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REVIEW /*Interventional imaging*

Expanding the borders: Image-guided procedures for the treatment of musculoskeletal tumors

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Abstract Interventional radiology has revolutionized the local management of bone tumours, offering new minimal invasive alternatives to surgery and radiotherapy. Its role has continuously increased over the past years for the treatment of benign tumors and also of some malignant ones, especially in palliative situations. The development of protective techniques and new ablative technologies, such as cryoablation, contributes to expand the role of the interventional radiologist to new fields of applications in musculoskeletal oncology.

Musculoskeletal (MSK) tumors represent a wide variety of tumors, ranging from benign non-neoplastic lesions (such as vascular malformation or osteoid osteoma for example) to locally aggressive lesions (desmoid tumors) and primary/secondary malignant tumors (sarcoma, metastases) [1,2]. The classical management of MSK tumors involves surgery to resect the lesion and consolidate the bone if necessary; and radiation therapy to complete the results of surgery, or as a solitary treatment depending on the specific situation [3—5]. However, this approach does not allow managing all patients with these conditions properly. In this perspective, percutaneous image-guided interventions may represent a valuable alternative for some MSK lesions [6].

The beginning of interventional radiology in MSK treatment

Interventional radiology (IR) started to be included in the treatment algorithm of MSK lesions in the 1990s [7,8]. The

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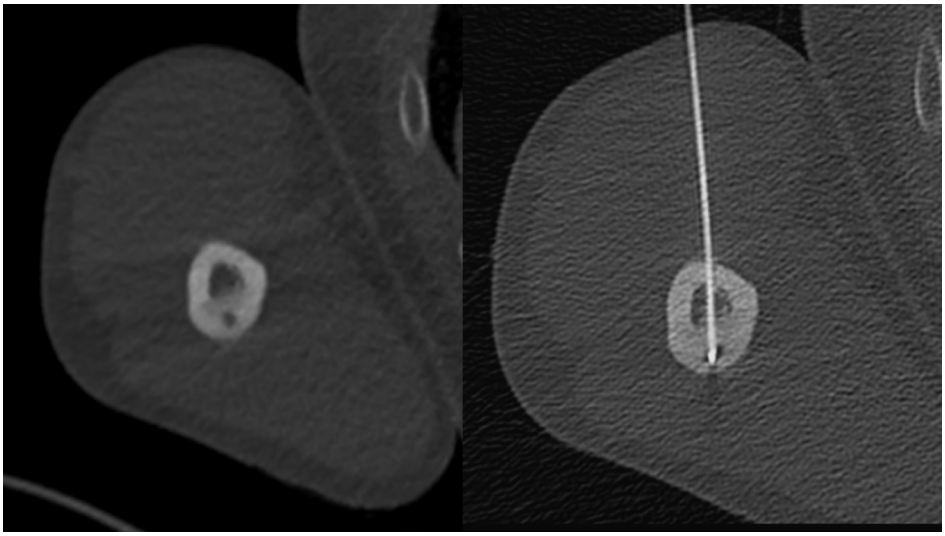

Figure 1. Radiofrequency ablation (RFA) of a humeral osteoid osteoma. Computed tomography image in the transverse plane demonstrates a 7-mm active tip RFA probe located inside the nidus.

treatment of osteoid osteoma represents one of the first major breakthroughs of IR in the world of orthopaedic surgery. For years, complete surgical excision of the nidus was considered as the gold standard treatment of this small (< 1 cm) benign lesion [9]. However, surgery was challenging as it involved large excision with potential functional consequences [10]; there was also a risk of mistargeting the tumor that is most of the time not visible during open surgery [11]. With the development of computed tomography (CT)-guidance [12], osteoid osteoma became a target for interventional radiologist [13]. The percutaneous approach for osteoid osteoma initially included ablation using either ethanol injection or laser [14,15], or manual excision with large biopsy devices [16,17]. In all cases, IR was associated with a high rate of complete ablation, a low rate of complication, and a short hospital stay [18]. As a result, IR rapidly became the new standard for the treatment of osteoid osteoma (Fig. 1). Later on, radiofrequency ablation (RFA) contributed to expand the indications of IR, with a primary success rate greater than 90% [19]. Until recently, lesions close to the spinal cord or radicular/troncular nerves were still electively resected because of the risk of unintended neural thermal damage with thermal ablation [20].

Another success story of IR in MSK tumors management was the development of percutaneous interventions to treat low-flow vascular malformations, therefore offering new minimal invasive treatment possibilities for benign lesions that would otherwise require extensive surgery [21,22]. Hence, cementoplasty was described for the first time in 1987 for the management of an aggressive C2 spinal hemangioma [23]; and is still widely used in that specific indication with excellent results [24]. Percutaneous sclerotherapy was also one of the earliest percutaneous interventions offering a valuable minimal invasive alternative for the treatment of some symptomatic low-flow vascular malformations [25]. Like cementoplasty, it is still part of the arsenal of the interventional radiologist to treat such lesions [26].

Finally, IR was also involved in the management of malignant bone tumors [27]. RFA is a heat-based technology that uses an alternating current to produce coagulation necrosis [28]. This modality changed the face of IR and oncology at the end of the 1990s/beginning of the 2000s, as it offered treatment possibilities for patients with malignant liver, kidney and lung tumors, who were otherwise untreatable [29—31]. Rapidly, RFA was also studied in bone and showed excellent results in palliative oncology [32]. The management of painful bone metastases is complex because external beam radiation therapy (EBRT), the gold standard treatment [33], is associated with a primary success rate of around 70%, and a symptom recurrence of 50% after 6 months [34]. As a result, not all patients benefit from radiotherapy and some of them might require repeated EBRT, which can either be not effective or not feasible because of dose limitations [35]. In this perspective, RFA showed promising results with a response rate of 75%, even for patients refractory to EBRT or without previous EBRT treatment [36]. Another advantage of percutaneous RFA is the delay of response (usually a few days, faster than with EBRT), which is not linked to the histological type of metastasis (kidney or colon bone metastases for example are reported to be more resistant to EBRT than other cancers) [36].

Expanding the indications of IR with technical improvements

Since the introduction of IR treatments into the field of MSK tumors, many technical improvements have occurred and helped to expand the indications of percutaneous interventions.

The game changer: cryoablation

Cryoablation is a cold-based modality, which started to be used by interventional radiologists in the beginning of the 2000s [37]. Originally, cryoablation was using liquid nitrogen and was developed for surgical purposes [38]. First