [15]. In recent years, microwave ablation technology has become a safe, reliable, and effective surgical method. Microwave ablation has a principle advantage [16]. The mechanism of microwave ablation is that the microwave alternating electric field can cause frictional heat generation of charged ions in the tissue. Water, protein, and other polar molecules can generate friction and heat at the same time. The high temperature causes the degeneration of tumor tissue protein, which leads to in situ cancer coagulation necrosis. The high efficiency of microwave heat production translates to shorter treatment duration, which means higher patient tolerance [17]. In addition, the use of water-cooled microwave equipment can effectively reduce the temperature of the needle bar, which helps to increase the energy used to transmit safely to the tissue. Therefore, for kidney cancers with abundant blood supply, microwave ablation therapy is less affected by blood supply and has advantages over other ablation methods.

In the present study, the diagnosis of renal cell carcinoma was confirmed by means of preoperative US-guided biopsy. The diagnosis results were: 29 cases of clear cell carcinoma (93.5%), one case of papillary cell carcinoma (3.2%), and one case of mixed cell carcinoma (3.2%). According to kidney cancer TNM staging criteria [18], the maximum diameter of the tumors was within 3.2 cm combining preoperative clinical and radiological examinations. There was no regional lymph node metastasis or distant metastasis. All cancers were in T1aN0M0 stage. Follow-up review time was 12–36 months, with an average of 20.2 ± 9.2 months. Follow-up showed that 96.8% (30/31) of patients had no local recurrence or distant metastasis after ablation, which suggested a good clinical effect and proved that US-guided percutaneous microwave ablation for T1a renal cancer was an effective micro-invasive treatment. The rate of local recurrence after surgery was low and no serious complications occurred. One patient had local tumor recurrence 6 months after surgery, so a second microwave ablation was performed. No further recurrence or distant metastasis was found. One case of transient hematuria resolved after having the patient drink more water and performing hemostatic therapy. The suspected reason was micro-injury of the renal pelvis wall during the needle biopsy, not microwave ablation. One case of perirenal hematoma was found on US examination after surgery. Hemostatic therapy was performed, and the hematoma was completely absorbed when reviewed 1 month later. One tip for kidney cancers with a rich blood supply: hemostatic drugs can be used prophylactically before treatment, and intraoperative and postoperative US examinations play an important role in detecting bleeding performance. Under normal circumstances, microwave needle ablation produces tissue coagulation and degeneration, and the needle channel is ablated in real time when the needle is retracted. Therefore, the formation of hematoma is considered to be a small amount of bleeding around the kidney during the needle biopsy. In the one case of cholecystitis, it resolved after symptomatic treatment with an anti-inflammatory. The reason for it was that the lesion was located at the middle upper part of the right kidney in the belly inner side. The patient was so thin that the fat capsule around the kidney was thin. The heat generated by the ablation caused thermal damage to the gallbladder wall. Insufficient use of spacer fluid during surgery may also be a cause of such complications. Reducing ablation power during surgery and using multipoint ablation and mobile ablation may avoid these complications.

CEUS can better show small vessels or even tiny vessels. Tumor location, size, shape, number, border, blood supply, and its relationship with surrounding tissues and vital organs, including the renal pelvis and colon, can be clearly imaged. During the operation, the puncture process of the ablation needle can be monitored, and the extent of the ablation zone and the residual tumor tissue can be rapidly evaluated immediately after the operation to ensure the accuracy and safety of the treatment area. In this study, CEUS was performed immediately after 10 min of ablation. A total of 10 patients underwent supplementary ablation after angiography, which avoided a second operation in a short period of time. The results of this study are similar to those of Zhao et al. [19]. Zhao et al. showed that the puncture efficiency could be increased from 86.1 to 94.6% under CEUS guidance. This point is also consistent with the findings of Carrafiello et al. [20].

Compared with radiofrequency ablation, microwave ablation is faster, and the thermal settling effect is relatively less, which can kill tumor cells more thoroughly. Microwave ablation produces heat quickly. The central temperature of the thermogenic area is higher than that of radiofrequency ablation. The ablation efficiency is high. At the same time, it can effectively prevent bleeding and shorten the operation time. It also has obvious advantages for large tumors and tumors close to blood vessels.

Our study had several limitations. Due to the limited number of subjects, the cure rate of microwave ablation needs to be further confirmed in a larger sample size. Due to the limited follow-up time, the long-term metastasis and recurrence need to be further compared with traditional treatment methods. The application of CEUS in microwave ablation makes preoperative and postoperative assessment more reasonable and objective. CEUS may play a more important role in the future, and its quantitative evaluation indicators need to be further standardized. In addition, the changes in the immune response that are triggered by microwave ablation after ablation need to be elucidated. How to detect the specific indicators, whether this change is involved in inhibiting tumor recurrence and distant metastasis, and the specific mechanisms and other issues will be the focus of our next research.

Conclusions

Microwave ablation therapy can be used as the first choice for patients who are frail, patients who have multiple diseases and cannot undergo surgery, and patients with isolated renal cell carcinoma or renal insufficiency. Therefore, US-guided percutaneous microwave ablation is a safe and effective micro-invasive therapy for T1a renal cancer patients.

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Compliance with ethical standards

Ethical statements This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Jilin University. Written informed consent was obtained from all participants.

Conflict of interest The authors declare that they have no conflicts of interest.

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