Original Article Clinics in Orthopedic Surgery 2021;13:278-285 • https://doi.org/10.4055/cios19179

The Efficacy of Radiofrequency Ablation for Bone Tumors Unsuitable for Radical Excision

Jun Sung Koo, MD, So Hak Chung, MD

Department of Orthopaedic Surgery, Kosin University College of Medicine, Busan, Korea

Background: Bone tumors can cause severe pain and poor quality of life due to recurrence and non-achievement of complete remission after surgery, chemotherapy, or radiotherapy. Radiofrequency ablation (RFA) can be considered for minimally invasive treatment of bone tumors that are difficult to radically excise. In this study, RFA was performed for bone tumors that were difficult to radically excise and did not respond to surgery, chemotherapy, or radiotherapy due to their large sizes and/or locations. The purpose of this study was to retrospectively analyze the clinical characteristics and survival rates of bone tumors after RFA and provide one more treatment option for the future.

Methods: There were 43 patients with bone tumors who underwent percutaneous RFA at our hospital from April 2007 to October 2017. The median age of the patients was 59 years (range, 31–75 years), and the median follow-up duration was 67.2 months (range, 10.2–130.5 months). Of the 43 patients, 26 were male and 17 were female. Thirty-four cases were metastatic bone tumors, 5 were chordomas, 3 were osteosarcomas, and 1 was a giant cell tumor. Pain and functional ability of the patients were evaluated using a visual analog scale (VAS) and the Musculoskeletal Tumor Society (MSTS) functional scoring system, respectively. Scores were recorded preoperatively, 1 week postoperatively, and 4 weeks postoperatively. The 1-year, 2-year, and 5-year survival rates were evaluated using the Kaplan-Meier method.

Results: The mean VAS score was 8.21 preoperatively. The mean VAS score at 1 week, 4 weeks, 12 weeks, and 24 weeks postoperatively were 3.91, 3.67, 3.31, and 3.12, respectively. The mean preoperative MSTS score was 64.0% (range, 32%–87%). The mean postoperative MSTS score was 71.0% (range, 40%–90%). The 1-year, 2-year, and 5-year survival rates were 95.3%, 69.8%, and 30.2%, respectively.

Conclusions: As per our study findings, RFA was effective in reducing pain and improving functional ability of patients with bone tumors that were difficult to radically excise.

Keywords: *Radiofrequency ablation, Bone neoplasms*

Several studies have recently reported on minimally invasive therapies for primary or metastatic bone tumors.[1] Some bone tumors recur or are difficult to treat with surgery, chemotherapy, or radiotherapy, causing cancerous pain and lowering the quality of life of patients. For these bone tumors, radiofrequency ablation (RFA) can be considered one of the minimally invasive treatment options. It uses a concept that a lethal amount of heat applied to the target tissue could cause necrosis through the tissue coagulation process.[1] RFA is mainly used as a palliative treatment for primary and metastatic hepatocellular carcinoma, renal cell carcinoma, and lung cancer. As the surgical procedure is relatively safe and can relieve the patient's pain immediately after surgery, it is used in many cases as a minimally invasive treatment.

Recently, there were reports that it can be selec-

Received December 23, 2019; Revised June 23 2020;
Accepted December 22, 2020
Correspondence to: So Hak Chung, MD
Department of Orthopaedic Surgery, Kosin University Gospel Hospital, 262 Gamcheon-ro, Seo-gu, Busan 49267, Korea
Tel: +82-51-990-6467, Fax: +82-51-243-0181
E-mail: shchung@kosin.ac.kr

tively used for osteoid osteoma in musculoskeletal cancer. However, RFA is a relatively new technique in the treatment of musculoskeletal cancer with histologically diverse tumors, and the indications have not been established academically.[2-4] In this study, RFA was performed in patients who had either recurrence or no improvement after several operations, chemotherapy, or radiotherapy and whose tumors could not be resected due to their sizes and locations. To reduce complications such as destruction of normal tissues, damage to major structures such as nerves around the tumor, and skin burns caused by RFA, the surgery was performed using the C-arm to determine the exact location of the bone tumor. This study aimed to retrospectively analyze the clinical features and survival rates of bone tumors treated with RFA for the past 10 years and to contribute to the treatment of bone tumors such as metastatic bone cancer, osteosarcoma, chordoma, and giant cell tumor.

METHODS

This study was conducted on patients with primary and metastatic bone cancers who were treated at our hospital from April 2007 to October 2017. The design and protocol of this study were approved by the Institutional Review Board of Kosin University Gospel Hospital (IRB No. 2019-10-037-001). As it is a retrospective study, the need for informed consent was waived.

As for the indication of RFA, it was performed on a bone tumor that could not be surgically removed.

In this study, the experimental groups were divided as follows: (1) patients with unresectable metastatic bone tumors who underwent radiotherapy because the tumor invaded the posterior nerve and caused neurological symptoms but did not have symptom relief, (2) patients with chordoma at high risk for surgery due to the large size or difficulty of resection of metastatic tumor, (3) patients with osteosarcoma that is refractory to chemotherapy and unresectable, and (4) patients with a giant cell tumor that repeatedly recurs despite surgical treatment and cannot be resected. A total of 56 subjects were initially enrolled, but 13 patients discontinued treatment during the study, were transferred to another hospital in the middle of the treatment, or failed to return for follow-up after 3 months.

Their medical and radiology records were retrospectively reviewed, and the average age of the subjects was 59 years (range, 31–75 years). The average follow-up period was 67.2 months (range, 10.2–130.5 months). Of the 43 participants, 26 were male and 17 were female. The 43 subjects were divided into four groups: group 1, 34 patients with a metastatic bone tumor; group 2, 5 patients with recurrent chordoma; group 3, 3 patients with osteosarcoma; and group 4, 1 patient with giant cell tumor. Group 1 had 19 men and 15 women, with an average age of 61 years (range, 44–75 years) and an average follow-up period of 65.8 months (range, 55–130.5 months). The distribution of musculoskeletal tumors and primary cancer in group 1 is specified in Table 1. In 11 of the 17 cases where primary tumor metastasized to the lumbar spine, vertebroplasty was performed after RFA to fill the empty space. Group 2 was composed of 5 men with an average age of 58 years (range, 48–65 years) and an average follow-up period of 100.8 months (range, 84–110 months). Group 3 was composed of 2 men and 1 woman, where the average age was 40 years (range, 31–45 years) and the average follow-up period was 60.2 months (range, 10.2–85 months).

Table 1. The Distribution of Bone Tumors and Corresponding Primary Malignancies in Group 1

Site of the primary neoplasm	Number
Kidney	5
Lung	5
Liver	4
Prostate	4
Colon/rectum	4
Thyroid	4
Bladder	4
Stomach	3
Uterus	1
Total	34
Site of metastasis	**Number**
L-Spine	17
Sacrum	5
C-Spine	3
Scapula	3
T-Spine	2
Ilium	2
Humerus	1
Acetabulum	1
Total	34

Table 2. Demographics and Characteristics of Patients

Variable	Number (%)
Sex	
Male	26 (60.5)
Female	17 (39.5)
Site of the primary tumor	
Kidney	5 (11.6)
Lung	5 (11.6)
Sacrum	5 (11.6)
Other	28 (65.1)
Site of metastasis	
L-Spine	17 (39.5)
Sacrum	10 (23.3)
Other	16 (37.2)
Size	
< 3 cm	28 (65.1)
≥ 3 cm	15 (34.9)
Radiographic pattern	
Lytic	31 (72.1)
Blastic	9 (20.9)
Mixed	3 (7.0)
Cortical bone disruption	
No	22 (51.2)
Yes	12 (27.9)
Previous surgery	
No	27 (62.8)
Yes	16 (37.2)
Previous radiation therapy	
No	30 (69.8)
Yes	13 (30.2)
Concomitant chemotherapy	
No	24 (55.8)
Yes	19 (44.2)
Imaging modality used for follow-up	
CT	7 (16.3)
PET scan	5 (11.6)
MRI	21 (48.8)

CT: computed tomography, PET: positron emission tomography, MRI: magnetic resonance imaging.

Group 4 was composed of one 31-year-old woman who was followed up for 42 months (Table 2).

Before resection, computed tomography (CT) was used to measure the size of the lesion by determining its exact location and depth on cross-sectional images. Through radiographic imaging, the patterns were classified into three categories (osteolytic, osteogenic, and mixed), and the previously obtained images were analyzed to evaluate lesion characteristics, electrode location, and the possibility of resection. RFA was performed under general anesthesia, and upon applying povidone-iodine solution to the skin, electrodes were inserted into the musculoskeletal tumor-bearing tissue. In some cases, induction needles were used for coaxial placement of the electrode, and using an insulated induction needle to keep the active tip of the electrode in contact with the induction needle, skin burn at the needle insertion site was prevented. As done in a study by Ahrar,[5] more than one RFA was performed with an emphasis on the tumor-bone interface, and the number of resections was different depending on the size of the lesion.

In this study, a cooled 17-G length-adjustable electrode (Proteus RF Electrode; STARmed, Goyang, Korea) and a 200-W RF generator (VIVA RF System, STARmed) were used during RFA. The type of the electrode and the length of the active tip were selected according to the size, location, and shape of the tumor, as well as the surgeon's preference. The electrode tip was inserted approximately 1 cm away from the center of the tumor and to remove the tumor-bone interface, the electrode was slowly entered. Afterward, ablation was performed with 100 W energy for 30 seconds. The number of electrodes placed, ablation time per electrode, total ablation time, and total energy delivered to targets, as well as the temperature of the lesions, were recorded. For lesions less than 3 cm (28 out of 43 cases), surgery was performed with one electrode, and for lesions of 3 cm or more (15 out of 43 cases), two or more electrodes were used (Table 3).

In order to determine the degree of pain relief and functional ability before and after the treatment, a visual analog scale (VAS) for pain and Musculoskeletal Tumor Society (MSTS) scores were compared. The MSTS scoring system consists of six domains that score pain in the upper and lower extremities, functional and emotional acceptance, use of supports, walking ability and gait of the lower extremities, hand-positioning, and dexterity/lifting ability, each scored on a scale of 0 to 5.[6] The total score can go up to 30.

The degree of treatment response was evaluated via the local control rate and the survival rate, and the local

Table 3. Characteristics of Lesions and Treatment

No. of lesions	Lesion size (cm)	No. of electrode placements	Duration of radiofrequency energy deposition (min)
28	< 3	1	3
9	3	1	4
2	4	4	8
3	5	4	10
1	7	8	15
Total: 43			

Table 4. The Effect of Radiofrequency Ablation on Pain Analyzed by the Visual Analog Scale

Group	Preop	Postop 1 wk	Postop 4 wk	Postop 12 wk	Postop 24 wk	*p*-value
Group 1	8.32	4.00	3.71	3.52	3.41	< 0.002
Group 2	7.20	3.80	3.60	3.42	3.26	< 0.005
Group 3	7.00	3.33	3.00	2.75	2.54	< 0.004
Group 4	7.00	3.00	2.00	1.00	1.00	-
Total	8.21	3.91	3.67	3.31	3.12	< 0.003

Group 1: metastatic bone tumor, Group 2: chordoma, Group 3: osteosarcoma, Group 4: giant cell tumor.
Preop: preoperative (the day before the operation), Postop: postoperative.

control rate was evaluated by comparing the change in tumor size before and after surgery via magnetic resonance imaging (MRI) between 3 and 6 months after surgery and measuring the long axis in the sagittal and coronal planes of MRI. Kaplan-Meier analysis was used to calculate the results over time, as well as 1-, 2-, and 5-year survival rates, which were evaluated for patients who had been followed up for 5 years.

RESULTS

Most of the patients showed rapid improvement in pain during the first week after surgery. In group 1, the VAS scores preoperatively and 1, 4, 12, and 24 weeks postoperatively were 8.32, 4.00 (51.92% decrease), 3.71, 3.52, and 3.42, respectively. In group 2, the VAS scores preoperatively and 1, 4, 12, and 24 weeks postoperatively were 7.20, 3.80 (47.22% decrease), 3.60, 3.42, and 3.26, respectively. In group 3, the VAS scores preoperatively and 1, 4, 12, and 24 weeks postoperatively were 7.00, 3.33 (52.43% decrease), 3.00, 2.75, and 2.54, respectively. In group 4, the VAS scores preoperatively and 1, 4, 12, and 24 weeks postoperatively were 7, 3 (57.14% decrease), 2, 1.81, and 1.64, respectively. For all patients in groups 1–4, the VAS scores preoperatively and 1, 4, 12, and 24 weeks postoperatively were 8.21, 3.91 (52.38% decrease), 3.67, 3.31, and 3.12 ($p < 0.5$), respectively, suggesting that pain was significantly improved upon surgery (Table 4, Fig. 1).

On the six domains of MSTS, the average preoperative scores were 3.1 for pain, 3.0 for functionality, 3.2 for emotional acceptance, 3.9 for the use of supports/hand-positioning, 3.5 for walking ability/dexterity, and 2.5 for gait/lifting ability. The average total score was 19.2 points, and the average MSTS was 64.0% (range, 32%–87%). After surgery, the average scores were 4.0 for pain, 3.1 for functionality, 3.5 for emotional acceptance, 4.0 for the use of supports/hand-positioning, 3.9 for walking ability/dexterity, and 2.8 for gait/lifting ability. The average total score was 21.3, and the average MSTS was 71.0% (range, 40%–90%), indicating improvement in MSTS after surgery (Table 5).

Regarding the local control rate, the preoperative size and postoperative size, and the local control rate were 2.6 cm^2, 2.2 cm^2, and 0.85, respectively, in group 1; 2.8 cm^2, 2.6 cm^2, and 0.93, respectively, in group 2; 1.7 cm^2, 1.4 cm^2, and 0.82, respectively, in group 3; and 1.0 cm^2, 0.8 cm^2, and 0.80, respectively, in group 4. In all patients in groups 1–4, the preoperative size, postoperative size, and local control rate were 2.6 cm^2, 2.2 cm^2, and 0.85, respectively (Table 6). The average survival of all patients was about 20

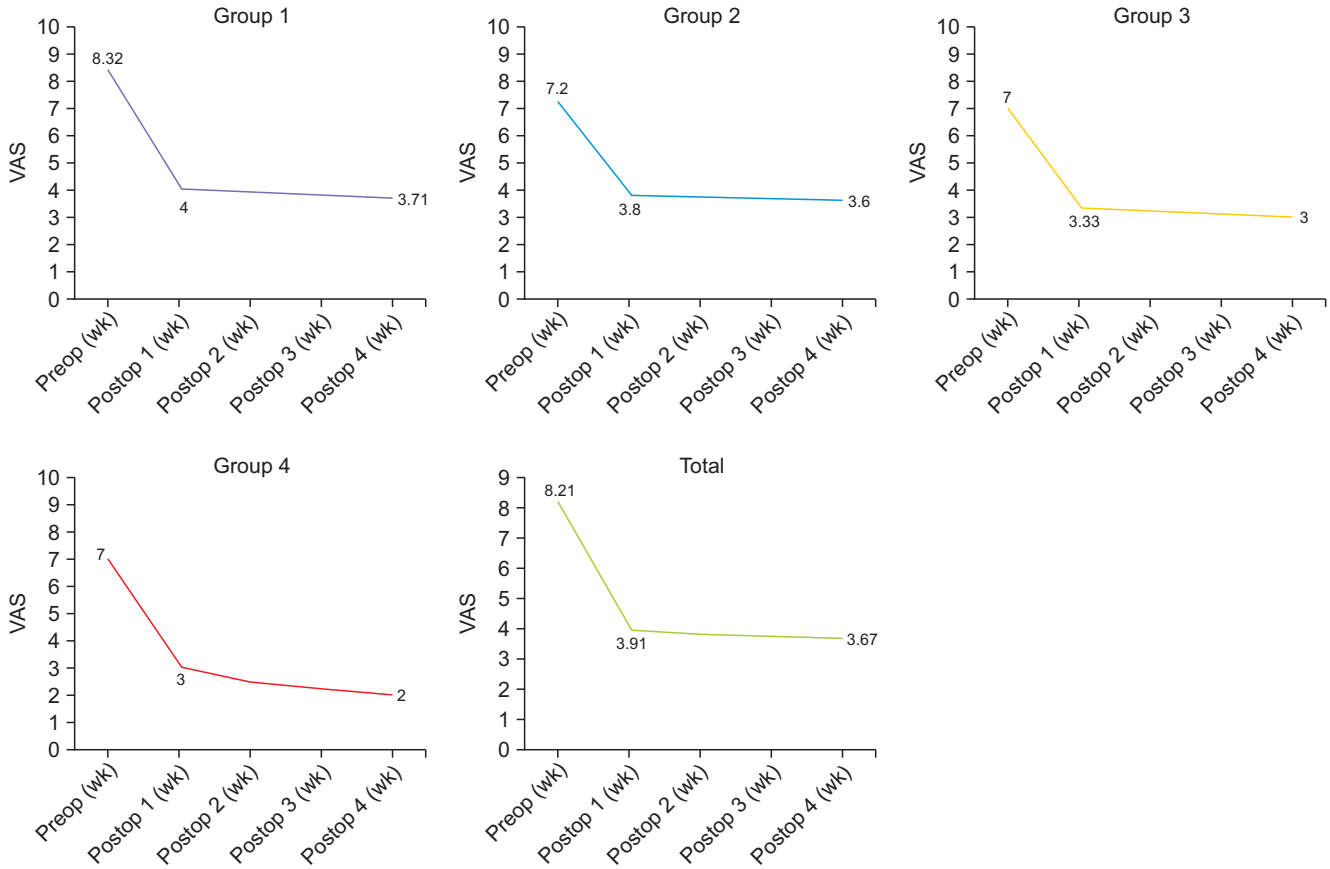

Fig. 1. Preoperative (Preop) and postoperative (Postop) visual analog scale (VAS) scores. Group 1: metastatic bone tumor, Group 2: chordoma, Group 3: osteosarcoma, Group 4: giant cell tumor.

Table 5. The Effect of Radiofrequency Ablation on the Functional Ability

MSTS scoring system domain	Preoperative score	Postoperative score
Pain	3.1	4.0
Function	3.0	3.1
Emotional acceptance	3.2	3.5
Use of supports/hand positioning	3.9	4.0
Walking ability/dexterity	3.5	3.9
Gait/lifting ability	2.5	2.8
Total	19.2	21.3
Percent	64.0	71.0

MSTS: Musculoskeletal Tumor Society.

months, and the 1-year, 2-year, and 5-year survival rates were 95.3%, 69.8%, and 30.2%, respectively (Figs. 2 and 3).

DISCUSSION

RFA was introduced in 1928 when a neurosurgeon, Harvey Cushing, and a physicist, W. T. Bovie, collaborated to develop a device that uses locally generated heat to per-

Table 6. The Effect of Radiofrequency Ablation on Local Progression

Group	Preoperative (cm)	Postoperative (cm)	Local control rate
Group 1	2.6	2.2	0.85
Group 2	2.8	2.6	0.93
Group 3	1.7	1.4	0.82
Group 4	1.0	0.8	0.80
Total	2.6	2.2	0.85

Group 1: metastatic bone tumor, Group 2: chordoma, Group 3: osteosarcoma, Group 4: giant cell tumor.

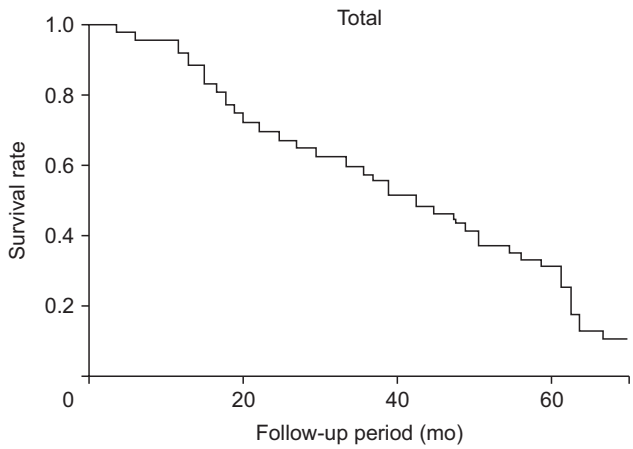

Fig. 2. The Kaplan-Meier curve showing the survival rate of all patients.

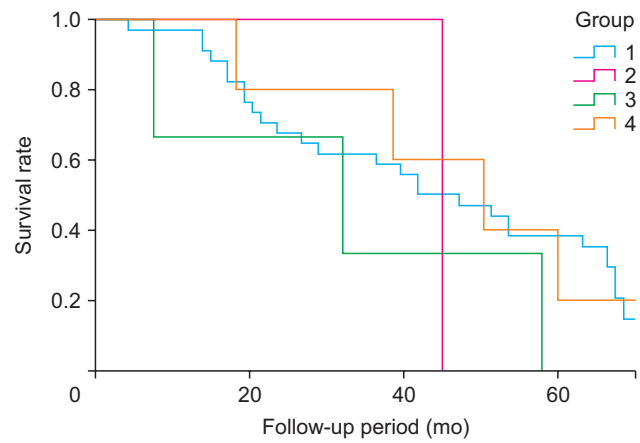

Fig. 3. The Kaplan-Meier curve showing the survival rates of different groups of patients.

form surgical coagulation and amputation.[7] RFA was later used to treat trigeminal neuralgia and for dorsal myelotomy. Tillotson et al.[8] reported the effect of RFA by inducing bone marrow fat necrosis and reactive fibrosis with RFA at 80°C in dog femur, resulting in necrosis the size of 0.9–1.3 cm. A study using this principle to treat bone tumors via RFA was first reported in 1992,[9] and since then, it has been used to treat several other musculoskeletal lesions.[1] Dupuy et al.[10] reported that RFA was effective as a palliative treatment for patients with metastatic bone tumors experiencing severe pain. In addition, Callstrom et al.[11] reported that 12 patients with osteolytic bone metastasis experiencing cancerous pain showed significant pain relief after RFA. Goetz et al.,[12] in a multicenter study of 43 patients with metastatic bone tumors complaining of severe pain, reported that RFA was associated with clinically significant pain relief, reduced opioid use, and mild complication rates. Neeman et al.[13] reported that percutaneous RFA is effective in treating patients whose chordoma metastasized to the near rectum, which causes local sciatic pain.

RFA works in the same way as a typical electrosurgical device. Current passes through the electrodes to the body and exits through a grounding pad usually placed on the leg. The size of the lesion that appears after RFA depends on several factors such as tissue type, current duration, and temperature. Due to the current, the bio-electrolyte in the tissue around the electrode generates unstable heat, and when the tissue temperature reaches 60°C, apoptosis proceeds almost immediately. Apoptosis can occur even at low temperatures of 46°C–60°C, but a longer exposure time is required at such low temperatures.[14] If a high temperature of more than 100°C is applied, the normal tissue around the tumor either melts or evaporates, creating unnecessary coagulation and increasing the impedance for additional currents, thus reducing the therapeutic effect.[1]

As thermal resistance is generated only by current around the electrode and induces immediate cell death, the tissue adjacent to the electrode is heated to the highest temperature and dies, but as the distance from the electrode increases, the heat applied from the single electrode device exponentially decreases. As a result, tissues far from the electrode are heated only by heat conduction, which

limits the size of the lesion to which RFA is applied. With this principle. RFA can be safely performed as a minimally invasive treatment.[15-18)]

The principle that RFA reduces pain is thought to be due to the inhibition of pain transmission through destruction of the sensory nerve fibers in the periosteum and bone cortex, reduction of stimulation of the sensory nerve fibers through decrease in lesion volume, destruction of tumor cells that produce nerve stimulating cytokines such as tumor necrosis factor and interleukin, and inhibition of osteoclast activity.[19,20)]

When the primary tumor metastasizes to the spine, the pain appears localized. Expansion of the metastasized tumor leads to stimulation of the area responsible for pain in the periosteum and around the joints. As a result, pain is constantly present, and it becomes more severe during joint motion or weight bearing. Metastatic spinal tumors lead to a rapid decline in the quality of life due to short life span and pain. In addition, a study by Jang and Park[21)] conducted in our hospital in 2011 found that RFA and vertebroplasty performed together for metastatic spinal tumors relieved pain and improved the quality of life. In addition, in this study, 11 out of 17 metastatic spinal tumor cases were treated with RFA and vertebroplasty. In the case of metastatic spinal tumors, it is difficult to obtain immediate pain reduction and stability of the spine with conventional radiotherapy, and an extensive surgical procedure such as vertebrectomy has a narrow scope of application; it is also a very invasive procedure with high risk. On the other hand, when percutaneous RFA is performed to reduce tumor cells and when bone cement is inserted into the empty space, it can reduce pain and fill the space, stabilizing the vertebral body. Although the effect of bone cement on tumor cell necrosis is also known, Gronemeyer et al.[22)] and Nakatsuka et al.[23)] reported that tumor cell necrosis is related to the efficiency of RFA rather than the effect of bone cement injection. Possible side effects of RFA include infection, bleeding, neurological complications, and skin burn. In this study, skin burn occurred in one case after the previous radiotherapy, and no side effects were observed in other cases.

However, given that the sample size of this study is relatively small and this study is not a randomized prospective study, the limitations of this study are that the efficacy of RFA was not compared with other treatment modalities and that it was conducted with patients with multiple disease entities and tumors in various anatomical locations. In addition, as no protocol for RFA management has been established yet, further studies that define the protocol for this technique and evaluate the safety and long-term efficacy of RFA in the treatment of other neoplasms are necessary.[24)]

This study aimed to provide a basis for future RFA treatment in patients with bone tumors. Image-guided RFA is a conventional modality for the treatment of bone tumors associated with severe pain; it is also a relatively effective, minimally invasive, and safe treatment. Based on the VAS, MSTS, local control rate, and survival rate observed in this study, RFA seemed to reduce pain level, increase functionality, and locally suppress the tumor in patients with bone cancer. In addition, some patients who underwent RFA did not show tumor recurrence during the follow-up period.

RFA did not show recurrence during the follow-up period in patients with primary and metastatic bone tumors that did not respond to prior treatment and were difficult to resect. It also increased the 5-year survival rate, suggesting that it could be attempted for future treatment and used as a palliative treatment for pain relief and functional improvement.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

ACKNOWLEDGEMENTS

This Article was presented as an invited lecture in the 52nd Annual Musculoskeletal Tumor Meeting of the Japanese Orthopaedic Association, July 12th, 2019, Saitama, Japan.

ORCID

Jun Sung Koo https://orcid.org/0000-0002-4098-664X
So Hak Chung https://orcid.org/0000-0003-0689-0270

REFERENCES

1. Volkmer D, Sichlau M, Rapp TB. The use of radiofrequency ablation in the treatment of musculoskeletal tumors. J Am Acad Orthop Surg. 2009;17(12):737-43.
2. Dupuy DE, Goldberg SN. Image-guided radiofrequency

tumor ablation: challenges and opportunities: part II. J Vasc Interv Radiol. 2001;12(10):1135-48.

3. Rosenthal DI, Hornicek FJ, Torriani M, Gebhardt MC, Mankin HJ. Osteoid osteoma: percutaneous treatment with radiofrequency energy. Radiology. 2003;229(1):171-5.
4. Gazelle GS, Goldberg SN, Solbiati L, Livraghi T. Tumor ablation with radio-frequency energy. Radiology. 2000;217(3):633-46.
5. Ahrar K. The role and limitations of radiofrequency ablation in treatment of bone and soft tissue tumors. Curr Oncol Rep. 2004;6(4):315-20.
6. Enneking WF, Dunham W, Gebhardt MC, Malawar M, Pritchard DJ. A system for the functional evaluation of reconstructive procedures after surgical treatment of tumors of the musculoskeletal system. Clin Orthop Relat Res. 1993;(286):241-6.
7. Wagshal AB, Pires LA, Huang SK. Management of cardiac arrhythmias with radiofrequency catheter ablation. Arch Intern Med. 1995;155(2):137-47.
8. Tillotson CL, Rosenberg AE, Rosenthal DI. Controlled thermal injury of bone: report of a percutaneous technique using radiofrequency electrode and generator. Invest Radiol. 1989;24(11):888-92.
9. Rosenthal DI, Alexander A, Rosenberg AE, Springfield D. Ablation of osteoid osteomas with a percutaneously placed electrode: a new procedure. Radiology. 1992;183(1):29-33.
10. Dupuy DE, Liu D, Hartfeil D, et al. Percutaneous radiofrequency ablation of painful osseous metastases: a multicenter American College of Radiology Imaging Network trial. Cancer. 2010;116(4):989-97.
11. Callstrom MR, Charboneau JW, Goetz MP, et al. Painful metastases involving bone: feasibility of percutaneous CT-and US-guided radio-frequency ablation. Radiology. 2002;224(1):87-97.
12. Goetz MP, Callstrom MR, Charboneau JW, et al. Percutaneous image-guided radiofrequency ablation of painful metastases involving bone: a multicenter study. J Clin Oncol. 2004;22(2):300-6.
13. Neeman Z, Patti JW, Wood BJ. Percutaneous radiofrequency ablation of chordoma. AJR Am J Roentgenol. 2002;179(5):1330-2.
14. Goldberg SN, Gazelle GS, Mueller PR. Thermal ablation therapy for focal malignancy: a unified approach to underlying principles, techniques, and diagnostic imaging guidance. AJR Am J Roentgenol. 2000;174(2):323-31.
15. Mazzaglia PJ, Berber E, Milas M, Siperstein AE. Laparoscopic radiofrequency ablation of neuroendocrine liver metastases: a 10-year experience evaluating predictors of survival. Surgery. 2007;142(1):10-9.
16. Lencioni R, Cioni D, Crocetti L, Bartolozzi C. Percutaneous ablation of hepatocellular carcinoma: state-of-the-art. Liver Transpl. 2004;10(2 Suppl 1):S91-7.
17. Davis KW, Choi JJ, Blankenbaker DG. Radiofrequency ablation in the musculoskeletal system. Semin Roentgenol. 2004;39(1):129-44.
18. Curley SA, Izzo F, Delrio P, et al. Radiofrequency ablation of unresectable primary and metastatic hepatic malignancies: results in 123 patients. Ann Surg. 1999;230(1):1-8.
19. Honore P, Luger NM, Sabino MA, et al. Osteoprotegerin blocks bone cancer-induced skeletal destruction, skeletal pain and pain-related neurochemical reorganization of the spinal cord. Nat Med. 2000;6(5):521-8.
20. Mannion RJ, Woolf CJ. Pain mechanisms and management: a central perspective. Clin J Pain. 2000;16(3 Suppl):S144-56.
21. Jang JH, Park YK. The comparision of the radiofrequency ablasion therapy with vertebroplasty and radiotherapy in metastatic spine tumor. J Korean Orthop Assoc. 2011;46(2):122-9.
22. Gronemeyer DH, Schirp S, Gevargez A. Image-guided radiofrequency ablation of spinal tumors: preliminary experience with an expandable array electrode. Cancer J. 2002;8(1):33-9.
23. Nakatsuka A, Yamakado K, Maeda M, et al. Radiofrequency ablation combined with bone cement injection for the treatment of bone malignancies. J Vasc Interv Radiol. 2004;15(7):707-12.
24. Thanos L, Mylona S, Galani P, et al. Radiofrequency ablation of osseous metastases for the palliation of pain. Skeletal Radiol. 2008;37(3):189-94.