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CONTINUING EDUCATION PROGRAM: FOCUS...

Percutaneous ablation of bone tumors

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Abstract Percutaneous ablation (radiofrequency or cryotherapy) of bone tumors is most often performed for palliative purposes. Many studies have shown that percutaneous ablation of a painful bone metastasis can significantly and sustainably reduce symptoms. It is therefore an alternative to radiotherapy and to long-term opiates. Percutaneous ablation can also be performed for curative purposes. In this situation, its efficacy has however only been studied to a very small extent (apart from radiofrequency ablation of osteoid osteomas in which the success rate is almost 100%). In our experience, the success rate after radiofrequency ablation of a bone metastasis is 75% if it is less than 3 cm in diameter and fall significantly over this (to 40%, $P = 0.04$). This treatment can therefore be justified in oligometastatic patients whose disease is progressing slowly. Its benefit on survival has however not been assessed in this selected population. Whether it is performed for palliative or curative reasons, percutaneous ablation should ideally be followed by an injection of cement if the metastasis being treated is lytic and located in a bone, which is subject to mechanical forces. The aim of consolidating cementoplasty is to counterbalance the additional risk of fracture due to destruction of the percutaneously ablated bone.

The tumor destruction techniques used routinely to treat bone metastases are the 'thermal' ablation techniques such as radiofrequency and cryotherapy.

Radiofrequency ablation involves positioning a needle electrode under CT guidance inside the tumor in order to deliver an alternating current of 400 to 500 kHz. The regions through which this radiofrequency beam passes are subject to ionic agitation, which heats the tissue as a result of friction between the particles. The desired aim is to expose the tumor cells to a temperature over 60 °C, which almost immediately and irreversibly denatures them.

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In the same way, cryotherapy requires one or more needles to be positioned within the tumor under CT guidance. The principle of this technique is based on the Joule-Thompson effect: rapid decompression of argon gas at the end of the needle reaches a temperature of −180 °C in a few seconds.

These 'thermal' ablation techniques, which were initially used as curative treatment for liver tumors [1,2], are now being used for other sites including kidney [3,4], lung [5,6] and bone [7—11] tumors. Heat ablation of bone tumors has several specific features compared to other anatomical sites. The first is related to the electrical and thermal properties of the bone structure. Trabecular bone conducts heat less well than muscle and the volume of the area destroyed is therefore less in bone than in muscle. In addition, cortical bone has heat insulating activity [12], which protects neighboring structures, provided that cortical bone is preserved. This heat insulation can also be used advantageously to treat internal bone tumors thanks to the 'oven effect', which concentrates heat on the tumor site as opposed to other organs. The other specific feature of thermal ablation of bone metastases is due to the fact that the indications are rarely curative but usually palliative in patients with pain. Very few studies are available on the curative efficacy of ablation of bone tumors, probably because the indications for this are very rare and only one study has been published on the subject [9]. This was a retrospective assessment of the efficacy of curative cryotherapy on 37 bone metastases in 17 oligometastatic patients. The local control rate was 68% at 1 year, all bone tumor histologies combined, probably because the indications for its use were extremely limited. In our experience (122 bone metastases treated with curative purposes in 89 patients between September 2001 and February 2012), the complete response rate was 67% at 1 year and the tumor size of under 20 mm was predictive of success ($P = 0.001$). Kashima et al. [13] showed that complete curative treatment of bone metastases from a hepatocellular carcinoma was an independent predictive indicator for survival in this population with a response rate and 3 year median survival of 10.4% and 16.8 months, respectively if treatment was complete compared to 0% and 6.5 months with incomplete treatment ($P < 0.04$). Several recent studies however [13—15] have demonstrated the analgesic effectiveness of radiofrequency and cryotherapy ablation on painful bone tumors. One prospective multicenter trial has been carried out on palliative care for bone tumors [14], which included 43 patients with lytic bone tumors between 1.4 at 18 cm in size, causing pain scoring an average of 7.9 points on a pain assessment scale ranging from 1 to 10 points. In this study, radiofrequency ablation achieved a 3 point reduction in pain severity in 40 % of patients after 1 week, in 55% after 3 weeks, and in 84% at some time after treatment. Other more recent studies report similar results (Table 1).

The aim of thermal ablation in the treatment of bone pain is not to destroy the entire tumor but rather to target the margins between tumor and bone structures in order to try to destroy endosteal nerve endings which are probably greatly involved in the origin of pain as a result of their stimulation by chemicals such as prostaglandins and bradykinine, substance P or histamine, which are released by the destroyed bone. Whilst the specific heat sensitivity of nerves is used in the treatment of pain, it should be remembered that all neuronal structures including the spinal cord are very heat sensitive. Temperatures of over 45 °C or under 10 °C are considered to be toxic to the bone marrow and peripheral nerves. As a result, the procedure must be performed extremely cautiously for spinal tumors. A vertebral body tumor can be treated with heat ablation therapy provided that cortical bone is still present in the posterior vertebral wall and it is more than 1 cm from the spinal cord. It would appear somewhat arbitrary to believe that heat is dissipated by thermal convection as a result of CSF circulation or the periarachnoid venous plexus is sufficient to protect the spinal cord as suggested by some authors. In addition, a high complication rate has been reported in the treatment of vertebral tumors. Cryotherapy appears to be more appropriate than radiofrequency ablation for these bone sites close to neurological structures. The area of freezing which develops around the tip of the needle can occasionally be visualized on CT during the procedure (Fig. 1). As peroperative cryotherapy is less painful than radiofrequency ablation, conscious patient sedation is possible.

Cryotherapy therefore offers a clear advantage for CT and clinical monitoring of complications compared to radiofrequency ablation.

Regardless of whether administered palliatively or curatively, heat ablation should ideally be followed by injection with cement when the metastasis, which has been treated, is lytic and located in a bone subject to mechanical forces (Fig. 2). The aim of consolidating cementoplasty is to counterbalance the additional risk of fracture caused by the thermal destruction of bone.

Table 1 Change in pain on visual analog scale (VAS) after radiofrequency (RF) ablation of painful bone metastases.

	Number of patients [Reference]	Number of tumors	Before RF	Number of week(s) after RF				
				1	4	8	12	24
VAS	43 [14]	43	7.9	7.3 ($P = 0.2$)	4.5 ($P < 0.0001$)	3.5 ($P < 0.0001$)	3.0 ($P < 0.0001$)	1.5 ($P < 0.0005$)
	29 [13]		6.1	1.8 ($P < 0.001$)				
	30 [15]	34	8.3	4.9	3.6	2.1		