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Research Article

Percutaneous Treatment Of Benign Bone Tumours, Are They Safe And Effective Options?

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Abstract

Purpose: To Analyze the safety and efficacy of percutaneous radiofrequency and cryotherapy on benign tumors of the locomotor system, in addition to assessing its complications to establish some recommendations for use.

Material and methods: Retrospective study in which 41 patients treated between 2000 and 2021 were collected, with the following inclusion criteria: diagnosis of benign tumors (clinical-radiological and/or pathological diagnosis), who were treated percutaneously guided by CT with radiofrequency or cryotherapy. We analyzed demographic and clinical data before and after the procedure, tumor location, response to treatment, local and orthopedic complications, and local recurrence. Statistical analyzes were performed with IBM SPSS Statistics 25.

Results: We studied 41 cases with a mean age of presentation of 36.9 years (11-71), and a mean follow-up of 14 months (3-36). Histologically confirmed: 12 osteoid osteomas, 4 chondroblastomas, 3 osteoblastomas and one phosphaturic mesenchymal tumor, including 21 osteoid osteomas without histological confirmation despite biopsy.

We performed radiofrequency in 34 patients and cryotherapy in 7. Relapse of symptoms occurred in 10 patients. There have been no local or orthopedic complications derived from thermal therapies for the treatment of tumors.

Conclusions: CT-guided radiofrequency is a minimally invasive, safe, and highly effective treatment for these tumors. In certain anatomical locations it could be subject to joint or vascular-nervous complications. In this sense, cryotherapy allows direct control of the volume of treatment, defining its limits more accurately, to avoid said complications. Therefore, both techniques are safe, effective, and interchangeable in the treatment of this pathology. We recommend individual planning for each case.

Keywords : Radiofrequency, cryotherapy, benign bone tumours, percutaneous treatment.

INTRODUCTION

Traditionally, open surgery has been considered the standard treatment for some benign bone conditions. However, since the beginning of this century, technological advances have facilitated the development of multiple minimally invasive techniques. These technologies include the most commonly used radiofrequency ablation (RFA) and cryoablation (CA). (Wu, Xiao et al. 2019). Briefly, RFA delivers high-frequency alternating current to the patient through an RFA probe, trying to reach local tissue temperature reaches between 60°C to produce protein denaturation and instant coagulative necrosis. On the other hand, CA uses a liquid gas, usually argon, and through the Joule-Thompson effect (pressurized gas when allowed to expand, produces a dramatic descent of temperature) results in an enlarging ice ball over time generating cell death.

In addition, percutaneous thermal ablation is a well-established curative treatment for a wide variety of benign mesenchymal tumors, bone and soft tissue, that generally do not metastasize, although they may still cause not only important local impairment because of their growth, but also general complications such as oncogenic osteomalacia. (Cazzato, de Rubeis et al. 2021). (Koch, Cazzato et al. 2018). Some of these conditions are: osteoid osteoma, osteoblastoma, chondroblastoma, mesenquimal phosphaturic tumor, etc. In certain situations, the local and systemic symptoms of these tumors are very subtle at the beginning, so diagnosis is delayed for several months resulting in significant local or general complications. Therefore, stablishing the correct diagnosis is the critical point for these disorders, as well as local and systemic (when needed) staging before performing any biopsy. Subsequently, reviewing the case at de multidisciplinary team meeting is the next step before treatment in any case we are planning to deal with bone or soft tissue conditions.

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These percutaneous modalities of treatment are associated with that may accelerate the recovery of physical function, return to work, and consequently patients can accept minimally invasive procedures more readily than open surgery (Wu, Xiao et al. 2019).(Tomasian, Wallace et al. 2016). Furthermore, percutaneous treatment for these tumors is usually curative after a single treatment with very low complication rates. This successful experience with radiofrequency has resulted in other percutaneous image-guided techniques being attempted, such as cryotherapy. The latter may have some advantages over the former in difficult anatomic locations, because of direct control over the total volume during treatment.

The aim of this study is to analyse safety and eficacy of percutaneous radiofrequency and criotherapy on benign bone tumours, as well as complications in order to stablish their treatment recommendations.

MATERIALS AND METHODS

This single-institution retrospective study includes a consecutive series of 46 patients of our database from 2000 to 2021, with the inclusion criteria of being diagnosed of benign bone tumors that can be treated percutaneously, RFA or CA. A detailed anamnesis was taken from all patients. We analyze demographic and clinical data before and after treatment, type of tumor and its localization, response to treatment, local and orthopaedic complications, and local relapse as well as therapy after the latter. All patients underwent adequate local studies (X-ray, CT and/or MRI, and scintigraphy with TC^{99}), to completely delineate the tumor for complete ablation, characterize the lesion and extent, and assess adjacent neural or vascular structures which require avoidance, displacement, or monitoring (intraoperative neurophysiological monitoring was used when needed).

The diagnosis of the bone lesions was settled by radiologists and oncology orthopedic surgeons, evaluating the clinical and radiological findings separately. With tumors different to osteoid osteoma (OO) and whenever there was a clinical or radiological doubt biopsy was performed before any further procedure. Every case was finally reviewed before therapy at the multidisciplinary team meeting. Routine X-ray imaging follow-up was obtained at 3, 6 and 12 months after ablation. In some cases, with tumors localized in complex anatomy, or after local recurrence MRI and/or CT were performed. The statistical analyses were performed with IBM SPSS Statistics 25.

The intervention

We use two methods, RFA or CA, depending on which entity we are going to treat, the anatomy and structures at risk of being damaged (cartilage, nerves, vessels, tendons, etc). The procedure is performed by the same interventional radiologists and orthopedic surgeons in the CT unit under aseptic conditions, and with the patient under regional o general anesthesia to perform either RFA or CA with strict CT control. Firstly, we do CT scan mapping for the entry point with a radiopaque skin marker. Secondly, under aseptic conditions, percutaneous method is developed by a bone cannula between 8G and 11 G of width, which is placed by hand or with a drill (sometimes a K-Wire is required if cortical bone is very thick). At this time, we take a sample of bone tissue for pathology even if there is previous diagnosis based on biopsy (in case of OO sometimes the tissue is not enough for diagnosis). After checking the position on the CT, the RFA or CA probe is introduced inside the cannula and rechecked its position. Sometimes the procedure requires more than one CA probe depending on the planification targeted volume. Whenever there is a nerve at risk, intraoperative monitorization (IOM) is carried out by our neurophysiology team. This allows us to stop the procedure if any change is detected on the nerves. Additionally, percutaneous fluid dissection is used, using saline or glucose serum, for different anatomical structures at risk, also intraarticular to protect the cartilage. Then we perform RFA or CA as follows.

Radiofrequency

A radiofrequency (RF) generator was used to deliver high-frequency alternating current (375–600 kHz) to the patient through an RFA probe. The current goes through the exposed active tip of the probe and results in oscillation of charged tissue molecules within the ablation zone producing frictional heat. The thermal effect depends on the electrical-conducting properties of the treated tissue as well as the characteristics of the RF probe. When local tissue temperature reaches between 60°C and 100°C, there is protein denaturation and immediate coagulative necrosis. (7). We currently apply RFA energy to achieve a temperature of 90°C for 5 to 6 minutes. Besides, we use active probe tips of 5 or 10 mm depending on the size of the lesion and anatomical localization.

Cryoablation

Cryoablation system uses a liquid gas, commonly argon, and through the Joule-Thompson effect (pressurized gas when allowed to expand, results in a drastic drop of temperature) forms an enlarging ice ball over time, followed by a “thawing” phase, commonly achieved with helium gas, resulting in osmotic gradient. Formation of extracellular ice results in a relative imbalance of solutes between intra and extracellular environment, followed by intracellular water extraction by osmosis and cellular dehydration damaging the enzymatic machinery of the cell and the cell membrane. Furthermore, intracellular ice crystals damage organelles, and even thawing results in osmotic gradient and cell membrane injury. A temperature of minus 40°C or lower is necessary to ensure complete cell death. (7). The ice ball can easily be seen on CT during procedure which allows us to check whether

the whole tumor volume is being treated, as well as to avoid important anatomical structures.
Patients are followed routinely at the orthopaedic oncology unit (clinical and imaging). In the last evaluation of the study, the patients were called by telephone or checked in our unit and questioned whether there were any changes in their final status.

RESULTS

This single-institution retrospective study includes a consecutive series of 46 patients of our database from 2000 to 2021 that matched our criteria. The median age at the procedure was 36 years old (11-71). The time period was selected to assure that every patient completed their follow up time, with a median of 18 months.
According to anatomical location (**Table 1**), 31 of the tumors were located in the lower limb, 7 in the upper limb. Three of them had a pelvic location: 2 in the ilium; 1 in the ischium. And only 5 were located in the axial skeleton: 1 in the lumbar vertebral body, 2 in lumbar pedicles, and 2 in the posterior arch of S2 and S3, close to the corresponding nerve roots.

Table 1. Anatomical location of the benign bone lesions.

Anatomical location	Patients
Femur	17
Pelvis	3
Tibia	10
Tarsus	1
Metatarsus	1
Foot phalanx	2
Humerus	5
Radius	1
Metacarpus	1
Sacrum	2
Lumbar vertebrae	3

Regarding the etiology (**Table 2**) based on biopsy results there were: 12 OO, 4 chondroblastomas, 3 osteoblastoma, 1 bone phosphaturic mesenchymal tumor. The remaining 26 patients had no histological confirmation, even after biopsy during treatment, but based on the clinico-radiological findings they were diagnosed as OO.

Table 2. Etiology.

Etiology	Patients
Osteoid osteoma	12
Chondroblastoma	4
Osteoblastoma	3
Bone phosphaturic mesenchymal tumor	1
OO (No histological confirmation)	26

According to the treatment (**Table 3**) RFA was chosen for 35 patients, while 11 of them received cryoablation.

Table 3. Type of treatment regarding the etiology.

Treatment	Etiology	Location
RFA	34 OO	13 Femur 3 Pelvis 9 Tibia 1 Foot phalanx 4 Humerus 1 Radius 1 Metacarpal 1 Sacrum 1 Lumbar vertebra
	2 Chondroblastoma	1 Femur 1 Tibia
Cryoablation	3 OO	1 Humerus 1 Metatarsus 1 Sacrum
	3 Chondroblastoma	3 femur
	3 Osteoblastoma	1 Tarsus 1 Foot phalanx 1 Lumbar vertebra
	1Phosphaturic Mesenquimal tumour	1 Lumbar vertebra

Local relapse (**Table 4**) occurred in 8 patients, all of them OO. It was confirmed clínically, reappearing the symptoms, and radiologically by CT. 5 of them received a new percutaneous treatment, all of them RFA, except one in S2 lamina with CA. In 3 of them open surgery was deemed a better option.
At the end of the follow-up none of the patients had local or regional complications (hematoma in the intervention site, nerve damage, fracture of the bone, etc.) or related to anesthesia or intervention. Two patients feel non-inflammatory soft pain after osteoid osteoma treated with RFA, which it does not seem related to OO. None of the patients were lost to follow up.

Table 4. Location, treatment and date of relapsed OO.

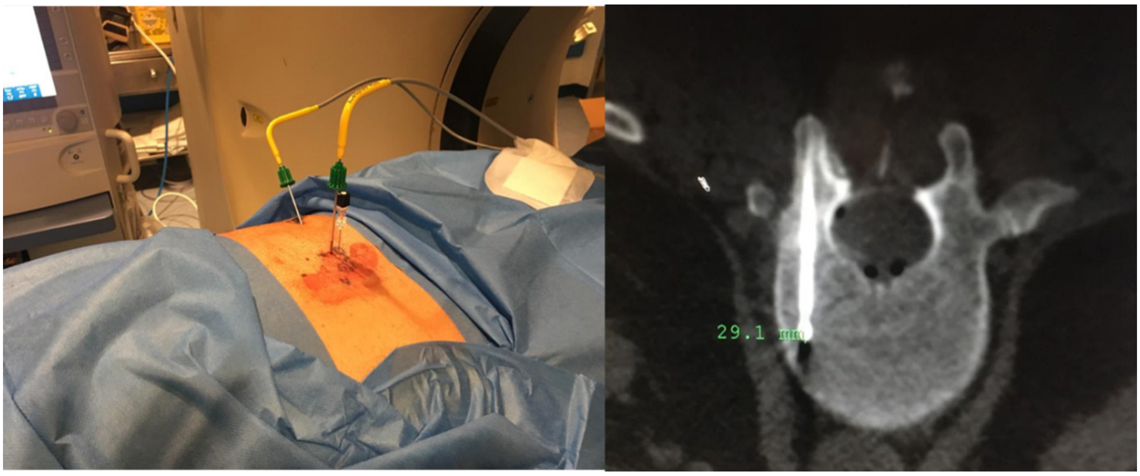
Etiology	Location	Initial treatment	Recurrence Treatment	Date
OO	Femur	RFA	RFA	2010
OO	Femur	RFA	Open surgery	2004
OO	Tibia	RFA	Open Surgery	2005
OO	Metatarsus	RFA	Open Surgery	2005
OO	Tibia	RFA	RFA	2009
OO	Humerus	RFA	RFA	2016
OO	Foot phalanx	RFA	RFA	2020
OO	Sacrum	Cryoablation	Cryoblation	2022

DISCUSSION

Percutaneous ablation treatment of certain benign tumours has become ´the gold standard´. (11, 12) The indications have been widening to other entities as the experience with these techniques has increased. Furthermore, CT guided minimally invasive percutaneous techniques have proven to be safe and effective, causing minimal morbidity in adjacent anatomical structures, with low recurrence rates and minimal orthopaedic related complications (12-19). Even on tumors in difficult anatomical sites such as spine or pelvis, with nerves and vessels at risk, or next to weight bearing bone cartilage, RFA or CA are the first step of treatment after diagnosis (20).

According to our experience, CA may offer some advantages in certain situations. We know that it has been mainly reported for the treatment of OO, but few case reports exist describing management of other benign conditions such as osteoblastoma, aneurysmal bone cyst, and non-ossifying fibroma (7). In our study, we show that we are increasing our experience with this technique treating different tumors in specific anatomical locations (**Figure 1**): one phosphaturic mesenchymal tumour located in L1 vertebral body; three osteoblastoma located in the tarsal scaphoid, in the vertebral lamina of L3 and on foot phalanx; three OO located next to shoulder cartilage, one on posterior arch of S2 and one in a metacarpus; and three condroblastomas right under knee cartilage (2 in distal femur and one in proximal tibia).

Figure 1. CA of mesenquimal phosphaturic tumour located in L3. The CA neddle is placed based on CT and MRI planification.



During their treatment we observed some advantages that we have combined as follows. First, with CA is possible to associate different probes to achieve with precision the targeted preoperative tumor volume. Moreover, the ice ball that forms during the procedure is easily identified in most of the situations on CT, which allows avoiding damaging cartilage of the joints, physis or major neurovascular bundle, by stopping the procedure. Besides, we can check on CT whether the whole tumor volume is being treated during the procedure, reproducing preoperative targeted volume planning. In case tumor location is next to a nerve, we routinely use intraoperative nerve monitoring IOM (**Figure 2**) since 2018 to detect any variation of intraoperative neurophysiology of the nerve so we can stop sharply the procedure without any damage. Additionally, we know that with CA, motor fascicles of nerves or roots are more resistant to its damage than sensitive, which offers us being more confident during the procedure such as the cases located in the spine. Moreover, if index treatment failed, CA treatment may be repeated after new CT imaging planification.

Figure 2. Treatment with percutaneous CA and IOM monitoring, in a 67-year-old patient with OO located in the vertebral lamina of L1.

RFA has been our gold standard for OO (**Figure 3**), using it in 24 cases, as well as one chondroblastoma. This tool produces an "oven-like effect" in the bone as temperature increases, the heat might transmit outside the bone and may damage important adjacent structures. Thus, this treatment should be carefully applied on certain locations such as hand, spine or pelvis, because of the risk of damaging the skin, tendons, vessels, spinal cord or nerve roots (21, 22).

In certain cases, as we did for instance for an OO of the third metacarpal (**figure 4**), we can protect structures such as tendons and subcutaneous nerves roots as well as skin through a mini-open approach to avoid treatment related complications. RFA must be carefully planned.

Our overall cure results of percutaneous treatment of these lesions is 77,8% while the recurrence rate is 22%. This is similar to the current literature (14, 21, 23-27). We have to keep in mind that these entities are benign, being intralesional treatment the gold standard, and thus some likelihood to relapse. All patients were followed for 18 months at least and there were no orthopaedic or medical complications after any percutaneous treatment. The three cases that recurred and were subsequently treated opened occurred at the very beginning of the study. After those ones (table 4) open treatment was not used again after recurrence in the rest of the cases. After relapse, we repeat imaging studies for diagnosis and new treatment planification, and after that we reproduce the percutaneous ablation. For instance, in the case of the OO located in S2 lamina (**figure 5**), we observed in the CT after symptoms relapse that the nidus in the recurrence was at relatively some distance from the primitive one, which helped us for new planification, and the patient was again treated with CA and IOM without complications.

Figure 3. A 21-year-old man with a 2-month history of intense, persistent pain adjacent to the posterior articular surface of the trochlea. A and B: ultrasound-guided localization of the lesion. C and D: Multiplanar CT reconstructions during RFA using a SMK-TC 10-mm electrode.

Figure 4. OO of the third metacarpal of the right hand in a 58-year-old man. A and B Mini-open approach for electrode placement avoiding noble structures such as tendons and cutaneous nerve roots. C and D Multiplanar CT reconstruction of the intraoperative procedure.

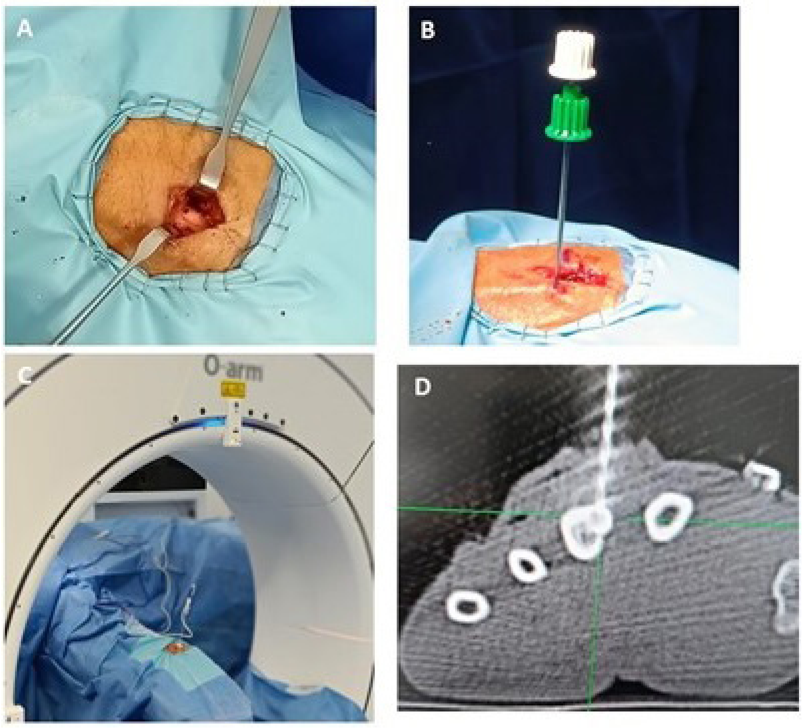
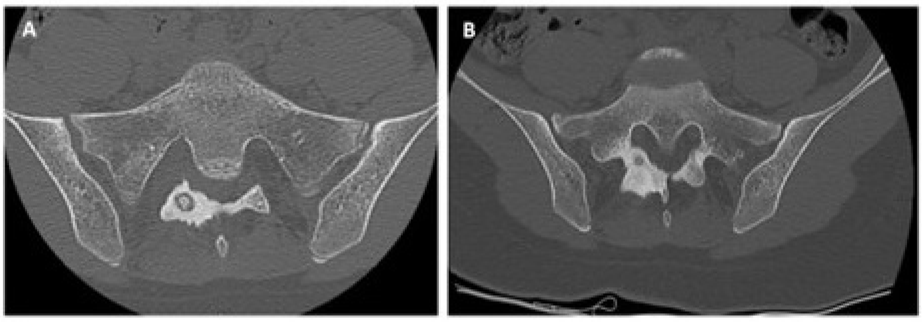


Figure 5. A 15-year-old woman with osteoid osteoma in the posterior arch of S2. A: Multiplanar CT image before the first CA. B: Image of local recurrence 6 months later showing sclerosis of previous nidus, and the new one located distal and posterior from the previous one.



There are several drawbacks in this report such as the low number of cases (41), as well as the absence of a control group and the retrospective nature of the. In addition we have treated different entities which require different preoperative, postoperative planning and follow-up. In 20 cases we were not able to confirm the pathology (all of them were OO based on clinical course and imaging), although not having this verification does not seem to be a disadvantage according to literature for treatment of OO. (21) As we know, due to the difficulty obtaining sufficient histological material confirmation percentages range from 15% to 60%. (21, 23, 28) The results obtained by our unit are promising and consistent with the ones published by other specialized teams, widening the use of CA for other benign bone lesions. It is our belief that open surgery barely has no place nowadays as a first choice treatment in these patients.

CONCLUSIONS

Image-guided percutaneous thermal ablation is a safe and effective treatment of a wide variety of benign bone conditions. The critical stage is adequate diagnosis of the lesions by a multidisciplinary musculoskeletal tumor specialized team in order not to misdiagnose any tumor. Having that in mind, we must carefully plan the treatment focusing on reaching the lesion without causing any harm to the surrounding tissues or any other complications, being CA and RFA excellent options. We strongly recommend performing these procedures in a referral center with multidisciplinary musculoskeletal tumor specialized team, minimizing the patient risk with adequate diagnosis, proper patient selection, careful planning of the procedure, and correct follow-up.

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