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SPINAL MONOGRAPH

[Translated article] Tumor ablation and vertebral augmentation in the treatment of vertebral metastases: A multicenter study

M. Alfonso[a,*], R. Llombart[a], L. Gil[a], I. Martinez[a], C. Rodríguez[b], L. Álvarez[c], J. Gallego[c]

[a] *Departamento de Cirugía Ortopédica y Traumatología, Clínica Universidad de Navarra, Pamplona, Spain*
[b] *Neurorradiologia Intervencionista, Grupo Quirón Hospitales, Madrid, Spain*
[c] *Departamento de Cirugía Ortopédica y Traumatología, Fundación Jiménez Díaz, Madrid, Spain*

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Augmentation

Abstract
Introduction: Treatment of metastatic vertebral fractures without neural compression is performed with percutaneous cementation techniques. The increase in intratumoral pressure by these techniques can send tumor cells into the bloodstream. To prevent this dissemination and improve pain treatment, ablation techniques have been introduced that would allow the creation of a cavity in the tumor prior to cementation or directly necrosing the metastasis when its size is small.
Material: We present the experience with ablation of two hospitals and two different ablation techniques. The first group used radiofrequency ablation (A) in 14 patients (26 vertebrae), 4 of whom underwent vertebral arthrodesis. The second group used microwave ablation (B) in 93 patients (129 lesions) without associated vertebral instrumentation.
Results: In group A pain improvement in VAS was 7.7–2.6 at 6 weeks. There were no complications derived from the ablation. In most cases cementation was associated. In the group B pain improvement in VAS went from 6.8 to 1.7 at 6 weeks. Cementation was associated in all cases. There were no complications derived from the ablation.
Conclusion: The association of ablation techniques with vertebral cementation is a safe technique that significantly improves the patient's pain and can help control the disease.

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* Corresponding author.
E-mail address: malfonsool@unav.es (M. Alfonso).

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PALABRAS CLAVE
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Fractura vertebral;
Cementación

Ablación tumoral y cementación en el tratamiento de las metástasis vertebrales. Estudio multicéntrico

Resumen
Introducción: El tratamiento de las fracturas vertebrales metastásicas sin compresión neural se realiza con técnicas percutáneas de cementación. El aumento de presión intratumoral por estas técnicas puede enviar células tumorales al torrente sanguíneo. Para evitar esa diseminación y mejorar el tratamiento del dolor se han introducido las técnicas de ablación que permitirían crear una cavidad en el tumor previo a la cementación o directamente necrosar la metástasis cuando el tamaño es pequeño.
Material: Presentamos la experiencia con la ablación de dos hospitales y dos técnicas de ablación distintas. El primer grupo usó la ablación por radiofrecuencia (ARF) en 14 pacientes (26 vértebras) de los cuales en cuatro se asoció una artrodesis vertebral. El segundo grupo usó la ablación por microondas (AMO); 93 pacientes (129 lesiones) sin asociar instrumentación vertebral.
Resultados: En el grupo de ARF la mejoría del dolor en la escala visual analógica (EVA) fue de 7,7 a 2,6 a las seis semanas. No hubo complicaciones derivadas de la ablación. En la mayoría de los casos se asoció la cementación. En el grupo de AMO la mejoría del dolor en EVA pasó de 6,8 a 1,7 a las seis semanas. En todos los casos se asoció la cementación. No hubo complicaciones derivadas de la ablación.
Conclusiones: La asociación de las técnicas de ablación a la cementación vertebral es una técnica segura, que permite mejorar notablemente el dolor del paciente y puede ayudar al control de la enfermedad.

Introduction

The improvement in the evolution of cancer treatments has led to an improvement in the survival and quality of life of cancer patients. The World Health Organization (WHO) estimates that the incidence of cancer in 2040 will be 29.4 million cases.[1] The bone is the organ most frequently affected by metastasis, the spine being the most frequent location. A systematic review of recent publications estimates the incidence of vertebral metastases at 15.6% and of these approximately 9.56% will suffer pathological vertebral fractures and 6.45% spinal cord or root compression.[2]

The treatment of vertebral metastases is, in most cases, palliative and includes various therapeutic modalities including radiotherapy (considered the ''gold standard''[3]), chemotherapy and surgery. Surgical treatment[4] is considered when metastases originate from radioresistant tumors or in the event of an unstable pathological fracture or neurological compression. The advance in surgical techniques toward less invasive interventions has increased the use of percutaneous instrumentation and cement reinforcement techniques such as vertebroplasty and kyphoplasty with which we can reduce the procedure morbidity.

As an alternative to improve local control of the tumor, techniques have emerged that allow tumor ablation.

There are several tumor ablation methods that can be used in the spine. The best known and most frequently used is the one performed by radiofrequency.[5] This consists of an electromagnetic current through an electrode that is placed inside the tumor. It causes a temperature rise caused by molecular friction and ionic agitation. Cell death occurs by thermal necrosis.

Ablation produced by microwaves[6,7] produces a coagulation due to the heat produced by the agitation of the water molecules. The advantage over radiofrequency is that microwaves propagate through all tissues, even dehydrated ones.

Other less used methods are laser ablation, which has the disadvantage that the necrosis caused is in a very small area. Cryoablation causes cold necrosis and its advantages are control of the tumor area by computed tomography (CT), magnetic resonance imaging (MRI) and ultrasound (US) as the treated area appears hypodense and causes less pain than other techniques and the high intensity focused ultrasound (HIFU) ablation causes necrosis without passing through the skin since the US beams are focused on the tumor. The disadvantage is that air, cortical bone, metal, and other factors prevent the correct placement of the bundles.[8]

These techniques can be used alone or in combination with cement reinforcement techniques. In the management of painful vertebral metastases[9] radiofrequency ablation (RFA) achieves a decrease in pain and short-term disability.

The main indication for ablation includes multiple myelomas[10] and vertebral metastases.[11]

The objective of this study is to describe the experience in the treatment of patients with vertebral metastases using percutaneous ablation and cementation techniques.

Material and methods

This is a retrospective study in which the results of two cohorts are presented. The first is the group in which RFA was performed and the second is the group in which microwave ablation (MWA) was performed. Each procedure was performed at a single center.

Inclusion criteria are patients with bone metastases and multiple myeloma with limiting pain not controlled by opioids or radiation. Osteolytic or mixed tumors in which pedicle access was possible were included. Patients with osteoblastic metastases and those in whom pedicle access was not possible were excluded from the study.

Surgical technique

In the RFA group, surgery was performed percutaneously in most cases and guided by fluoroscopy with a transpedicular approach to the vertebral body (when associated with open surgery, surgical incision was used). A 10G cannula was inserted and a flexible steerable osteotome was used to create one or more bone channels. The number of channels made and the unipedicular or bipedicular approach depended on the tumor extension. For RFA, the Tumor Ablation System (STAR) (DFINE; San José, CA) was used, which includes an articulated probe that allows the introduction and directing of a bipolar electrode. The probe is able to monitor the temperature acquired by the electrodes during the procedure, and the radiofrequency energy stops when the proximal sensor (located 15 mm from the center of the electrode) registers 50°. In the cases in which cementation was associated, this was performed immediately after the ablation, using the Stability Vertebral Augmentation System (DFINE; San José, CA). Arthrodesis was associated with those patients with instability or massive involvement of the vertebral body and open decompression was associated with cases with neurological compromise. A total of 14 patients (15 interventions, one of the patients required a second ablation) and 26 vertebrae were included.

In the microwave ablation group, surgery was performed using two systems. The ECO-100A1 MW ablation unit with a frequency of 2450 MHz (ECO Microwave Electronic Institute, Nanjing, China) and the AMIKA-GEN 2.45 GHz ablation unit (HS Hospital Service, Aprilia, Italy). The procedures were performed in hybrid operating rooms and in angiographic rooms converted into ambulatory operating rooms equipped with Philips Azurion 7 C20 FlexArm angiographic equipment as an image-guided therapy system. Surgery was performed percutaneously guided by fluoroscopy with a transpedicular approach to the vertebral body. The unipedicular or bipedicular approach depended on the tumor extension. When necessary due to the characteristics, location or size of the tumor, a computerized axial tomography (CT) was performed to assist the process. A 12 or 14G cannula was introduced into the pedicle and a 3D rotational acquisition was performed to adjust the angle and direction of the cannula, through which the antenna was coaxially inserted into the tumor. According to the ablation parameters provided by the manufacturer and the location of the tumor, the appropriate power and time were selected. MWA power was 20–40 W. Repeated short microwave cycles (30–90 s) were performed. Total ablation time was 3–5 min. In case of location close to neural structures, hydro or pneumodissection of the epidural space was performed through transforaminal access. In cases in which vertebroplasty was associated, cementation was performed immediately after ablation. Ninety-three interventions and 129 vertebrae were performed.

Evaluations

The study variables recorded were: the age and sex of the patient, the anesthetic risk according to the American Society of Anesthesiology (ASA) anesthetic risk scale, the affected vertebrae, the histology of the primary tumor, and the postoperative evolution time. The surgical data recorded were the number of vertebrae treated, unipedicular or bipedicular access, the number of ablations performed at each level, the performance or not of cementation associated with the ablation, and the need to add further surgical treatment, such as spinal cord decompression or arthrodesis of the affected levels.

To assess the effectiveness of the procedure, pre- and postoperative pain was recorded according to the VAS, and functionality was assessed using the pre- and postoperative Oswestry Disability Index[12] (ODI) scale.

All patients underwent prior imaging tests: X-rays, CT, and MRI. Vertebral body or pedicle involvement was evaluated for surgical planning. The same tests were performed postoperatively to observe tumor evolution.

All patients gave their informed consent to participate in the study.

Statistical analysis

A statistical analysis was made of the RFA results using the SPSS® program, version 18.0 (SPSS Inc., Chicago, IL, USA). Values of $p \leq .05$ were considered significant. The Wilcoxon test was used for paired samples, due to the small sample size, the improvement of pain in the VAS and of the disability in ODI were evaluated.

With the data from the MWA, a descriptive analysis was carried out, exposing the values of the means and standard deviations of the pre- and postoperative pain values in the VAS.

Results

General data

One hundred and seven patients underwent surgery during the study period by vertebral tumor ablation for myeloma or vertebral metastasis.

Table 1 shows the types of primary tumor by number of patients and distribution of affected vertebrae in the RFA group. Most of the tumors were located in the lower back and upper lumbar area.

Of the 107 patients, 14 patients (eight women and six men, one of whom was operated on twice) with a total of 26 tumors belonged to the RFA group. The mean age was 67 years and the ASA was 3.1. Ninety-three patients with a total of 129 operated vertebrae belonged to the MWA group.

Table 1 Primary tumors and location in the radiofrequency ablation series.

Primary tumor	Number of patients	High lumbar (L1–L3)	Low lumbar and sacrum (L4–S1)	High thoracic (T1–T6)	Low thoracic (T7–T12)
Multiple myeloma	5	2	2	–	6
Lung cancer	4*	1	–	2	2
Bladder	1	1	–	–	1
Kidney	1	–	–	–	2
Ovarian	1	2	1	–	–
Cholangiocarcinoma	1	–	–	3	–
Thyroid	1	1	–	–	–

* One of them was operated on a second time, due to the appearance of another tumor.

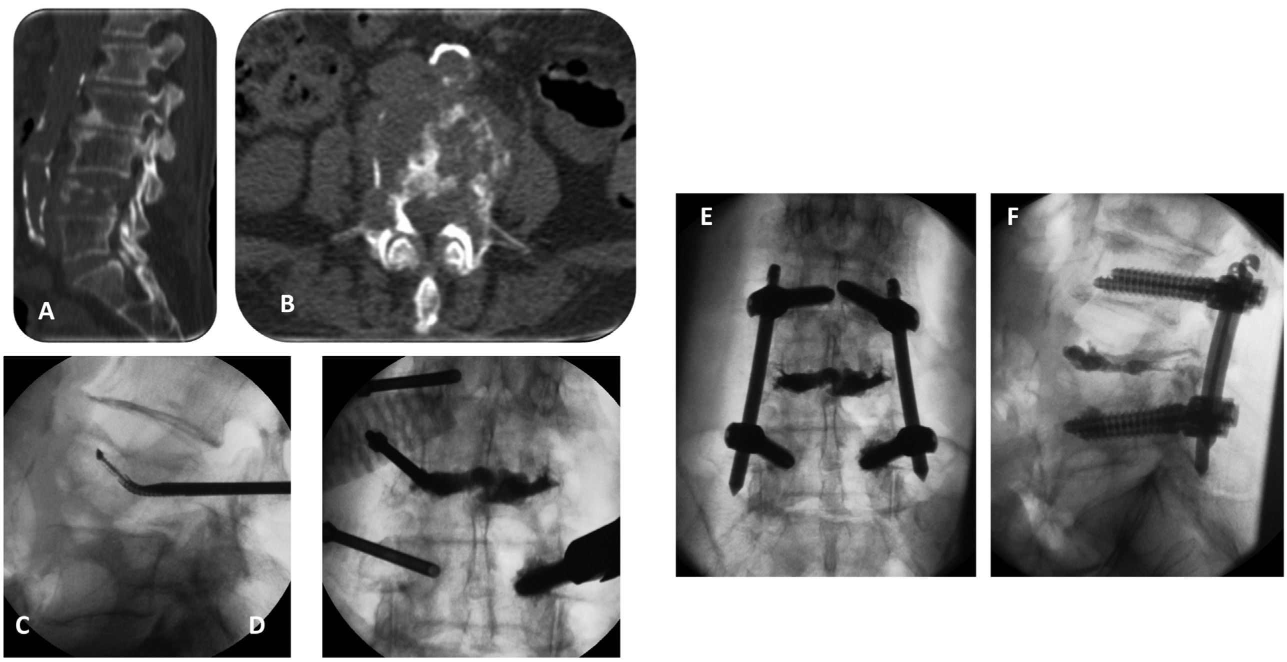

Figure 1 Sixty-nine-year-old patient, metastatic adenocarcinoma of the lung. Patient bedridden for two months with high doses of morphine for low back pain (VAS 9) and pain in the lower extremities. Previous radiotherapy. (A) L4 fracture due to metastasis. (B) Axial CT scan showing posterior and anterior wall destruction. (C) Radiofrequency ablation. Electrode directed to the upper plateau. (D) Cementation. (E and F) Percutaneous fixation L3–L5. The patient returned to walking with marked improvement in pain (VAS at 2).

Procedure

In the RFA group, 21 out of 26 vertebrae underwent cementation of the tumor. Additionally, open spinal cord decompression was performed with instrumented arthrodesis in three cases and percutaneous arthrodesis in one case (Fig. 1). In the MWA group, cementation was associated in all cases (Fig. 2) and in no case was associated surgery performed.

The approach used in the MWA group was unipedicular in 58% of the vertebrae and bipedicular in 42%. In the RFA group, unipedicular was used in 63% and bipedicular in 37%. Bipedicular was preferred in large tumors that were not accessible through a single pedicle.

The most frequent complications were increased postoperative pain (2 cases in the RFA group and 11 in the MWA group). There were no symptomatic leaks or neurovascular tumors.

During follow-up, no patient presented pathological fractures despite the fact that the tumors were subjected to load-bearing.

Function

Median follow-up was eight months in the RFA group (six weeks to 21 months) and 6.5 months in the MWAO group.

There was a significant improvement in pain between the preoperative period and the last review on the VAS ($p < .05$). In the RFA group, the VAS score prior to the intervention was 7.7 ± 1.9, decreasing to 2.6 ± 1.6 in the first post-surgical review, carried out six weeks after the intervention (Table 2). With this technique it was therefore possible to

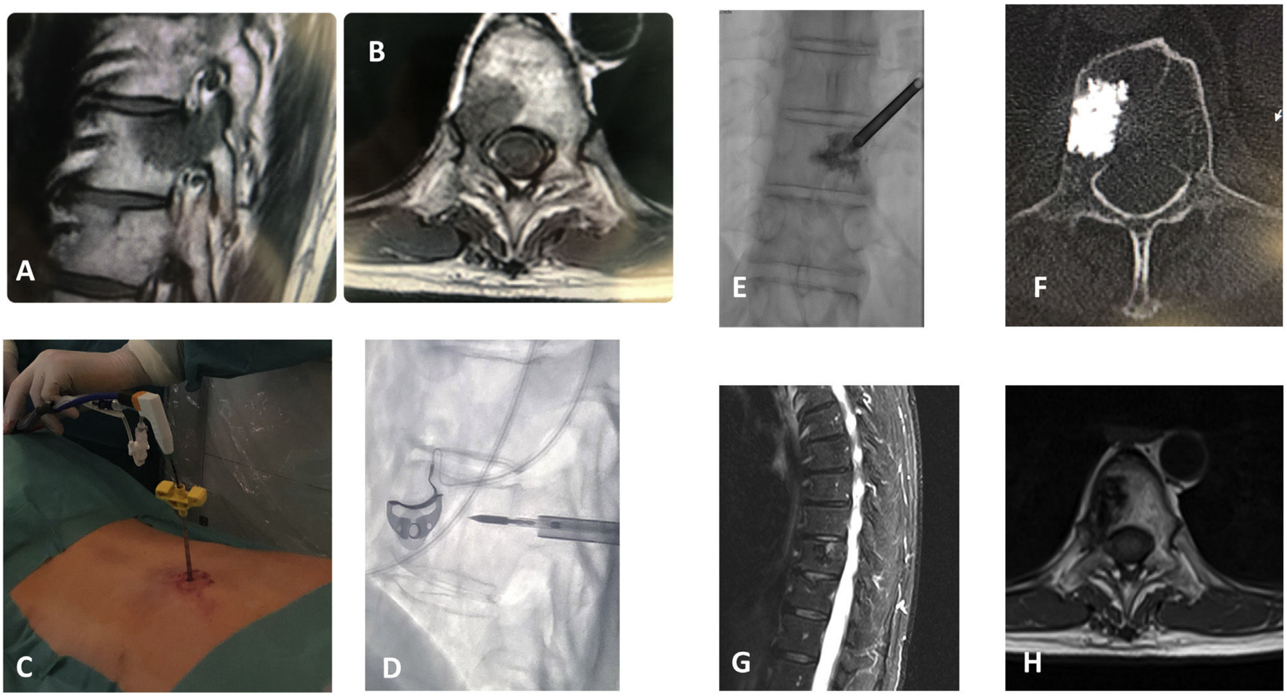

Figure 2 Sixty-six-year-old patient, colon tumor metastasis. (A and B) Metastatic lesion at T10 affecting pedicle, posterior wall and vertebral body. (C and D) Two moments of microwave ablation. (E) Cementation. (F) Filling of the vertebral body in CT. (G and H) Result at 12 months in MRI with no signs of tumor progression.

Table 2 Summary of VAS pain results.

Treatment	Number of patients	Number of tumors	Preoperative VAS	Postoperative VAS (at 6 weeks)
Radiofrequency	14	26	7.7 ± 1.9	2.6 ± 1.6
Microwaves	93	129	6.8 ± 1.4	1.7 ± 1.4

Results are expressed as mean ± standard deviation.

reduce an average of 5.1 points on the VAS scale (Table 2). In the MWA group prior to the intervention, the mean VAS score was 6.8 ± 1.4 (Table 2) and at six weeks the mean score was 1.7 ± 1.4 and 73% of the patients were pain-free (Table 2). The result of pain improvement using both ablation methods was very similar.

In the RFA group there was a statistically significant improvement between the degree of disability assessed by ODI12 preoperatively and at the six-week follow-up with $p < .05$. The mean preoperative score was 56.3 ± 31 (severe disability), while the postoperative score, measured at six weeks, was 30.4 ± 15 (moderate disability).

Discussion

Until a few years ago, the technique of choice for treating vertebral fractures without instability and without neurological compression when conservative and radiotherapy treatment had failed, was vertebral cementation. The results obtained are excellent,[13] publishing an improvement in pain from 9.1 in VAS to 2.8. The level of evidence for cementation in vertebral metastatic tumors is the highest, 1-A[14] Cementation is able to stabilize the vertebra and improve pain, also due to the thermal and chemical effect of the cement on nociceptors.[8] However, it is not able to control tumor development beyond the surface in contact with the cement.

It has been shown that after vertebral cementation the number of circulating tumor cells in the blood increases after 20 min in both vertebroplasty and kyphoplasty. This is due to the pressure exerted by the cement or balloon on the tumor which would cause the tumor cells to escape through the blood vessels.[15] Because of this, the creation of a cavity in the tumor by ablation could decrease or prevent this spread. Other experimental strategies would include the addition of antineoplastic drugs to the cement[16,17] which could increase disease control in the short and medium term.

Tumor ablation with or without cementation appears in most of the scenarios proposed by the Metastatic Spine Disease Multidisciplinary Working Group[18] for the treatment of vertebral metastases as a therapeutic option, which shows the importance of incorporating this technique into our therapeutic arsenal. The level of evidence for ablation in vertebral metastatic tumors with or without cementation is II, 2-B.[14]

Our results have been similar to those obtained by other authors with radiofrequency, as in a systematic review of 15 studies in 2021,[9] achieving a decrease in pain and disability in the short term. Our results with the microwave technique have also been similar to those in the literature. A systematic review of eight studies in 2020 concluded that microwave ablation improved short-term pain in patients with vertebral metastases.[7]

We may think, given that there are very good results with cementation alone, that the results obtained in our study may be due to cementation rather than ablation. This is something that we cannot demonstrate in our study, but it can be demonstrated in the literature. This is demonstrated by Goetz et al.[5] in a series of 31 tumors treated by radiofrequency without cementation in which they obtained a clinical improvement in VAS pain from 7.9 to 1.4 at 24 weeks, although there was a risk of fracture in large tumors.

Disease control can be aimed at in small, demarcated tumors where we can ensure good access with ablation cannulae to the entire tumor. In tumors involving the entire vertebral body, disease control is more difficult. In the work of Yildizhan et al.[19] they show that radiofrequency ablation plus cementation achieves better results in controlling pain and tumor progression than RFA alone.

Regarding the comparison of the two ablation techniques used in our study, we have not found any randomized clinical trial comparing radiofrequency with microwaves. Pusceddu et al.[20] observed better results in their cases performed with microwaves – 98% improvement in 98% of cases – than those published by Clarençon et al.[21] with radiofrequency – improvement in 81% of cases. This may be attributable to the technique, but mainly to the fact that in their series all cases were cemented whereas in the Clarençon et al.[21] series only half the cases were cemented, and as we know, this associated technique improves the outcomes. In our study we found similar results with the two techniques, with an average decrease of 5 points in VAS, and they seem equally safe, since we had no complications beyond the exacerbation of pain in the immediate postoperative period attributable to tissue necrosis.

Our study has a number of limitations. Each center used a different ablation technique, so we could not directly compare one technique with another performed by the same operators. The radiofrequency group included patients with vertebral instability due to a pathological fracture in whom percutaneous or open fixation and decompression were performed if required, while in the microwave group the cases were less advanced and did not require additional fixation and decompression.

Conclusions

Radiofrequency and microwave ablation techniques are safe and free from serious complications if performed under strict radiological control. They offer very good outcomes when combined with vertebral cementation. The results of both techniques are comparable in terms of pain improvement after six weeks.

Level of evidence

Level of evidence III.

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Conflict of interests

The authors have no conflict of interests to declare.

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