Cancer Management and Research

Open Access Full Text Article

ORIGINAL RESEARCH

Clinical Efficacy of Microwave Ablation Combined with Percutaneous Osteoplasty in the Treatment of Flat Bone Metastases

Zhipeng Lin, Xiaolong Hu, Dabei Huang, Xugong Zou, Yuan Chen, Xiaoqun Li, Jian Zhang

Department of Interventional Medicine, Zhongshan People's Hospital, Guangdong, 528400, People's Republic of China

Correspondence: Jian Zhang, Email wy18988583838@163.com

Video abstract

Point your SmartPhone at the code above. If you have a QR code reader the video abstract will appear. Or use: https://youtu.be/qe15tN_fEZ0

Purpose: Evaluating the clinical efficacy and safety of microwave ablation combined with percutaneous osteoplasty (MWA + PO group) versus percutaneous osteoplasty (PO group) for the treatment of flat bone metastases.

Methods: Patients with flat bone metastases and intractable pain who underwent PO and/or MWA from January 2016 to January 2023 in our hospital were included, with 36 cases in the MWA+PO group and 21 cases in the PO group. Changes in the visual analog scale (VAS), Oswestry Disability Index (ODI), and quality of life assessment scale(QOL) were evaluated regularly. Postoperative complications and target lesion tumor treatment responses were also observed.

Results: The VAS and ODI in both the MWA+PO group and the PO group significantly decreased at 1 week, 1 month, and 3 months postoperatively, The VAS and ODI in the MWA+PO group were lower than those in the PO group postoperatively. The QOL in both the MWA+PO group and the PO group significantly increased at 1 week, 1 month, and 3 months postoperatively, with the QOL in the MWA+PO group being higher than that in the PO group postoperatively. According to the mRECIST criteria (target lesion tumor treatment response), the ORR in the MWA+PO group and PO group was 52.8% and 9.5%, respectively, while the DCR was 94.4% and 57.1%, respectively ($P<0.001$ and <0.001). Different degrees of bone cement extravasation were observed in both the PO group (38.1%) and MWA+PO group(19.4%)(χ^2=2.38, P=0.12), but none of the patients developed clinical symptoms related to bone cement extravasation. The average cost of surgery was ¥10,480.43 higher in the MWA+PO group than in the PO group.

Conclusion: The MWA+PO treatment is more effective in relieving patients' local pain, improving local dysfunction, and enhancing quality of life, and can effectively improve target lesion tumor ORR and DCR, but it is also more costly.

Keywords: microwave ablation, percutaneous osteoplasty, bone metastases

Introduction

Malignant tumor bone metastasis is common in lung cancer, breast cancer, prostate cancer, and other cancers. The incidence of bone metastases is 50–70% in advanced cancer patients.[1] The most common sites of tumor bone metastasis are the vertebrae, followed by the pelvis, scapula, ribs, and femur.[2] Complications of bone metastases mainly include severe pain, pathological fractures, and limited mobility, which significantly affect patients' quality of life.[3] Some patients experience poor pain relief from traditional methods such as drug, radiation therapy, and chemotherapy. Surgery is not the first choice for patients with advanced tumors due to high trauma and risk. Minimally invasive interventions provide a less traumatic, faster recovery, and more effective treatment option for these patients. Percutaneous osteoplasty (PO) can increase bone stability and has shown good efficacy in preventing and treating pathological fractures.[4] Percutaneous microwave ablation (MWA) technology, due to its short duration and high temperature has been widely used in the treatment of bone metastases. Flat bone, such as the ribs, ilium, scapula, play a role in assisting respiratory and limb movement. Reports indicate that PO and MWA treatments for bone metastases are effective.[5,6] However, the combination of the two is rare. Therefore, we retrospectively analyzed the clinical efficacy and safety of MWA combined with PO in the treatment of flat bone metastases and compared it with PO treatment alone.

Received: 24 July 2024
Accepted: 25 September 2024
Published: 5 October 2024

Materials and Methods

Clinical Data

Clinical data of patients who received MWA combined with PO (MWA+PO group) or PO alone (PO group) for flat bone metastases from January 2016 to January 2023 at Zhongshan People's Hospital were retrospectively collected. The workflow diagram of this study is illustrated in Figure 1. The study was conducted in accordance with the Declaration of Helsinki and other ethical principles for medical research involving human subjects. The Ethics Committee of Zhongshan People's Hospital approved the retrospective study (Ethics approval number: 2024–035), and the requirement for individual consent for this retrospective analysis was waived. Patient consent for the review of their medical records was not required by the Ethics Committee of Zhongshan People's Hospital. However, patient data confidentiality was strictly maintained, and all personal identifiers were removed to protect privacy.

Inclusion criteria: ① Imaging confirmed flat bone osteolytic or mixed metastases; ② Bone metastases locally causing intractable pain, with poor radiotherapy effect, requiring opioids for analgesia; ③ Expected survival period of more than 3 months; ④ MWA combined with PO or PO alone performed.

(7) Exclusion criteria: (1) uncorrectable coagulation disorder; (2) infection around the lesion; (3) serious insufficiency of liver, kidney, heart or lung function; (4) important nerves or blood vessels at the edge of the tumor (<1cm); (5) incomplete data; (6) localized radiotherapy, cryotherapy, or implantation of iodine 125 particles during the follow-up period; (7) systemic therapy during the follow-up period;(8)Imaging confirmed flat bone osteogenic metastases.

A total of 57 cases of flat bone metastases were included, comprising 45 males and 12 females, with a mean age of 63.0±13.1. Among them, 36 cases were in the MWA+PO group and 21 cases were in the PO (Table 1).

Surgical Procedure

The preoperative plan is formulated based on the lesion site and extent as observed on CT/MR images. The shortest possible distance, a puncture path that avoids nerves and blood vessels, and an easy-to-operate access point are selected. The distance from the puncture path to the lesion is measured, and the appropriate length of the bone puncture needle and ablation needle are chosen. Considering the operation time, patient comfort and the stability of the patient's position, most patients were placed

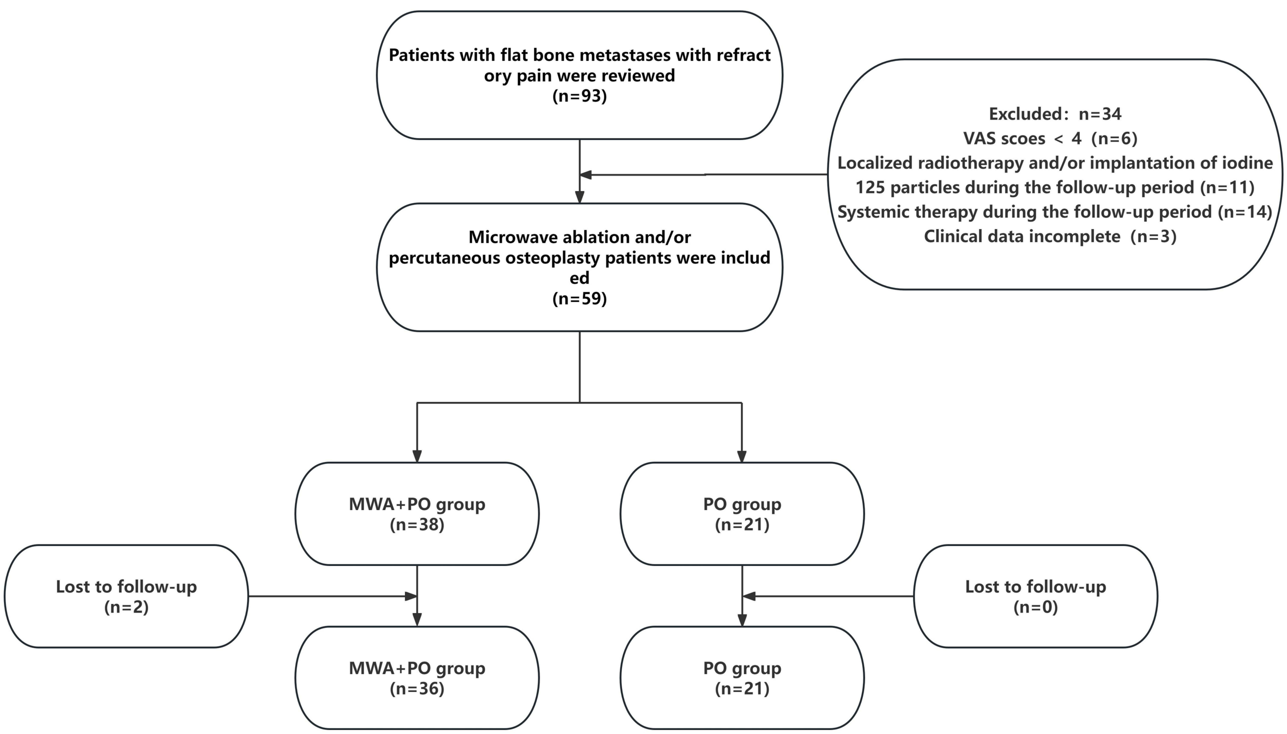

Figure 1 The workflow schematic diagram of this study.

Table 1 Basic Data of 57 Patients with Flat Bone Metastases

Characteristics	MWA+PO group	PO group	X^2 value	P value
Gender			–	0.33
Male	30	15		
Female	6	6		
Age(yr)			–	1.00
<50	6	4		
≧50	30	17		
Primary tumor			–	0.80
Lung cancer	13	7		
Liver cancer	15	7		
Esophageal cancer	2	3		
Multiple myeloma	1	0		
Nasopharyngeal cancer	1	0		
Pheochromocytoma	1	0		
Colorectal cancer	2	2		
Cholangiocarcinoma	1	2		
Bone metastatic tumor site			–	1.00
Ilium	13	8		
Rib	17	10		
Scapula	6	3		
Maximum diameter of tumor			2.23	0.14
≤3cm	6	8		
>3cm	30	13		

Note: *No chi-square value for fisher exact probability calculation.

in either the supine or prone positions. Basic anesthesia combined with local anesthesia was administered (local anesthesia was infiltrated from the skin to the subperiosteum; basic anesthesia involved hydromorphone hydrochloride injection, 2 mg + 0.9% saline 50 mL, which was infused at 15 mL/h starting 15 minutes before the operation, and was maintained at 30 mL/h during the operation, with dosage adjusted depending on the patient's pain level). The bone puncture needle (13G, COOK Inc., USA) was advanced into the center of the lesion under the guidance of DSA or CT, and two-dimensional and three-dimensional reconstructions were performed (reconstruction methods included maximum intensity projection (MIP), multiplanar reconstruction (MPR), and volumetric rendering (VR)) to fully display the position of the target lesion and its relationship with adjacent tissues. After confirming that the puncture needle was in place, the needle core was withdrawn. For patients requiring microwave ablation, the microwave ablation needle (Yigao, China 16G) was inserted into the target lesion, and bone puncture needle was withdrawn to fully expose the working area of the microwave ablation needle. The ablation parameters are determined according to the size of the target lesion, and the ablation area should exceed the actual size of the target lesion by 2 mm to ensure complete ablation. Depending on the lesion location, size and adjacent tissues, choose 40–60 W of ablation power and an ablation time of 3–8 minutes. During ablation, attention should be paid to the skin and soft tissues around the puncture opening. For patients who do not need microwave ablation or who have already undergone microwave ablation, bone cement is injected into the target lesion through the bone puncture needle, with the amount of bone cement injected ranging from 3–8 mL. Two-dimensional and three-dimensional reconstructions are performed again after the procedure to observe the distribution of bone cement. The puncture needle tract is compressed for 3–5 minutes.

Evaluation of the Efficacy of Treatment

Visual Analog Score (VAS), Oswestry Dysfunction Index Questionnaire (ODI), and Quality of Life Score (QOL) were used to evaluate the clinical efficacy of the preoperative and postoperative periods at 1 day, 1 week, 1 month, and 3 months.

Assessment of target lesion tumor treatment response was conducted using RECIST1.1 and mRECIST criteria for assessing tumor response. Tumor responses are classified as complete response (CR), partial response (PR), stable disease (SD), or progressive disease (PD). Objective Response Rate(ORR) is the percentage of patients who achieved a CR or PR. Disease Control Rate (DCR) represents the percentage of patients who did not have PD. The incidence of postoperative bone cement extravasation was also assessed. Target lesion tumor treatment response mRECIST evaluation criteria: CR: Disappearance of intratumoral arterial enhancement in all target lesions. PR: ≥30% decrease in the sum of the diameters of viable (enhancing) target lesions. SD: No significant shrinkage or increase to qualify for PR or PD. PD: ≥20% increase in the sum of the diameters of viable target lesions or new lesions. Target lesion tumor treatment response RECIST 1.1 evaluation criteria: CR: Disappearance of all target lesions. PR: At least a 30% decrease in the sum of the diameters of target lesions. SD: Neither sufficient shrinkage to qualify for PR nor sufficient increase to qualify for PD. PD: At least a 20% increase in the sum of the diameters of target lesions.

Statistical Methods

SPSS 20.0 software was used for statistical analysis. Normally distributed measurement data were expressed as mean ± standard deviation. Count data were expressed as frequency or percentage. Baseline data, target lesion tumor treatment response, and the proportion of bone cement extravasation occurrences between the two groups of patients were compared using the χ^2-test or Fisher's exact test. Comparisons of VAS, ODI, and QOL scores at each time point between the MWA+PO group and the PO group, both before and after surgery, were performed using *t*-tests. Comparisons within the same group before and after surgery were conducted using analysis of variance (ANOVA) with repeated measures at multiple time points. $p < 0.05$ was considered significant differences.

Results

Successful surgical treatment was performed in 57 cases, with no serious surgical complications reported. In the MWA +PO group, the average power of microwave ablation was 46.7±9.8 W, the average ablation time was 5.2±2.7 minutes, and the average amount of bone cement injected was 4.3±1.5 mL (ranging from 3.0 mL to 8.0 mL). Figure 2 shows the changes in lesions before and after MWA+PO treatment in a patient with lung cancer and rib metastases. Figure 3 shows the changes in lesions before and after MWA+PO treatment in a patient with lung cancer and right iliac bone metastasis. In the PO group, the average amount of bone cement injected was 4.1±1.8 mL (ranging from 3.0 mL to 7.0 mL). Figure 4 shows the changes in lesions before and after PO treatment in a patient with hepatocellular carcinoma and a metastatic tumor in the right seventh rib. The average cost of surgery in the MWA+PO group was ¥10,480.43 higher than in the PO group.

In the MWA+PO group, the VAS scores at preoperative, 1-day postoperative, 1-week postoperative, 1-month post-operative, and 3-month postoperative were 7.39±1.09, 6.53±1.17, 1.94±0.70, 1.11±0.66, and 1.39±0.59, respectively. There was a statistically significant change in VAS scores before and after surgery in the MWA+PO group (F=92.51, p<0.01). In the PO group, the VAS scores at preoperative, 1-day postoperative, 1-week postoperative, 1-month post-operative, and 3-month postoperative were 7.52±1.01, 6.81±0.66, 3.38±0.65, 2.33±0.56, and 2.52±0.50, respectively. There was also a statistically significant change in VAS scores before and after surgery in the PO group (F=5.61, p<0.01). The differences in VAS scores between the two groups were statistically significant at 1 week postoperatively (t=−7.62, p<0.01), 1 month postoperatively (t=−7.28, p<0.01), and 3 months postoperatively (t=−7.58, p<0.01) (Table 2).

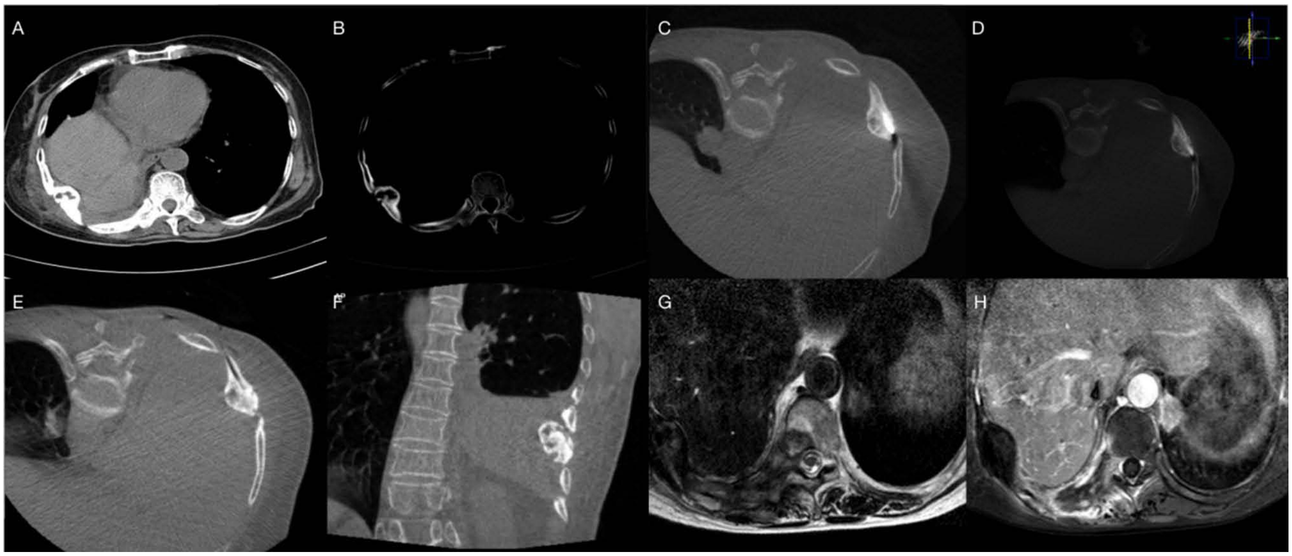

Figure 2 Changes of lesions before and after surgery in a patient with lung cancer and rib metastases. (**A**) CT shows a metastasis in the right seventh rib; (**B**) CT bone window shows reveals a mixed bone metastasis; (**C**) Bone puncture needle positioned at the target lesion area; (**D**) Microwave ablation needle performs ablation treatment on the target lesion; (**E**) Bone puncture needle injects bone cement into the lesion; (**F**) Coronal view shows the distribution of bone cement in the lesion; (**G** and **H**) No significant enhancement of the target lesion area on follow-up MRI at 3 months postoperatively (The new bone metastasis was observed on the right seventh rib and the right section of the T7 vertebral body. However, the patient was clinically asymptomatic and was not treated).

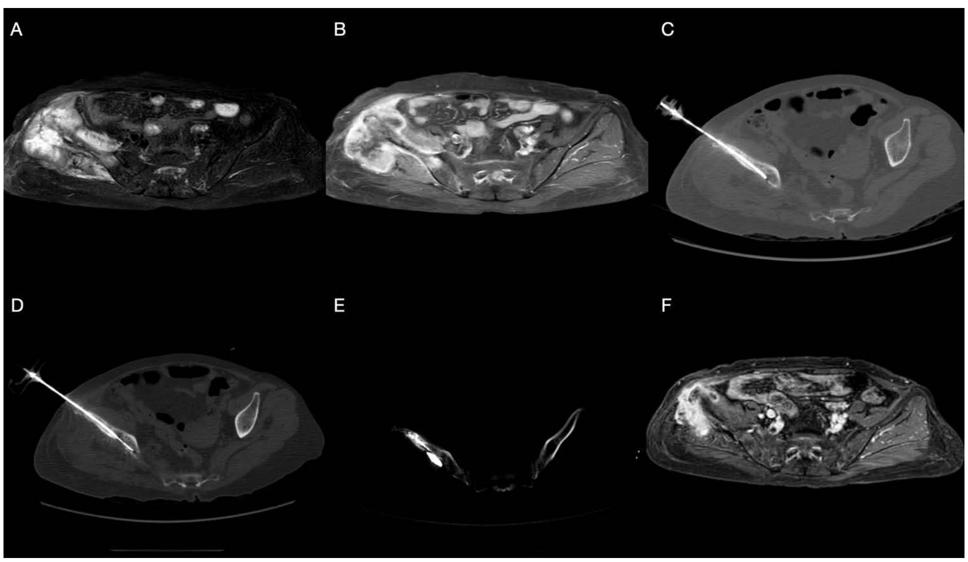

Figure 3 Changes of lesions before and after surgery in a patient with lung cancer and right iliac bone metastasis. (**A** and **B**) MRI shows right iliac bone metastasis; (**C**) Bone puncture needle reaches the target lesion area; (**D**) Microwave ablation needle performs ablation treatment in the target lesion; (**E**) Bone puncture needle injects bone cement into the lesion; (**F**) Follow-up MRI at 3 months postoperatively shows significant weakening of the enhancement in the target lesion area.

In the MWA+PO group, the ODI scores at preoperative, 1-day postoperative, 1-week postoperative, 1-month postoperative, and 3-month postoperative were 44.33±2.91, 44.08±2.82, 15.92±3.04, 14.00±2.39, and 16.08±3.61, respectively. There was a statistically significant change in ODI scores before and after surgery in the MWA+PO group($F=247$, $p<0.01$). In the PO group, the ODI scores at preoperative, 1-day postoperative, 1-week postoperative, 1-month postoperative, and 3-month postoperative were 45.67±3.03, 45.14±2.80, 22.38±3.09, 19.76±2.99, and 22.10±3.10, respectively. There was also a statistically significant change in ODI scores before and after surgery in the PO group($F=6.66$, $p<0.01$). The differences in ODI scores between the two groups were statistically significant at 1 week postoperatively ($t=-7.50$, $p<0.01$), 1 month postoperatively ($t=-7.37$, $p<0.01$), and 3 months postoperatively ($t=-6.51$, $p<0.01$) (Table 3).

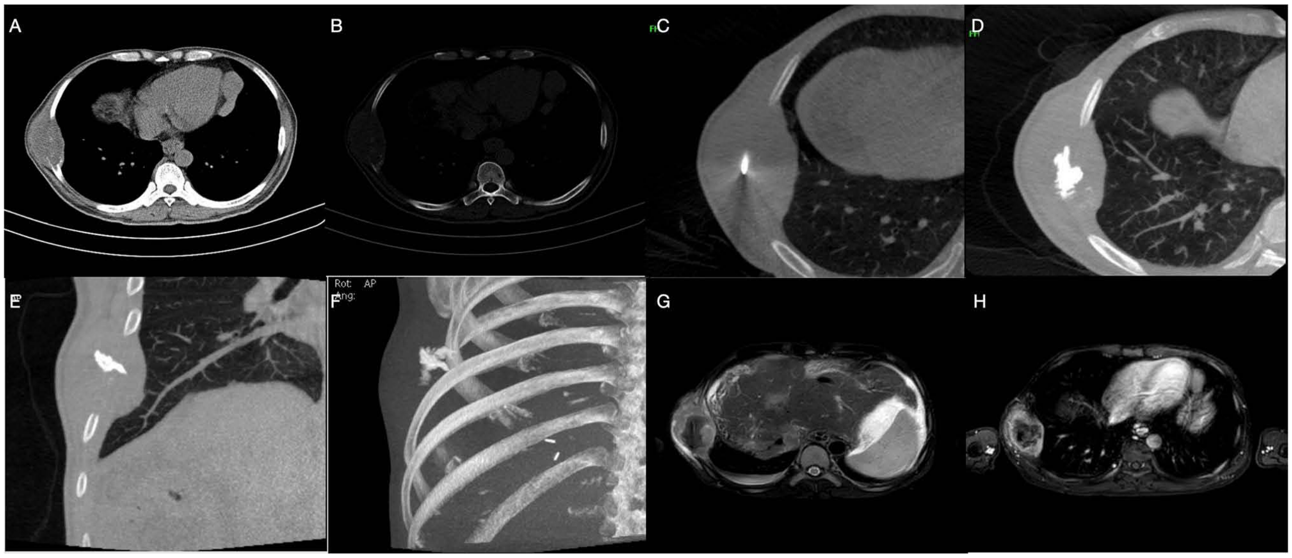

Figure 4 Rib osteoplasty in a patient with hepatocellular carcinoma and metastatic tumor of the right seventh rib. (**A**) CT shows metastatic tumor of the right seventh rib; (**B**) CT bone window shows osteolytic type of bone metastasis; (**C**) Bone puncture needle arrives at the area of the target lesion; (**D**) Changes after injection of bone cement in the lesion; (**E**) Coronal position shows the distribution of bone cement in the lesion (**F**) Three-dimensional imaging shows the distribution of bone cement. (**G** and **H**) Follow-up MRI at 3 months postoperatively shows a reduction in enhancement of the target lesion area.

In the MWA+PO group, the QOL scores at preoperative, 1-day postoperative, 1-week postoperative, 1-month postoperative, and 3-month postoperative were 24.69±3.92, 26.06±3.05, 38.67±3.00, 40.25±3.42, and 39.58±3.99, respectively. There was a statistically significant change in QOL scores before and after surgery in the MWA+PO group ($F=33.55$, $p<0.01$). In the PO group, the QOL at preoperative, 1-day postoperative, 1-week postoperative, 1-month postoperative, and 3-month postoperative were 24.43±3.53, 26.76±3.05, 32.81±2.17, 33.95±2.68, and 31.19±4.27, respectively. There was also a statistically significant change in QOL scores before and after surgery in the PO group

Table 2 Changes of VAS in Patients Before and After Surgery

Group	Preoperative	1-Day Postoperative	1-Week Postoperative	1-Month Postoperative	3-Month Postoperative
	VAS	VAS	VAS	VAS	VAS
MWA+PO group	7.39±1.09	6.53±1.17	1.94±0.70	1.11±0.66	1.39±0.59
PO group	7.52±1.01	6.81±0.66	3.38±0.65	2.33±0.56	2.52±0.50
t value	−0.46	−1.14	−7.62	−7.28	−7.58
P value	0.64	0.26	<0.01	<0.01	<0.01

Table 3 Changes of ODI in Patients Before and After Surgery

Group	Preoperative	1-Day Postoperative	1-Week Postoperative	1-Month Postoperative	3-Month Postoperative
	ODI	ODI	ODI	ODI	ODI
MWA+PO group	44.33±2.91	44.08±2.82	15.92±3.04	14.00±2.39	16.08±3.61
PO group	45.67±3.03	45.14±2.80	22.38±3.09	19.76±2.99	22.10±3.10
t value	−1.59	−1.37	−7.50	−7.37	−6.51
P value	0.12	0.18	<0.01	<0.01	<0.01

Table 4 Changes of QOL in Patients Before and After Surgery

Group	Preoperative	1-Day Postoperative	1-Week Postoperative	1-Month Postoperative	3-Month Postoperative
	QOL	QOL	QOL	QOL	QOL
MWA+PO group	24.69±3.92	26.06±3.05	38.67±3.00	40.25±3.42	39.58±3.99
PO group	24.43±3.53	26.76±3.05	32.81±2.17	33.95±2.68	31.19±4.27
t value	0.26	−0.83	8.34	7.56	7.18
P value	0.80	0.41	<0.01	<0.01	<0.01

Table 5 mRECIST and Recist1.1 Criteria for Assessing Response to Treatment of Target Lesions in Two Groups

Table 2 Summary of Best Response						
	mRECIST			RECIST1.1		
	Group.No.(%)			Group.No.(%)		
Treatment response	MWA+PO group	PO group	P value	MWA+PO group	PO group	P value
CR	1	0	–	0	0	–
PR	18	2	–	13	1	–
SD	15	10	–	21	11	–
PD	2	9	–	2	9	–
ORR,%	19 (52.8%)	2 (9.5%)	<0.001	13 (43.1%)	1 (4.8%)	0.007
DCR,%	34 (94.4%)	12 (57.1%)	<0.001	34 (90.2%)	12 (57.1%)	<0.001

Abbreviations: CR, complete response; PR, partial response; SD, stable disease; PD, progressive disease; ORR, objective response rate; DCR, disease control rate.

(F=4.16, p<0.01). The differences in QOL scores between the two groups were statistically significant at 1 week postoperatively (t=8.34, p<0.01), 1 month postoperatively (t=7.56, p<0.01), and 3 months postoperatively (t=7.18, p<0.01) (Table 4).

In the MWA+PO group, there were 1 case of CR, 18 cases of PR, 15 cases of SD, and 2 cases of PD, while in the PO group, there were 0 cases of CR, 2 cases of PR, 10 cases of SD, and 9 cases of PD when mRECIST was used to evaluate the tumor response in target lesions. The ORR was 52.8%(19 cases) and 9.5%(2 cases) (χ^2=10.7, p<0.001), and the DCR was 94.4%(34 cases) in the MWA+PO group versus 57.1%(12 cases) in the PO group(χ^2=11.9, p<0.001). When RECIST 1.1 was used to evaluate tumor response, the MWA+PO group had 0 cases of CR, 13 cases of PR, 21 cases of SD and 2 cases of PD, whereas the PO group had 0 cases of CR, 1 case of PR, 11 cases of SD, and 9 cases of PD. The ORR was 43.1%(13 cases) in the MWA+PO group and 4.8%(1 case) in the PO group (χ^2=7.0, P=0.007), with the DCR being 90.2% (34 cases) in the MWA+PO group compared to 57.1%(12 cases) in the PO group(χ^2=11.9, p<0.001) (Table 5).

Postoperative bone cement extravasation occurred in 7 cases (19.4%) in the MWA+PO group and 8 cases(38.1%) in the PO group. However, the difference was no statistically significant (χ^2=2.38, p=0.12). No other serious surgical complications were observed in either group.

Discussion

Bone metastases are a common complication in patients with advanced cancer, often leading to severe pain in the affected area, local dysfunction, and increased psychological distress, which can seriously affect the patient's quality of life.[7] For patients with localized severe pain due to bone metastases, the primary treatment goals are to alleviate pain, prevent complications, and enhance quality of life, rather than focusing on the complete eradication of the localized bone metastases.

Flat bones are a category of bones characterized by their thin, flattened shape. They are typically comprised of two layers of compact bone with a layer of spongy bone in between. This structure provides both strength and flexibility while reducing the overall weight of the skeleton. Examples of flat bones include the ribs, ilium, scapula. These bones play important roles in assisting respiratory movement, upper limb movement, lower limb activity, and supporting the torso. Consequently, metastases in flat bone can cause severe local pain, limit breathing and limb activities, and significantly affect patients' quality of life.

With the development of modern medicine, various treatments such as surgery, radiotherapy, and local minimally invasive interventional therapy are available for managing bone metastases. However, for patients with advanced tumors, the physical condition may not permit surgery. While radiotherapy can reduce cancer pain, it typically takes 5–20 weeks to achieve palliative effects, and its effectiveness in treating cancer pain is only 60–70%.[8] Consequently, local minimally invasive interventional therapy plays a crucial role in alleviating cancer pain in patients with advanced bone metastases.

According to our results, MWA combined with PO demonstrated significant clinical efficacy and safety in the treatment of flat bone metastases. First, we observed that the procedure's success rate was 100%, and no serious postoperative complications occurred, indicating a high degree of safety and reliability in the surgical operation. In terms of clinical outcomes, the MWA+PO group showed superior results compared to the PO group in postoperative pain relief, functional recovery, and quality of life improvement. The VAS, ODI, and QOL scores at 1 week, 1 month, and 3 months postoperatively were significantly better in the MWA+PO group than in the PO group, with statistically significant differences. This suggests that MWA combined with PO can more effectively reduce patients' pain and enhance their functional status and quality of life. Furthermore, the ORR and DCR of the MWA+PO group were significantly better than those of the PO group in terms of target lesion tumor treatment response.

PO is a commonly used method to treat bone metastases. Bone cement can increase bone stability, reduce the occurrence of pathological fracture, alleviate pain, and help control tumor progression. The pain-relieving mechanisms of PO may involve several factors: ① Thermal effect: When bone cement solidifies, the heat released can permanently ablate surrounding tumor cells and sensory nerve endings. ② Mechanical action: Injecting bone cement improves the biomechanical properties of the bone, stabilizes microfractures, reduces minor displacement of fracture ends, and provides support, thereby eliminating tissue compression and friction. ③ Blocks supply blockage: Bone cement blocks local tissue blood supply, which can damage tumor cells and sensory nerve endings. ④ Chemical toxicity: Bone cement exerts cytotoxic effects on tumor cells and nerve cells.[9] However, there are some controversial aspects of PO treatment: ① Uneven thermal distribution: The thermal effect produced by bone cement polymerization is unevenly distributed within the bone. Areas with lower thermal energy may not be sufficient to kill the tumor, and it remains to be demonstrated whether this can lead to tumor provocation.[10] ② In cases of osteolytic vertebral metastases with local bone cortical defects, the high pressure during bone cement injection may allow tumor tissue to enter the blood circulation via local arteries and paravertebral venous plexus, potentially causing multiple metastases near the original lesion.[11] This also suggests that the solid occupancy of bone metastasis in PO makes it difficult for the bone cement to uniformly distribute within the bone.

MWA offers several potential advantages in the treatment of bone metastases, including low operating costs, real-time image guidance, synergistic effects with other treatments, reproducibility of the procedure, and a short procedure time. MWA heats tissues by agitating water molecules with electromagnetic microwaves, which creates friction and induces coagulative necrosis of cells.[12] This method is particularly effective in high-impedance tissues like bone, which have relative permeability and low conductivity, allowing microwaves to penetrate deeper.[13] The mechanisms by which MWA reduces cancer pain in bone metastases include: ① Destruction of nociceptive nerve fibers: MWA destroys nociceptive nerve fibers in the periosteum and bone cortex, reducing pain transmission.; ② Reduction of tumor load: By decreasing the tumor burden, MWA reduces pain propagation through nerve endings; ③ Reduction of osteoclast activity: MWA decreases osteoclast activity around the tumor cells; ④ Localized coagulative necrosis:, MWA induces localized coagulative necrosis and reduces the production of nerve-stimulating cytokines, such as interleukins and α-tumor necrosis factor.[14]

This retrospective analysis demonstrates that the MWA+PO group is more effective than the PO group for pain relief in flat bone metastases. The combined treatment not only destroys the intraosseous tumor tissue but also stabilizes the bone structure. After percutaneous microwave ablation, the tumor tissue within the bone is carbonized, reducing the local tumor mass and facilitating the filling of bone cement, which in turn decreases the risk of bone cement extravasation.

Our study found that the average surgical cost in the MWA+PO group was ¥10,480.43 higher than that of the PO group. Despite the increased cost associated with the combined treatment, it remains a cost-effective option given its significant clinical advantages. Therefore, we recommend prioritizing MWA combined with PO as a safe and effective treatment option for flat bone metastases.

All patients in this retrospective study successfully completed the procedure without serious complications. The main complications associated with percutaneous microwave ablation combined with percutaneous osteoplasty for the treatment of bone metastases, as reported in the relevant literature, include bone cement leakage, skin burns, nerve injury, pathologic fracture, and skin infection.[15] Accurate preoperative assessment of MRI/CT images, needle path, ablation parameters, and the amount of bone cement is crucial. It is important to strictly adhere to aseptic techniques during the procedure. Prophylactic antibiotics are recommended for large lesions and prolonged ablation time, and antibiotics can be added to the bone cement if necessary to reduce infection risk. The needle site should be adjusted minimally, and careful local postoperative care, including bed rest, should be observed.

For the surgical operation, the author offers the following suggestions: ① Detailed preoperative planning: Thoroughly review enhanced CT/MRI imaging, to avoid vital organs and blood vessels, and carefully plan the needle path. ② Adequate preoperative anesthesia: Ensure sufficient local anesthesia, extending to the subperiosteum, combined with intravenous analgesia. This approach allows the patient to communicate with the operator throughout the procedure, facilitating immediate detection of any neurological symptoms or complications and improving the overall tolerance and safety of the procedure. ③ Needle entry path: Position the bone puncture needle as parallel as possible to the long axis of the lesion bone. This positioning enhances the effectiveness of microwave ablation and helps distribute the bone cement along the long axis of the entry path, reducing the risk of cement leakage.④Adjusting ablation parameters: Since there is no standardized parameters for bone microwave ablation, adjust the ablation parameters flexibly based on the tumor's nature, volume, internal structure and location. Initially, set the ablation power and time lower and adjusted according to the patient's tolerance. ⑤ Bone Cement Planning: Determine the amount of bone cement needed based on the continuity of the bone cortex and the extent of tumor invasion prior to surgery.

There are shortcomings in this retrospective study: 1. Heterogeneous Effects of Different Primary Tumors. 2. Single-Center Study. 3. Short Follow-Up Time: The follow-up period was relatively short, and long-term outcomes were not assessed. Extended follow-up is necessary to evaluate the durability of treatment effects and the long-term safety of the interventions.4. Small Sample Size.5. Physician's Experience-Based Choice of Surgical Method: The choice of surgical method was influenced by the attending physician's personal experience. This subjective approach may introduce variability in treatment techniques and outcomes, affecting the study's overall conclusions. Therefore, future research directions should: 1. Multicenter studies: To improve the generalizability of the findings, future studies should consider multicenter designs involving diverse patient populations and treatment settings.2. Long-term follow-up: Extended follow-up periods are needed to evaluate the long-term efficacy and safety of MWA combined with PO, including the assessment of late complications and the durability of pain relief.3. Larger sample sizes.4. stratification by tumor type.

Conclusion

Overall, the results of this study provide strong support for the clinical application of MWA combined with PO in the treatment of flat bone metastases and provide an important reference for clinical practice. However, further large-sample, multicenter randomized controlled studies are needed to verify its reliability and durability in long-term clinical practice.

Data Sharing Statement

The datasets generated during and/or analysed during the current study are not publicly available due to [REASON(S) WHY DATA ARE NOT PUBLIC] but are available from the corresponding author on reasonable request.

Ethical Statement

The study was conducted in accordance with the Declaration of Helsinki and other ethical principles for medical research involving human subjects. The Ethics Committee of Zhongshan People's Hospital approved the retrospective study (Ethics approval number: 2024-035), and the requirement for individual consent for this retrospective analysis was waived. Patient consent for the review of their medical records was not required by the Ethics Committee of Zhongshan People's Hospital. However, patient data confidentiality was strictly maintained, and all personal identifiers were removed to protect privacy.

Consent to Participate

Informed consent was obtained from all patients involved in the study.

Acknowledgments

We would like to acknowledge the reviewers for their helpful comments on this paper.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

No funds, grants, or other support was received for this study.

Disclosure

The author(s) report no conflicts of interest in this work.

References

1. Coleman RE, Croucher PI, Padhani AR, et al. Bone metastases. *Nat Rev Dis Primers*. 2020;6(1):83. doi:10.1038/s41572-020-00216-3
2. Qiu YY, Zhang KX, Ye X, et al. Combination of microwave ablation and percutaneous osteoplasty for treatment of painful extraspinal bone metastasis. *J Vasc Interv Radiol*. 2019;30(12):1934–1940. doi:10.1016/j.jvir.2019.08.008
3. Soeharno H, Povegliano L, Choong PF. Multimodal treatment of bone metastasis-A surgical perspective. *Front Endocrinol*. 2018;9:518. doi:10.3389/fendo.2018.00518
4. Wang Z, Zuo T, Lin W, Du Z, Zhang X, Liang Y. Clinical efficacy and safety of microwave ablation combined with percutaneous osteoplasty for palliative treatment in pelvic osteolytic metastases. *Br J Radiol*. 2024;97(1155):553–559. doi:10.1093/bjr/tqad049
5. Ibe I, Dussik CM, Callan AK, Barr J, Lee FY. Emerging minimally invasive percutaneous procedures for periacetabular osteolytic metastases. *J Bone Joint Surg Am*. 2023;105(6):479–489. doi:10.2106/jbjs.22.00694
6. Jing D, Zhao Q, Zhao Y, et al. Management of pain in patients with bone metastases. *Front Oncol*. 2023;13:1156618. doi:10.3389/fonc.2023.1156618
7. Clézardin P, Coleman R, Puppo M, et al. Bone metastasis: mechanisms, therapies, and biomarkers. *Physiol Rev*. 2021;101(3):797–855. doi:10.1152/physrev.00012.2019
8. Zeng L, Chow E, Bedard G, et al. Quality of life after palliative radiation therapy for patients with painful bone metastases: results of an international study validating the EORTC QLQ-BM22. *Int J Radiat Oncol Biol Phys*. 2012;84(3):e337–42. doi:10.1016/j.ijrobp.2012.05.028
9. Tian Q, Cheng Y, Wu C. Percutaneous osteoplasty for extraspinal metastases. *J Interv Med*. 2018;1(3):137–142. doi:10.19779/j.cnki.2096-3602.2018.03.02
10. Lai PL, Tai CL, Chen LH, Nien NY. Cement leakage causes potential thermal injury in vertebroplasty. *BMC Musculoskelet Disord*. 2011;12:116. doi:10.1186/1471-2474-12-116
11. Cruz JP, Sahgal A, Whyne C, Fehlings MG, Smith R. Tumor extravasation following a cement augmentation procedure for vertebral compression fracture in metastatic spinal disease. *J Neurosurg Spine*. 2014;21(3):372–377. doi:10.3171/2014.4.Spine13695
12. Lubner MG, Brace CL, Hinshaw JL, Lee FT. Microwave tumor ablation: mechanism of action, clinical results, and devices. *J Vasc Interv Radiol*. 2010;21(8 Suppl):S192–203. doi:10.1016/j.jvir.2010.04.007
13. Simon CJ, Dupuy DE, Mayo-Smith WW. Microwave ablation: principles and applications. *Radiographics*. 2005;25(1):S69–83. doi:10.1148/rg.25si055501
14. Botsa E, Mylona S, Koutsogiannis I, Koundouraki A, Thanos L. CT image guided thermal ablation techniques for palliation of painful bone metastases. *Ann Palliat Med*. 2014;3(2):47–53. doi:10.3978/j.issn.2224-5820.2014.04.02
15. Jiao D, Yao Y, Li Z, Ren J, Han X. Simultaneous C-arm computed tomography-guided microwave ablation and cementoplasty in patients with painful osteolytic bone metastases: a single-center experience. *Acad Radiol*. 2022;29(1):42–50. doi:10.1016/j.acra.2020.09.026