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Efficacy and safety of ultrasound-guided percutaneous thermal ablation for abdominal wall metastases: a retrospective study

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Abstract

Objectives To evaluate the efficacy and safety of ultrasound-guided percutaneous thermal ablation for abdominal wall metastases.

Materials & methods We retrospectively analyzed patients with abdominal wall metastatic nodules who underwent ultrasound-guided microwave ablation (MWA) from August 2018 to September 2024. Tumor volume (V), volume reduction rate (VRR), pain scores, and University of Washington Quality of Life (Uw-QOL) scores were measured at one, three, and six months postoperative.

Results A total of twelve patients were included in the study (8 males and 4 females), with one male patient excluded due to incomplete follow-up data. The median patient age was 51.5 years (range: 37–75). All patients were successfully treated, with no local recurrence noted during follow-up. Tumor volume reduction rates were 45.4%, 76.9%, and 96% at one, three, and six months, respectively. By the end of the follow-up period, the average pain scores decreased significantly from 7.09 ± 0.70 to 2.18 ± 1.16 ($p < 0.001$). The quality of life of patients was significantly improved, and the Uw-Qol of score increased from 1148.63 ± 94.07 to 1269.54 ± 118.25 ($p < 0.05$). No patient appeared serious complications. The clinical symptoms and quality of life of all patients were significantly improved.

Conclusion Ultrasound-guided percutaneous thermal ablation is a safe and effective minimally invasive method for the treatment of metastatic nodules of abdominal wall, presenting a viable option for patients who are unsuitable for or unwilling to undergo surgery.

Keywords Ultrasound-guided percutaneous thermal ablation, Abdominal wall metastases, Microwave ablation (MWA), Ultrasonography, Palliative treatment

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Introduction

Abdominal wall metastases refer to the metastasis of tumor cells in the abdominal wall through various metastatic pathways. It often occurs in the late stage of malignant tumor [1–3]. The clinical manifestations usually varied with the typical presentation being a local mass. This kind of mass is usually hard in texture, different in size, unclear in boundary [4, 5]. For some patients, the mass can be painless, but when it enlarges or invades the nerve, the patient may have obvious pain. Additionally, the skin of some patients with metastatic nodules of abdominal wall may change, showing that the local skin color is dark or ulcer formation. These skin changes are common when tumors grow superficially or invade the skin [6]. The occurrence of metastatic nodules in abdominal wall is closely related to the staging of primary tumors. Generally, the later the tumor stage, the higher the possibility of abdominal wall metastasis and the worse the prognosis of patients.

Traditional treatment methods for metastatic nodules in the abdominal wall include surgery and systemic chemotherapy. However, these traditional treatments have obvious limitations. Surgical intervention often involves resection of the local tumor and may require removal of abdominal wall muscles or fascia. While surgery can be effective, it is invasive and poses greater risks for elderly patients or those with advanced disease and multiple organ metastases [7, 8]. Many patients with metastatic nodules of abdominal wall were in the advanced stage of tumor when they were diagnosed with poor general condition. The stress from surgery or chemotherapy may exceed their tolerance, leading to increased risks of complications [9]. Furthermore, the hospitalization time after operation is longer, which increases the medical expenses and affects the quality of life of patients. Therefore, there is an urgent need for more suitable and effective palliative treatment options.

With the development of minimally invasive technology and targeted therapy, ultrasound-guided percutaneous thermal ablation brings new hope for the treatment of metastatic nodules of abdominal wall. Ultrasound-guided percutaneous thermal ablation technology can accurately locate the tumor through real-time imaging, accurately guide the ablation needle into the core area of the tumor, and ensure the accuracy of the treatment process. Because of the advantages of high resolution and dynamic monitoring, ultrasound can adjust the needle position and ablation range in real time during ablation to minimize the damage to surrounding healthy tissues [10–13]. This real-time monitoring makes ultrasound-guided percutaneous thermal ablation a very safe choice, especially in the case of complex anatomical structures or close to important organs. Additionally, ultrasound-guided percutaneous thermal ablation technology can flexibly adjust the scope and depth of ablation according to the location and size of the tumor, and can be repeated for many times. This is especially important for patients with multi-site metastasis or need phased treatment, which can ensure local tumor control and reduce the adverse reactions caused by systemic treatment. Therefore, the purpose of this study is to evaluate the efficacy and safety of ultrasound-guided percutaneous thermal ablation in the treatment of abdominal wall metastatic nodules.

Materials and methods

Patients

This retrospective analysis received approval from the ethics committees of the Sichuan Cancer Hospital (Reference No. SCCHEC-032017-008). A total of 12 patients received MWA treatment. One male patient was excluded because of missing follow-up data. This study was a single-center retrospective study, including 11 patients with metastatic nodules of abdominal wall who received MWA treatment from January 2020 to September 2024. The inclusion criteria were: [1] Metastatic nodules of abdominal wall confirmed by pathologically confirmed [2], The patient cannot tolerate or refuse the operation [3], Abdominal wall metastatic tumors with poor response to radiotherapy or chemotherapy [4], pain score > 6. The exclusion criteria were: [1] severe cardiopulmonary insufficiency [2], Coagulation dysfunction [3], Refusal to undergo MWA [4], No safe ablation pathway.

Preoperative evaluation

All patients underwent preoperative ultrasound or MRI examination, where the location, size, and blood supply of the tumor were further assessed using color Doppler ultrasound and contrast-enhanced ultrasound (CEUS). All nodules were diagnosed as metastatic nodules by ultrasound-guided puncture biopsy. Relevant laboratory tests were performed before MWA treatment, including complete blood count, prothrombin time, activated partial thrombin time and electrocardiogram examination.

Ablation procedure

All operations were carried out under the guidance of experienced ultrasound doctors, ensuring the safety and effectiveness of treatment. First, the procedure was performed using the Philips EPIQ7 ultrasound system (Philips Healthcare, Beaucert, Washington, USA), equipped with a high-resolution eL18-4 probe for two-dimensional (2D) ultrasound imaging and contrast-enhanced ultrasound (CEUS). Preoperative routine examination included evaluating the size, shape, boundary, echo, location and vascular structure of the lesion, and measuring the three vertical diameters of the lesion. Calculate the tumor volume (volume = product of three

diameters × π/6). The ablation was conducted under real-time ultrasound guidance, allowing for continuous monitoring of the tumor's size, location, and proximity to critical structures such as blood vessels and muscles. The needle placement was carefully guided using a combination of 2D imaging and CEUS to ensure accurate targeting of the tumor. Once the specific location of the tumor was determined, the puncture point, angle, and depth were established by combining MRI and ultrasound images. The procedure was performed under local anesthesia with the addition of a transversus abdominis plane block or paravertebral block as necessary for pain management. This approach ensured that the patient remained comfortable during the procedure without the need for general anesthesia. Additionally, for enhanced pain control, nerve block techniques were used to target the abdominal wall nerves. This was performed by injecting saline around the tumor and adjacent tissues to create a protective layer during the ablation. This technique significantly contributed to pain relief during and after the procedure, as evidenced by the patient-reported pain score reductions(Fig. 1). During the ablation procedure, transverse or oblique scanning was utilized to track the position of the microwave antenna and ensure that surrounding tissues were not affected. CEUS was used at key points during the procedure to monitor any changes in blood flow around the tumor, further guiding the treatment process.

The microwave ablation instrument adopted KY-2000 (Kangyou Medical Company, Nanjing, China) system, which can provide 1–100 W power. A 16-gauge microwave antenna with a 3 mm active tip and 10 cm shaft length were used. During the ablation process, transverse or oblique scanning was performed to ensure that the key surrounding tissues were continuously monitored. The placement of the microwave antenna was based on precise preoperative measurements of the tumor's three-dimensional size, and the needle was inserted at the optimal angle to cover the target area. Continuous monitoring of the needle's position was carried out throughout the procedure to ensure accurate delivery of thermal energy. The power was adjusted to 20–30 W based on the size and location of the lesion to ensure the ablation area covered and exceeded the tumor area by at least 5 mm. When the vaporized hyperechoic region completely encompassed the tumor under 2D ultrasound, ablation was paused, and CEUS was used to check for any enhanced signals in the diseased area to evaluate whether complete ablation was achieved.

Postoperative follow-up

At the 1st, 3rd, and 6th month after operation, the changes of tumor volume were evaluated by 2D ultrasound. At the same time, Uw-Qol was used to quantitatively evaluate the patients' quality of life [14]. The tumor volume reduction rate was calculated by the following calculation equation: volume reduction rate (VRR)= (initial volume-final volume)/initial volume ×100. The pain scores were used to evaluate the changes of pain degree [15].

Statistical analysis

All the data were analyzed with SPSS 25.0 and GraphPad Prism. Datas were presented as the mean values ± SD and

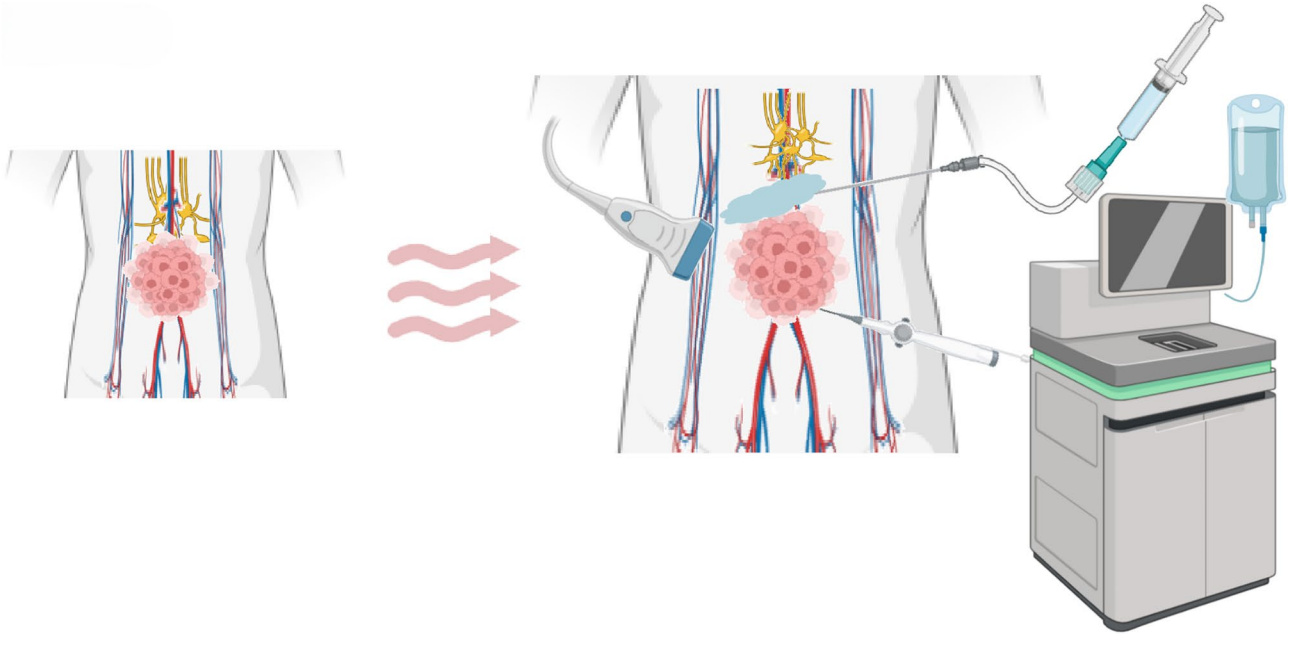

Fig. 1 Schematic diagram of ultrasound-guided percutaneous thermal ablation for metastatic nodules of abdominal wall

Table 1 Patient information, tumor characteristics and intraoperative situation

Pt. No/ Sex/ Age(Y)	Tumor type	Location	The Max Diameter (mm)	Treatment site	Treatment time (min)	VRR (%)
1/M/37	Malignant tumor of rectum	Left	17	Left	7 m	97.21
2/M57	Small cell lung cancer	Right	14	Right	18m48s	100.00
3/F/50	Endometriosis	Incision	28	Incision	18 m	98.21
4/F/55	Endometriosis	Incision	34	Incision	22 m	94.59
5/M/57	Intrahepatic cholangiocarcinoma	Lower	35	Lower	10min47s	95.15
		Right upper	16	Right upper	8min03s	97.32
6/M/60	Highly differentiated adenocarcinoma of gallbladder	Right lower	63	Right lower	19m31s	93.21
		Left	46	Left	19m31s	96.36
7/M/64	Renal clear cell carcinoma	Left	16	Left	3m17s	99.00
8/M/75	Gastrointestinal stromal tumor	Left	27	Left	7m11s	97.09
9/F/45	Malignant tumor of left kidney	Left	13	Left	4m21s	95.90
10/F/48	Oophoroma	Left	34	Left	50 m	1.00
11/M/53	Malignant liver tumor	Left upper	21	Left upper	6m58s	99.81

Table 2 Tumor V and VRR before TA and at each follow-up time-point after MWA

Follow-up time	The maximum diameter (mm)	*P* value	V (mm^3)	*P* value	VRR (%)	*P* value
Before TA ($n=9$)	28.00 ± 14.58		2705 (840–8146)		NA	NA
After TA ($n=9$)						
1-month ($n=9$)	22.15 ± 13.10	0.293	1293 (402–4052)	0.209	45.40 ± 22.12	NA
3-month ($n=9$)	15.77 ± 11.51	0.199	690 (98-1939)	0.158	76.92 ± 14.35	< 0.001
6-month ($n=9$)	8.38 ± 8.36	0.074	33 (6-433)	0.043	95.98 ± 3.71	< 0.001

P Value of the maximum diameter and V: after TA (1, 3, 6months) vs. before MWA

P Value of VRR: after MWA (3, 6months) vs. 1 month after MWA

NA: not applicable; V: volume; VRR: volume reduction rate

were analyzed using the independent-sample t-test or ANOVA analysis. $P<0.05$ were considered statistically significant.

Result

Patients information

In this study, a total of 11 patients with metastatic nodules of abdominal wall were treated with MWA from November 2019 to September 2024. Among them, there are 7 males and 4 females, ranging in age from 37 to 75, with a median age of 51.5. Primary tumors included endometriosis ($n=2$), Malignant tumor of left kidney ($n=1$),ovarian cancer ($n=1$), Malignant tumor of liver ($n=1$) and rectal malignant tumor ($n=1$). Small cell lung cancer ($n=1$), intrahepatic cholangiocarcinoma ($n=1$), well-differentiated adenocarcinoma of gallbladder ($n=1$), clear cell carcinoma of right kidney ($n=1$) and gastrointestinal stromal tumor ($n=1$). The largest diameter of abdominal metastatic nodules ranged from 1.40 to 6.30 cm, with an average of 2.80 ± 1.46 cm (Table 1).

Efficacy evaluation

In this study, a total of 11 patients with abdominal wall metastases treated by MWA were successfully completed. Before treatment, the average maximum tumor diameter was 2.80 ± 1.46 cm, and the average tumor volume was 7464.39mm^3. One month after operation, the average reduction VVR was 45.4%, and the ablation effect was initial. With the passage of time, the further reduction of tumor volume became more obvious at 3 months and 6 months of follow-up, and the reduction rates reached 76.9% and 96.0% (Table 2). These data showed that ablation therapy had a good lasting effect. As shown in Fig. 2, a 67-year-old male with sigmoid colon cancer accompanied by peritoneal metastasis. MRI revealed slightly thickened soft tissue in the umbilical region, appearing mildly patchy. Conventional ultrasound examination showed that the soft tissue in navel area was thickened, and slightly hyperechoic nodules with a size of about 15 × 12 × 14 mm were found in abdominal wall, with unclear boundary, irregular shape and uneven internal echo. There were some stripe blood flow signals in it. CEUS before ablation showed rapid signal enhancement in arterial phase and low enhancement in venous phase. There is no leakage around umbilical region, and the pain of patients is obviously relieved after ultrasound-guided palliative microwave ablation treatment of abdominal wall nodules in umbilical region. Similarly, a 62-year-old woman with abdominal wall malignant tumor underwent percutaneous thermal ablation under the guidance of ultrasound. The surface skin showed no significant

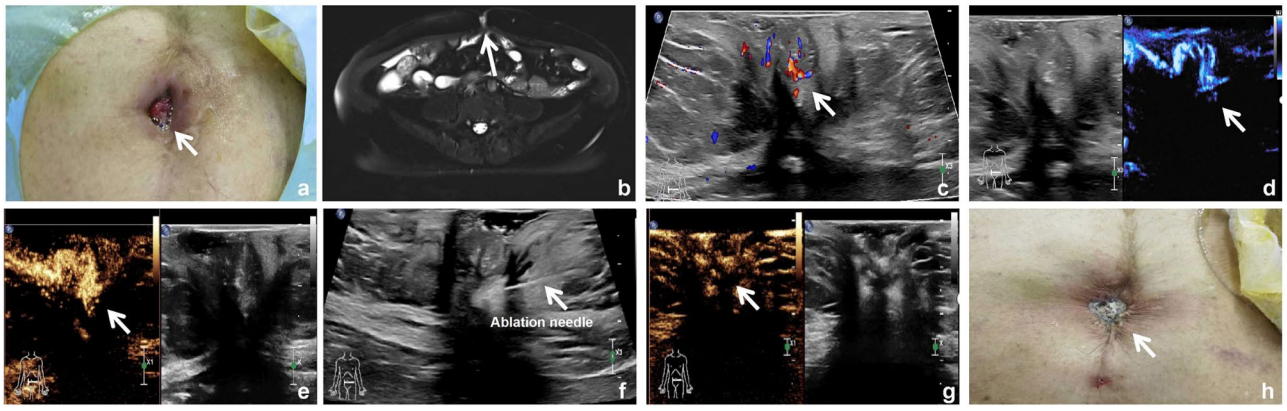

Fig. 2 A 67-year-old man with sigmoid colon cancer with peritoneal metastasis. **(a)** Peri-umbilicus condition of patients before treatment. Arrows showed the location of lesion. **(b)** MR showed that the soft tissue in navel area was slightly thicker and slightly patchy. Arrows showed the location of lesion. **(c)** Color Doppler showed the blood flow of the lesion. **(d)** The image of superb microvascular imaging (SMI). **(e)** preoperative CEUS examination image. **(f)**, placing the movable tip of the ablation needle at the far end of the tumor, and then performing segmented ablation from bottom to top until the tumor is completely covered by hyperechoic gas. Arrows showed the ablation needle. **(g)** CEUS examination was performed again after ablation, and no obvious contrast agent perfusion was found in the tumor. (h) Peri-umbilicus condition of patients after treatment.

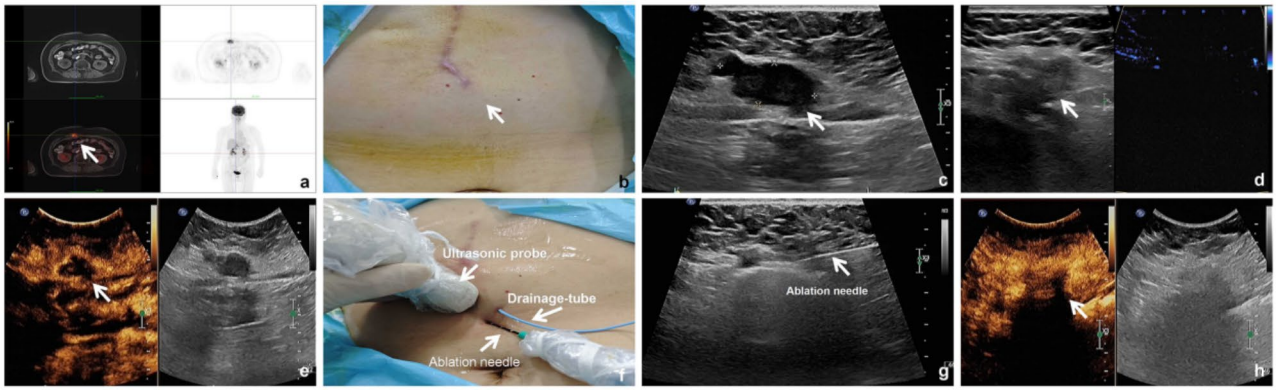

Fig. 3 A 62-year-old woman with abdominal wall malignant tumor. **(a)** PET-MRI T2 sequence. **(b)** Abdominal wall malignant tumor of patients before treatment. **(c)**, 2D ultrasound. **(d)** The image of super microvascular imaging (SMI). **(e)** Preoperative CEUS examination image. **(f)** Operating procedure. **(g)** The movable tip of the ablation needle is placed at the distal end of the tumor, and then segmented ablation is performed from bottom to top until the tumor is completely covered with strong echo gas. The arrow indicates the ablation needle. **(h)** CEUS examination was performed again after ablation, and no obvious contrast agent perfusion was found in the tumor

changes, and the patient's pain was significantly relieved (Fig. 3).

By the end of the follow-up, one tumor completely disappeared, and the VRR of the other 8 tumors was significantly reduced by more than 90%. In addition, the average pain scores also changed from 7.09 ± 0.70 to 2.18 ± 1.16 ($p < 0.001$) (Fig. 4a). The quality of life of patients was significantly improved, and the UW-QOl of score increased from 1148.63 ± 94.07 to 1269.54 ± 118.25 ($p < 0.05$) (Fig. 4b). One of the patients had a recurrence of abdominal nodules near the ablation area of the left abdominal wall after two years. The analysis of this phenomenon shows that the cause of recurrence may be closely related to the malignant degree of the primary tumor. No recurrence and other complications occurred in the rest. The clinical symptoms and quality of life of all patients were significantly improved (Table 3).

Complications and safety assessment

In this study, no serious complications were found, indicating that ultrasound-guided percutaneous thermal ablation was safe in the treatment of abdominal wall metastases. Although no serious complications occurred, two patients reported mild local pain after operation, which may be related to the thermal damage of local tissues during ablation. Fortunately, the pain of these patients was mild, and through conventional conservative treatment such as analgesic drugs and local cold compress, the pain symptoms were gradually relieved within a few days after operation. These results showed that ultrasound-guided percutaneous thermal ablation was

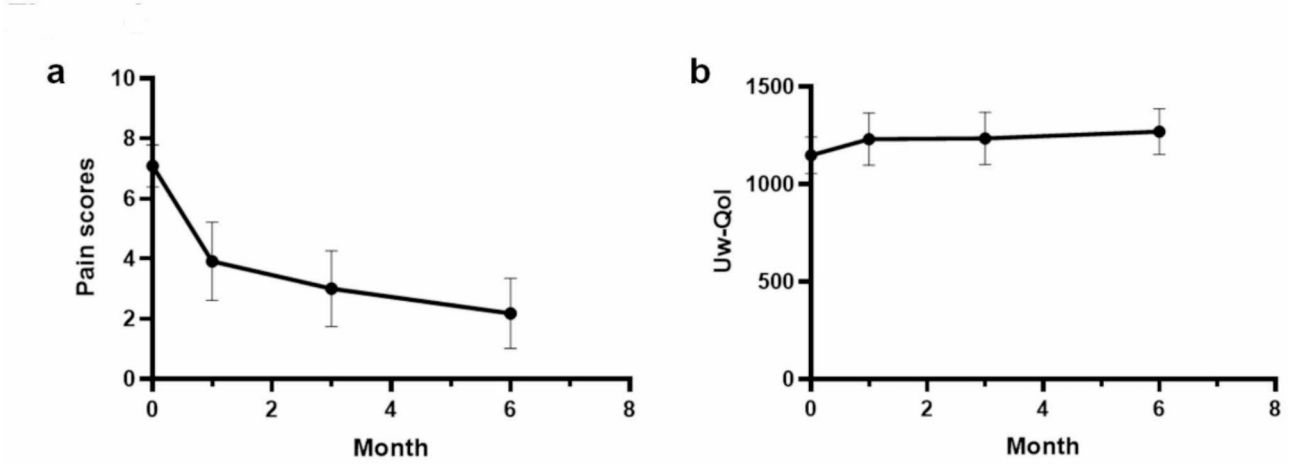

Fig. 4 Analysis of changes in mean pain scores and Uw-QoL at each follow-up time point. **(a)** Changes in mean pain scores at each follow-up time point. **(b)** Changes in mean Uw-Qol at each follow-up time point

Table 3 The university of Washington quality of life questionnaire (Uw-Qol) and numerical rating scale (pain scores) of the patients

Pt. No/ Sex/ Age(Y)	Uw-Qol				Pain scores			
	Before treatment	1 month	3 month	6 month	Before treatment	1 month	3 month	6 month
1/M/37	1170	1395	1395	1395	8	5	4	3
2/M57	1130	1370	1370	1395	7	4	3	0
3/F/50	1030	1205	1230	1270	7	5	3	3
4/F/55	1005	1205	1205	1270	8	5	4	3
5/M/57	955	1105	1105	1195	7	5	4	3
6/M/60	930	1055	1055	1080	7	5	4	3
7/M/64	1105	1295	1295	1320	6	3	2	2
8/M/75	905	1005	1005	1055	7	4	4	3
9/F/45	1030	1205	1230	1270	8	3	3	2
10/F/48	1170	1395	1395	1395	7	1	0	0
11/M/53	1105	1295	1295	1320	6	3	2	2

safe, which not only reduced the incidence of postoperative complications, but also provided a good foundation for postoperative recovery symptoms and quality of life of all patients were significantly improved. (Table 3).

Discussion

This study demonstrated that MWA was effective and safe in the treatment of metastatic nodules of abdominal wall. All patients successfully completed the ablation operation, and the follow-up data showed that the tumor volume was significantly reduced, and some patients' tumors completely disappeared without serious complications. This suggested that MWA can provide an effective local treatment for patients with advanced cancer, which not only reduced the tumor burden, but also improved the quality of life of patients. In the evaluation of effect, the tumor volume decreased by 45.4%, 76.9%, 96% at 1 month, 3 months and 6 months after operation. Among them, the abdominal wall metastatic nodules in two patients completely disappeared, while the VRR in the remaining nine patients decreased significantly by over 90%. These results were consistent with the current clinical treatment standards, and further support the clinical potential of thermal ablation as an effective local treatment.

Compared with the traditional treatment methods of abdominal metastatic nodules, such as surgical resection and radiotherapy, MWA has obvious advantages. Although surgical treatment can provide complete resection of tumors, it often requires a long recovery period, and for patients with poor physical condition [16, 17]. MWA is a minimally invasive technique with short operation time and little trauma, which can reduce the risk of complications and achieve effective tumor control. Although radiotherapy can be used to locally control tumors, its radiation damage to surrounding healthy tissues may lead to long-term side effects, while MWA can accurately eliminate tumor lesions by local heating to avoid the harm of whole body radiation [18]. Previous studies had shown that MWA have been successfully

used in the treatment of solid tumors such as liver and thyroid, but the efficacy of MWA in the treatment of metastatic nodules of abdominal wall has not been reported [19–21]. This study further verified the effectiveness of MWA in the treatment of abdominal metastatic nodules, especially for patients who can not tolerate surgery or radiotherapy, which has become a feasible alternative. In addition, the real-time guidance of ultrasound can realize the visualization of the whole treatment process and ensure the safety and effectiveness of the ablation process.

In this study, patients also received nerve block techniques during the surgery except local anesthesia. Pain scores during the procedure ranged from 0 to 4. It was remarkable that 2 patients was completely relieved. This indicated that nerve block techniques were highly effective in controlling pain. The principle of nerve block is to interrupt specific nerve conduction pathways to inhibit the transmission of pain signals. This method provides more precise and prolongs pain relief while reducing the need for general anesthesia. Ultrasound-guided enables real-time visualization of anatomical structures such as nerves, blood vessels, and muscles, assisting physicians in accurately locating the injection site, which minimizes the risk of injury to surrounding tissues and reduces the occurrence of complications. Ultrasound guidance not only increases the success rate of nerve blocks but also allows for a reduction in the amount of anesthetic required, consequently lowering the risk of drug-related side effects. For tumors located near the skin, muscle layers, or blood vessels during surgery, a fine needle is used to slowly inject saline between the tumor and adjacent tissues during ablation. This creates an isolation zone around the tumor, serving to protect the surrounding tissues and preventing unnecessary damage to normal tissues during the ablation process. This method enhances the safety of ablation while also providing better postoperative recovery conditions for the patient.

Although the results of this study were encouraging, there were some limitations. First, as a retrospective study, the design of this study itself may have some selection bias. Retrospective design limited the comprehensive evaluation of the therapeutic effect, and prospective studies were needed to verify the accuracy of these results in the future. Secondly, the sample size of this study was small, which can not fully represent the extensive clinical situation of abdominal wall metastatic nodules. Therefore, more large-scale studies are needed to verify the efficacy of MWA in different patient groups. Furthermore, the follow-up time was relatively short and followed the patients for 6 months. Therefore, it is impossible to evaluate the long-term tumor recurrence rate and patient survival. Long-term tumor management is particularly important for patients with abdominal metastatic nodules. Hence, future research should design multi-center and large-sample prospective clinical trials to verify the efficacy and safety of MWA with more representative patient groups. Secondly, we should also explore the combined application of MWA and targeted therapy or immunotherapy, which may further improve the therapeutic effect.

Conclusion

In conclusion, MWA is a safe and effective minimally invasive treatment for metastatic nodules of abdominal wall. This study showed that this technique can effectively reduce the tumor volume and realize the complete disappearance of the tumor in some patients. Ultrasound-guided percutaneous thermal ablation is a feasible alternative treatment for patients who cannot tolerate surgery or radiotherapy due to its real-time localization and minimally invasive, showing promising clinical application potential.

Abbreviations

MWA	Microwave Ablation
V	Tumor Volume
VRR	Volume Reduction Rate
Uw-QOL	University of Washington Quality of Life
CEUS	Contrast-Enhanced Ultrasound
2D	Two-Dimensional

Acknowledgements

Not applicable.

Author contributions

Li Han: Conceptualization, Methodology, Data Curation, Writing - Review & Editing. Xiaoxiao Xie: Investigation, Validation, Software. Min Zhuang: Resources and Methodology. Lu Wang: Investigation and Validation. Xiaobo Wu: Project Administration.Man Lu: Conceptualization, Funding Acquisition, Project Administration.

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Data availability

Availability of data and materials: The datasets used and/or analyzed during current study are available from corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This retrospective analysis received approval from the ethics committees of the Sichuan Cancer Hospital (Reference No. SCCHEC-032017-008). Written informed consent was obtained from all subjects (patients) in this study. This study adhered to the Declaration of Helsinki.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

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