Diagnostic and Interventional Imaging (2012) **93**, 680—684

ELSEVIER MASSON

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Radiofrequency ablation of bone tumours

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KEYWORDS
Radiofrequency ablation;
Bone metastases;
Pain;
Osteoid osteoma

Abstract The indications for radiofrequency bone ablation in the case of benign tumours (osteoid osteoma, osteoblastoma) are curative, whereas for bone metastases, the prime aim is palliative analgesia. The failure rate for osteoid osteomas is low (< 15%), and 70 to 90% of patients with metastases experience considerable relief, but if the treatment fails, it can be offered again. In the spine, heating can damage neighboring nerve structures, which means they need to be protected (CO_2 dissection). Radiofrequency ablation may be combined with an injection of cement. The osteonecrosis resulting from heating is painful and justifies performing the procedure under general anesthesia.

Pain can significantly alter the quality of life of cancer patients with bone metastases. The prognosis for these patients varies, related to the origin of the cancer, with considerable differences in survival depending on the primary tumour — from a few months for a bronchial carcinoma to several years for a breast cancer.

Approximately one third of patients are inadequately relieved by standard treatments, which are often associated with each other and include specific general (chemotherapy, bisphosphonates) or local (surgery, radiotherapy) treatments. In addition, analgesic drug treatment may be inadequate or associated with adverse reactions. To combat recalcitrant pain, alternative, image-guided therapeutic methods have developed, particularly methods of tumour destruction based on temperature, such as radiofrequency ablation (RFA) and cryotherapy. RFA is also widely used to treat benign bone tumours, namely osteoid osteomas. This point will also be developed.

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2211-5684/$ — see front matter
http://dx.doi.org/10.1016/j.diii.2012.06.008

Principles

Radiofrequency ablation uses an electromagnetic 300 to 500 KHz frequency current, carried by an image-guided electrode introduced into the tumour. Current phase changes induce local ionic agitation, which triggers molecular friction movements responsible for a rise in temperature. The temperature increases around the electrode and is then distributed by diffusion. The aim is to subject the whole volume of the tumour to be treated to a temperature higher than 70 °C in order to achieve irreversible cell death by coagulation necrosis of the cell proteins, tumour cells being no more resistant to heat than normal cells.

It has been shown that when the cortical bone of animals is intact, it has such good insulating properties that it is possible to heat close to joint surfaces without damaging the cartilage [1]. It has also been shown that there is a strong correlation between the size of the area of necrosis induced by the heating measured macroscopically, and the size of the ablation area measured by MRI [2]. When there are metastases, the pain, other than from fractures, is caused by a number of different factors and mechanisms, which are often associated: the release of chemical mediators stimulating bone and periosteal nociceptive fibres, mechanical factors such as an increase in intraosseous pressure due to the tumour, or stretching and distortion of the periosteum, reactive muscle contractions, infiltration and nerve compression causing neuropathic pain, etc. The pain is felt as background pain combined with spikes of breakthrough pain; it is not necessarily related to the degree of metastatic destruction. The heating induced by RFA does not produce consolidation but acts on the nerve endings and helps curb the volume of the tumour.

To treat these metastases, there are straight electrodes and electrodes with deployable tines. The equipment used varies depending on the amount of bone destruction required: deployable electrodes certainly need sufficient tumour tissue volume to be opened and are impossible to use in osteoblastic metastases.

Technique

In practice, the procedure is performed under CT or flat-panel detector guidance. The latter method uses software to help positioning; the procedure can be performed under radioscopy, while still having access to slice reconstructions. Hygiene rules need to be the same as for surgery in order to avoid any problem of infection, and the procedure is performed under general anesthesia because RF ablation is painful. If the cortical bone is preserved, it is drilled in advance with an 11 or 13 G trocar to prepare the path for the electrode (case n° 1, Fig. 1a—d). If the trocar is not insulated it must be withdrawn before the electrode is introduced, so as to avoid any burning along the pathway.

Indications and results

Radiofrequency ablation of bone metastases can be used alone or associated with stabilization by cementoplasty. Gangi has proposed a decisional algorithm [3,4]. For all the bones subjected to mechanical compression stresses, such as the vertebrae or acetabula, stabilization by cementoplasty is a priority and is often sufficient. RFA is offered if there is periosseous extension of the tumour, in order to reduce tumour volume, or in the case of an isolated metastasis, or one evolving slowly, which then requires local antitumour treatment that is as complete as possible. For the flat bones of the rib cage (case n° 2, Fig. 2a—c), the iliac wings, the superior pubic or ischiopubic rami, RFA is indicated in as far as the mechanical stabilizing effect of cementoplasty is less necessary. Few studies have evaluated the radiofrequency ablation of metastatic bone lesions. In a study [5], in 55 patients, RFA produced a significant reduction in pain, and a significant improvement in the relief felt and in mood, all assessed at one and three months. When the patients' least intense pain before RFA was compared with the same at three months after the treatment, the Odds ratio was eight (95% CI, 0.9—15.2; $P < 0.001$). Three patients presented grade III toxicity. Another feasibility study in 12 patients confirmed the analgesic efficacy of the technique with an absence of serious complication [6]. A multicentre trial evaluated RFA in a larger cohort of 43 patients who had painful, refractory, pelvic or sacral lesions of between 1 and 18 cm in size [7]. With assessments at 4, 12 and 24 weeks, 95% of them described improvement in their pain (a fall of at least two points in the most intense pain); a reduction in the consumption of analgesics was also shown at 8 and 12 weeks. Three incidents need to be mentioned: a cutaneous burn, transitory faecal and urinary incontinence following treatment of a sacral location, and an ace tabular fracture. One of the advantages is being able to reapply the treatment if the pain reappears: there is no dose-related limitation as in radiotherapy. Osteoblastic metastases are a good indication for the technique.

Evaluating the relief provided is sometimes difficult in these patients, because other bone metastases may become symptomatic. A prospective study is underway financed by the French Hospital Clinical Research Programme (PHRC). Its objective is to determine the analgesic efficacy at eight weeks following RF ablation of painful bone metastases refractory to radiotherapy, bisphosphonates and properly managed analgesic opioid treatment. An osteoid osteoma is a small, benign, intracortical bone tumour, and was the first type of bone tumour treated by thermal ablation [8,9]. RFA is close to 90% effective in dealing with the symptoms associated with this type of tumour, and because of the ease and efficacy of thermal ablation procedures (RF, laser), they have ousted surgery. A typical intracortical osteoid osteoma is less than 20 mm and appears as a lacuna (nidus) associated with cortical osteosclerosis. It fixes the tracer in scintigraphy and perilesional edema is visible with MRI. It is not imperative to perform a biopsy [10]; this should rather be reserved for atypical lesions [11]. However, in children or young adults, it is better to have histological evidence confirming the benign character of the lesion, especially since the biopsy does not lengthen or complicate the procedure. During the procedure, the route to be taken by the electrode for insertion into the nidus needs to be prepared by drilling the cortical bone. If the osteoid osteoma is located near the skin (in the anterior surface

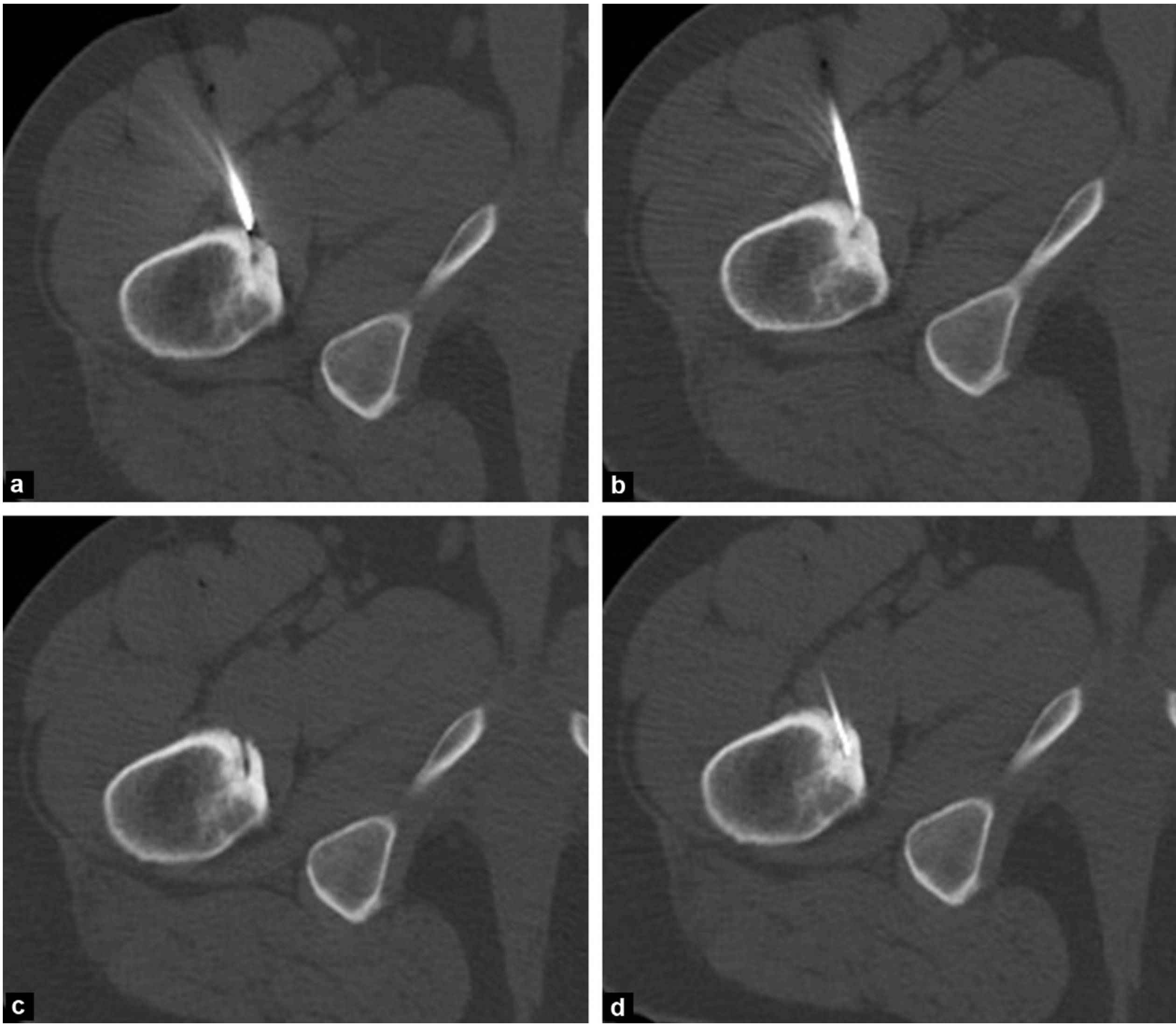

Figure 1. a, b: insertion of the bone biopsy trocar (11G coaxial system); c: biopsy path; d: position of the electrode in the biopsy path (straight electrode with a 7 mm active tip).

of the tibia, the radius, etc.), it is desirable to cool the skin to avoid burning. Follow-up imaging will show complete ossification or a residual nidus. Recurrence, often due to incorrect positioning of the electrode, can be retreated [11].

Complications

One of the problems of bone radiofrequency ablation is the potential risk of causing damage to nerves near the bone structures. It has been demonstrated in animal studies that the temperature of soft tissue adjacent to the radiofrequency ablation site depends on the thickness of the cortical bone, the distance relative to the periosteum and the duration of the radiofrequency treatment [12]. In order to avoid damaging nerve structures, maintaining a safety distance of 10 mm is recommended between the periosteum and the nearest nerve structure when the thickness of cortical bone between the electrode and the periosteum is less than 5 mm [13]. With bone metastases, it is obviously necessary to bear in mind that the cortical bone is often pathological and consequently its effect as an insulator is limited, with the risk of the area of thermal ablation extending into periosseous regions.

The risk of neurological damage due to a thermal lesion is greatest in the spine. If the lesion to be treated is too close (less than 10 mm) to a neurological structure (the spinal cord, a nerve root) there is a risk of the heat causing irreversible damage. A thermocouple must be positioned in contact with the organ to be protected, in order to check the temperature during the procedure, and this organ separated from the area of thermal ablation. This is possible by injecting a non-ionic solution or CO_2 to create an adequate barrier between the area to be heated and the neighboring organ [14,15]. CO_2 is practical and easy to use [16]. There are but a few other complications related to this technique when applied to bone:

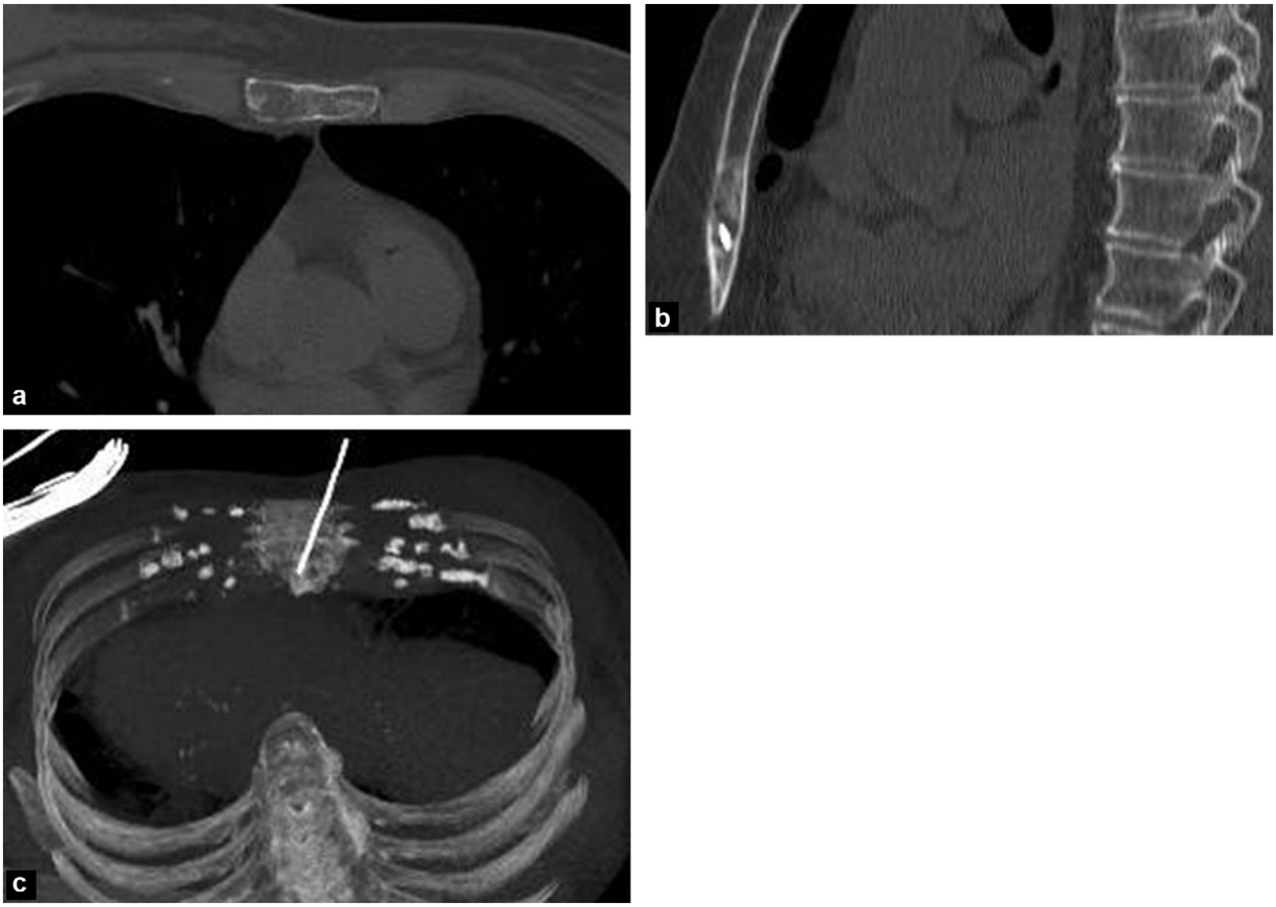

Figure 2. a: painful metastasis of a breast cancer, poorly relieved by level three analgesics; b, c: radiofrequency ablation: straight electrode with a 2 cm active tip in place. Efficacy for relieving pain almost complete (at 1 year).

- considerable increase in pain may occur immediately following the procedure, related to the brutal necrosis caused by the heat. This risk justifies the procedure being performed under general anesthesia and makes close analgesic monitoring in the first few hours essential;
- a cutaneous burn can occur at the patient return electrodes; this problem arises when exposure to the radiofrequency current is prolonged (> 20 minutes) and when the power delivered is considerable (> 150 W). These conditions are rarely met during radiofrequency ablation of bone tissue. To decrease this risk, simply watch the temperature during the procedure at the grounding pads placed on the patient's thighs;
- infection of the focus being treated is a possible risk but should be avoidable if surgery hygiene and asepsis measures are observed.

Conclusion

The decision must be multidisciplinary, taken together by the interventional radiologist, the radiotherapist, the pain specialist, the medical oncologist and the surgeon. The results of RFA are excellent for treatment of osteoid osteomas.

TAKE-HOME MESSAGES

- Radiofrequency ablation is very effective for benign bone tumours (osteoid osteomas).
- RFA treatment of bone metastases provides relief to the majority of patients.
- If the analgesia obtained is inadequate, radiofrequency treatment can be repeated.
- For the spine and acetabulum, radiofrequency ablation can be associated with cementoplasty.

Clinical case

Case nº 1

Osteoid osteoma of the lesser trochanter treated by RFA (Fig. 1).

Case nº 2

Painful sternal metastasis of a breast cancer (Fig. 2a) inadequately relieved by level three analgesics; radiofrequency ablation (Fig. 2b and c) almost completely effective on the pain (at one year).

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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