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Percutaneous management of bone metastases: State of the art☆

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Abstract Interventional radiology is playing an increasingly important role in the local treatment of bone metastases; this treatment is usually done with palliative intent, although in selected patients it can be done with curative intent. Two main groups of techniques are available.

The first group, centered on bone consolidation, includes osteoplasty/vertebroplasty, in which polymethyl methacrylate (PMMA) is injected to reinforce the bone and relieve pain, and percutaneous osteosynthesis, in which fractures with nondisplaced or minimally bone fragments are fixed in place with screws. The second group centers on tumor ablation. tumor ablation refers to the destruction of tumor tissue by the instillation of alcohol or by other means. Thermoablation is the preferred technique in musculoskeletal tumors because it allows for greater control of ablation. Thermoablation can be done with radiofrequency, in which the application of a high frequency (450 Hz–600 Hz) alternating wave to the tumor-bone interface achieves high temperatures, resulting in coagulative necrosis. Another thermoablation technique uses microwaves, applying electromagnetic waves in an approximate range of 900 MHz–2450 MHz through an antenna that is placed directly in the core of the tumor, stimulating the movement of molecules to generate heat and thus resulting in coagulative necrosis. Cryoablation destroys tumor tissue by applying extreme cold. A more recent, noninvasive technique, magnetic resonance-guided focused ultrasound surgery (MRgFUS), focuses an ultrasound beam from a transducer placed on the patient's skin on the target lesion, where the waves' mechanical energy is converted into thermal energy (65 °C–85 °C). Treatment should be planned by a multidisciplinary team. Treatment can be done with curative or palliative intent. Once the patient is selected, a preprocedural workup should be done to determine the most appropriate technique based on a series of factors. During the procedure, protective measures must be taken and the patient must be closely monitored. After the procedure, patients must be followed up.

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Manejo percutáneo de las metástasis óseas

Resumen La radiología intervencionista tiene un papel cada vez más importante en el tratamiento local, generalmente con intención paliativa, de las metástasis óseas, aunque en pacientes seleccionados puede realizarse con intención curativa.

Disponemos de dos grupos de técnicas principales, de las cuales unas se centran en la consolidación del hueso: la osteoplastia/vertebroplastia, que consiste en la inyección de polimetilmetacrilato para reforzar el hueso y mejorar el dolor, y la osteosíntesis percutánea, que consiste en la fijación mediante tornillos de las fracturas mínimamente/no desplazadas para su consolidación.

Por otro lado, tenemos la ablación tumoral, que nos permitirá la destrucción tumoral, ya sea por instilación de alcohol o a través de la termoablación. La termoablación es la preferida en musculoesquelético, ya que es una ablación más controlada. Dentro de este grupo tenemos: la radiofrecuencia, que aplica una onda de alta frecuencia alternante (450–600 Hz) en la interfase tumor-hueso que alcanza altas temperaturas y necrosis coagulativa; la ablación por microondas, que aplica ondas electromagnéticas (aproximadamente 900 y 2450 MHz) a través de una antena que se coloca directamente en el seno del tumor, produciendo agitación molecular y calor que provoca una necrosis coagulativa; la crioablación, que consiste en la aplicación de un frío extremo para destruir tumores, y, por último, la MRgFUS (Magnetic Resonance-guided focused ultrasound surgery), técnica no invasiva que funciona como un haz de ultrasonidos generado por el transductor colocado sobre la piel del paciente, concentrándose en la lesión diana donde la energía mecánica se convierte en energía térmica (65–85 °C).

El plan terapéutico ha de ser determinado por un equipo multidisciplinar, y puede tener intención paliativa o curativa. Una vez seleccionado el paciente, se realizará un estudio preprocedimiento y se decidirá cuál será la técnica más adecuada en función de una serie de factores. Durante el procedimiento se tomarán medidas de protección y monitorizacióny finalmente se realizará un seguimiento posprocedimiento.

Introduction

Interventional radiology plays an increasingly relevant role in local treatment of bone metastases (BM), generally with palliative intention, although in selected patients it can be performed with curative intention.[1] Its indication has increased rapidly in the last decade, offering new therapeutic solutions in combination with surgery, radiotherapy and medical treatments.

In this article we will review the different techniques along with their indications and the experience at our centre, illustrated by a series of cases.

Epidemiology and clinical manifestations of bone metastases

BM are the most common malignant bone lesions. They primarily affect the axial skeleton, the pelvic ring, and the proximal extremities. In Spain, between 65% and 75% of cancer patients present with bone metastases (although in autopsy studies the figure rises to 85%[2]) it being the third most common location for metastases,[3] after lung and liver metastases. The incidence of BM is particularly high in patients with breast, lung and prostate cancer; intermediate in patients with melanoma and renal or thyroid cancer; and relatively low in patients with gastrointestinal tumours,[4] although in general the increase in survival of cancer patients involves an increase in these patients of a situation of diffuse metastatic disease.

Up to 50% of patients with metastatic bone disease suffer from pain resistant to treatment due to direct bone tumour involvement, pathological fractures, compression of nerve structures or the spinal cord, etc. This has a negative impact on the quality of life of the patient and their life expectancy.[2,3] Therefore, on many occasions they may require radiotherapy and/or surgery, especially when there is spinal cord compression. These events are called skeletal-related events (SREs).[4] Pain is the most common SRE, followed by fractures. Current therapies to treat pain and prevent fractures are medical (analgesics, bisphosphonates and denosumab) and radiotherapy, with results that are acceptable, although far from being excellent (pain is not adequately treated in 56–82.3 % of cases).[4,5] Surgery is generally reserved for bone stabilisation, and has a limited role in alleviating pain caused by a pathological fracture.[6]

In patients with metastatic bone disease, an initial SRE is associated with an increased risk of a subsequent SRE, an increase in healthcare costs and a shortened life expectancy.[7]

Although radiotherapy is considered to be the best non-interventional therapy for the treatment of pain associated with BM, because it achieves a pain reduction in 50–80% of cases and complete pain reduction in a third of patients,[7] it does have certain limitations[4,8]:

1 It is not effective in BM from kidney tumours or melanoma, for example.
2 There is a latency of 1–2 weeks from the end of treatment until the pain subsides.
3 Pain remission, either complete or partial, is observed in less than 60% of patients, with relapse in more than 50% of those who respond between 20 and 24 weeks after treatment.
4 It is not always possible to re-treat with radiation therapy if the maximum radiation dose has been exceeded.
5 There is no immediate bone consolidation.

Despite all the above, radiotherapy continues to be the most frequent treatment for BM, especially in patients with poor general condition.

Interventional procedures

Osteoplasty/vertebroplasty (cementoplasty)

This consists of the injection of polymethyl methacrylate (PMMA), which improves pain and strengthens the bone in patients with malignant bone tumours. A mixture of PMMA in liquid (monomer) and in powder form is made once the needle is placed in the bone lesion. As soon as the consistency of the cement increases slightly, it can be carefully injected. After 8—10 min, the cement hardens during the polymerisation phase. This is then accompanied by an exothermic reaction with a peak temperature of up to 75 °C in the centre of the treated bone.[9]

PMMA is resistant to compression, but susceptible to torsional forces, so its use is indicated in bones that support compression loads such as vertebrae or acetabulum. However, it is not recommended in the diaphysis of long bones.[1,4]

This procedure is performed with palliative intent, since it does not hinder tumour progression, and therefore it is considered a complementary technique that is usually associated with other ablative techniques.[10] It is indicated in painful multifocal osteolytic lesions of vertebrae or other bones that bear loads due to metastatic involvement, multiple myeloma (MM) or lymphoma. Being multiple, surgery is rarely indicated, and radiation therapy does not improve bone healing, further delaying the therapeutic response. However, with cementoplasty, consolidation and pain relief are accelerated. It is performed in conjunction with other treatment modalities such as, for example, thermoablation in the event of invasion of the adjacent soft tissues[1] (Fig. 1A–C).

It is contraindicated in patients with irreversible coagulopathies, acute infections, vertebral metastases causing neurological symptoms or osteoblastic metastases and instability. In vertebral tumours with rupture of the posterior wall, care must be taken due to the risk of cement leakage into the epidural space.[1,4,11]

Regarding the technique, it can be performed under general anaesthesia or sedation and following strict asepsis.[4] using a transpedicular approach in sacral vertebrae, a intercostopedicular approach in thoracic vertebrae (to avoid the spinal canal and pleura) and an anterolateral approach in cervical vertebrae (between carotid and thyroid).[1]

It is an effective pain treatment[12] in metastatic osteolytic lesions and in myeloma up to 60–97%.[1,4] The cytotoxic effect is 3 mm around the cement, so the anti-tumour effect is insufficient and specific adjuvant anti-tumour therapies are required.[1]

Complications of cement injection techniques can be attributed to poor patient selection or application, traumatic injury from the needle path, leakage of extraosseous cement to adjacent soft tissues, intravascular cement embolism, displacement of the bone marrow with fat embolism and transient cardiovascular reaction to the cement.[13,14]

Percutaneous osteosynthesis

Percutaneous osteosynthesis consists of inserting screws for the fixation of minimally displaced or non-displaced fractures, especially in the pelvic ring, for their consolidation.[4] It can also be performed in the proximal femur for the consolidation of fractures known as impending fractures (pathological bone that will suffer imminent fracture if preventive action is not taken), which do not present significant trochanteric and cortical involvement.[15] Likewise, cases of shoulder girdle fractures repaired using this technique have also been described.[4]

Indication is reserved for cancer patients who are not candidates for surgery and with limited life expectancy, offering them rapid analgesia and mobility without requiring the suspension of systemic treatment and with a significant reduction in the risk of bleeding and infection.[4]

The procedure is performed under fluoroscopic guidance or computed tomography (CT), with planning of the screw trajectory and skin entry points,[3] and takes approximately two hours, so general anaesthesia is usually preferred.

The results seem to reflect effectiveness of the symptomatic treatment of pelvic and proximal femur fractures, with studies showing a reduction in pain of up to 6 points out of 10.[4]

Despite all this, surgery is preferred to percutaneous osteosynthesis whenever possible, since there is still not enough evidence on the long-term effectiveness of the latter.[4]

Tumour ablation

Tumour ablation techniques consist of the direct application of physical or chemical agents for the local destruction of the tumour regardless of its histology[16]; among them we find ablation by alcohol instillation and different thermoablation methods, with radiofrequency and cryoablation being the most commonly used techniques in bone ablation.

Generally, in musculoskeletal cases, tumour ablation is palliative in minimally invasive painful bone metastases within advanced oncological disease. Less frequently, it is curative, either in benign bone tumours such as osteoid osteoma or oligometastatic disease in selected patients[1]:

Ethanol injection: this is the simplest and cheapest method; it produces tumour necrosis directly through cellular dehydration and indirectly through vascular thrombosis

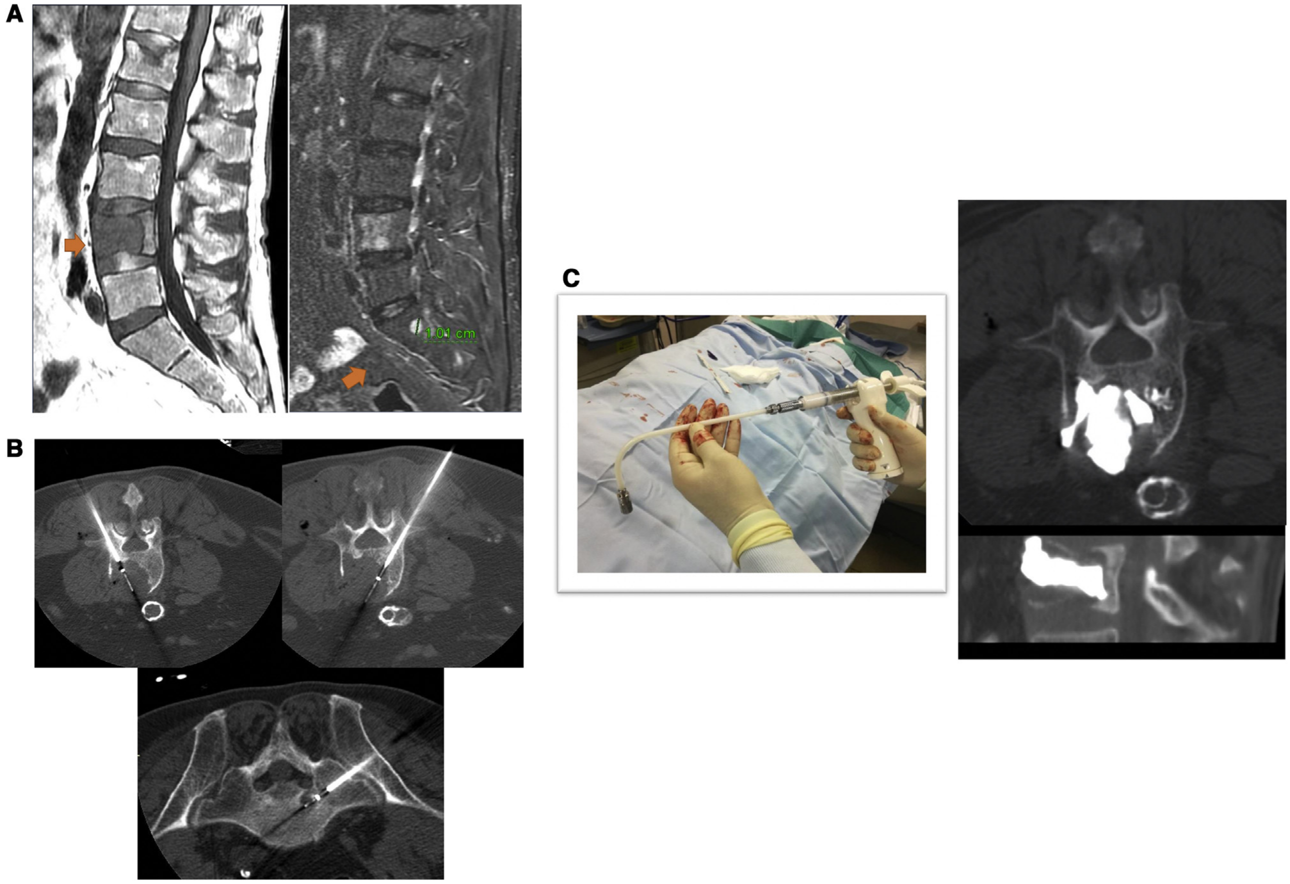

Figure 1 (A) Patient with renal cancer and vertebral lesions compatible with bone metastases in L4 and S1 (arrows) (B) Axial computed tomography planes with the patient in the prone position and percutaneous treatment by radiofrequency ablation (RFA) of the lesions in L4 and S1. (C) L4 vertebroplasty after RFA ablation.

and tissue ischaemia. First, a mixed solution of iodinated contrast (25%) and 1% lidocaine (75%) is injected into the lesion to locally anaesthetise and assess local diffusion and extension. If there is no intravasation or contact with vulnerable structures, 3–30 ml of 96% ethanol is injected into the tumour. However, this technique allows less control of ablation, since the diffusion of ethanol is not very predictable or reproducible.[17] Its indication is palliative, especially for pain management in bone metastases, also allowing a certain reduction in tumour size.[1] This technique is still used in the treatment of spinal vascular malformations such as complex aggressive haemangioma with paravertebral or epidural extension.

Thermoablation (includes radiofrequency ablation, microwave, cryoablation and MRgFUS (magnetic resonance-guided focused ultrasound surgery). It is preferred for the management of musculoskeletal tumours, as it is a more controlled ablation. It will almost always weaken the bone as in radiotherapy, so whenever possible it is associated with osteoplasty or percutaneous osteosynthesis.

- **Radiofrequency ablation (RFA).** Its main indication is palliative for a limited number of bone metastases, although it can sometimes be curative (Fig. 2A–C). It is the most promising technique for the treatment of localised tumours, preferably vertebral, although it has also been described as a safe and effective technique in the treatment of pain in extravertebral bone metastases.[18] The main objective is the ablation of the tumour-bone interface, where the main source of pain is located. A high frequency alternating wave (450–600 kHz) is applied to the lesion, causing agitation of the ionic molecules in the tissue, turning them into heat. The local tissue temperature reaches between 60 and 100 °C with immediate cell death and coagulative necrosis of the tumour. Above 100 °C, it induces vaporisation and carbonisation of the tissue adjacent to the electrode, degrading electrical conduction with a suboptimal treatment effect.[19] The electrical circuit is closed with the placement of skin plates[1] that act as an earth connection.

The intact cortical bone minimises the propagation of unwanted radiofrequency energy (protective effect).[3]

The advantages of RFA are the availability and extensive experience of interventional radiologists, in addition to real-time monitoring of the ablation area.

In terms of disadvantages, RFA allows small ablation areas (<3–4 cm)[3,20] that are not visible on CT, in addition to the cooling effect due to the proximity of the tumour to large vessels[10] and the vertebral venous plexuses. It is mainly used for the treatment of osteolytic or mixed lesions.[3] Its use is contraindicated in patients with pacemakers or implantable electrical devices.[4]

- **Microwaves** (MW) (Fig. 3 D). This is a technology that consists of the application of electromagnetic waves

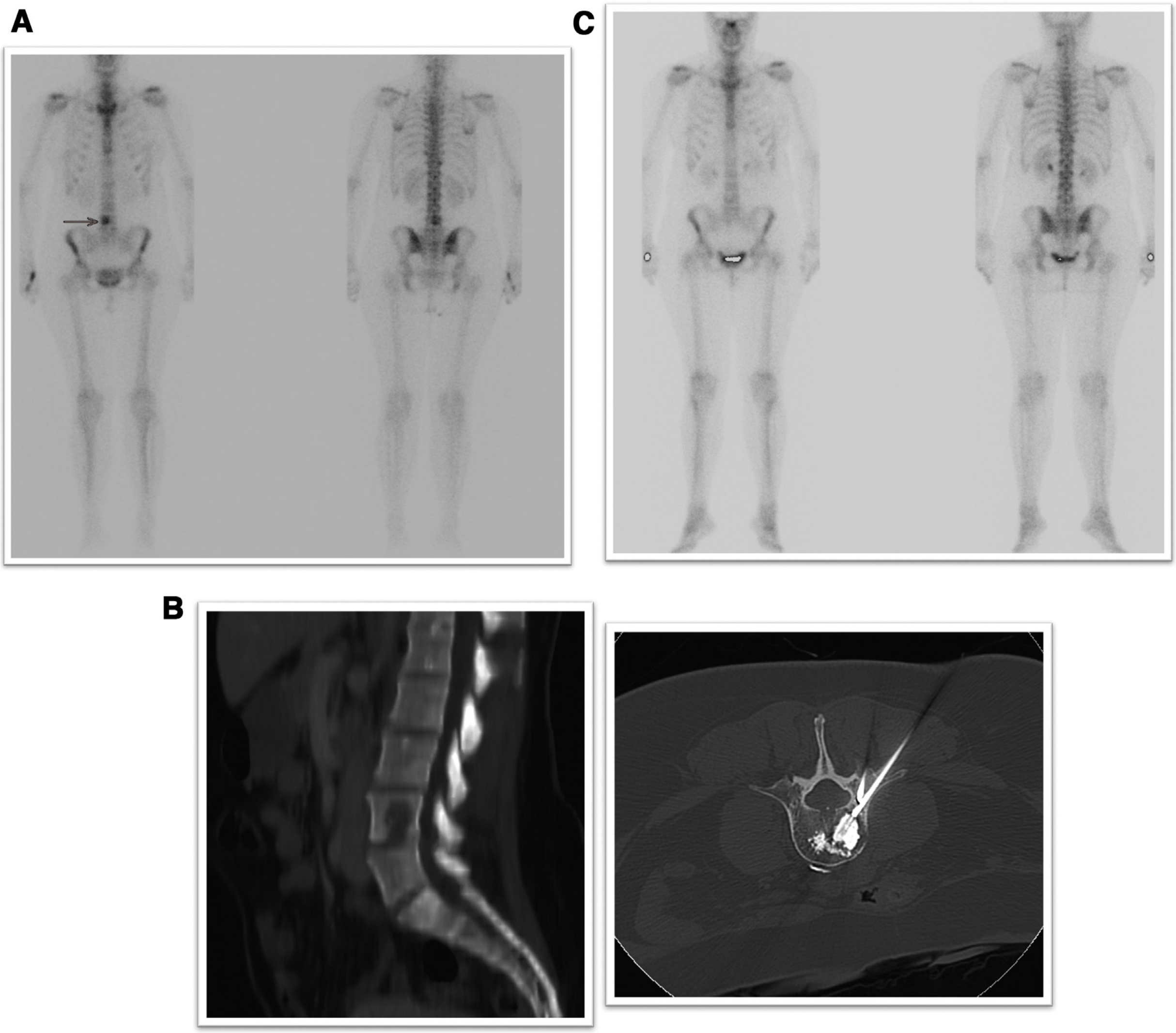

Figure 2 (A) Pre-treatment bone scan of a patient with breast cancer showing deposition of radiotracer in the vertebral body of L4 compatible with metastasis. (B) Left: lumbar spine sagittal plane computed tomography with a lytic lesion in the vertebral body of L4. Right: axial plane with patient in the prone position during radiofrequency ablative procedure and subsequent vertebroplasty (curative intention). (C) Post-treatment bone scan with disappearance of the radiotracer in L4.

(approximately 900 and 2450 MHz) through an antenna that is placed directly inside the tumour, producing molecular agitation and heat that causes coagulative necrosis. Microwave ablation is postulated to be less influenced by tissue impedance variability and perfusion-mediated tissue cooling (unlike RFA),[21,22] resulting in higher intratumoural temperatures, larger and more uniform ablation zones, and more efficient ablation using a single antenna. This offers greater efficiency in the management of osteoblastic lesions, which makes it possible to dispense with the use of skin plates and reduce the risk of burns.[1,23]

Compared to RFA, the energy of MW ablation is radiated throughout biological tissue, allowing for faster and more extensive ablation (up to 8 cm when multiple antennas are used simultaneously).[4]

Although ablated tissue is sometimes seen to be hypoattenuating on CT, the margins of the ablation site are often not well defined, which is a disadvantage for vertebral ablation.[23] Microwave ablation can increase the risk of pathological fracture similar to that seen after radiotherapy, as a direct result of the therapeutic effect and tumour regression, which can lead to cavity and reduction of bone cellularity.[24] For this reason, combined treatment with MW and cementoplasty is recommended.[25]

Cryoablation (CA). Cryoablation is the application of extreme cold to destroy tumours. It uses 13—17 g cryoprobes percutaneously with CT or MRI monitoring. Each cryoprobe can produce an ice ball approximately 5.5 cm in length and 3.5 cm in diameter.[7] Current systems allow 8–20 cryoprobes to be used simultaneously, resulting in much larger ice balls when the cryoprobes are activated synchronously.[7] The rapid expansion of the high pressure argon gas through the cryoprobe causes a sudden drop in temperature to below −100 °C due to the Joule-Thomson phenomenon (when pressurised gas expands, a drop in temperature occurs). In contrast, a rapid decompression

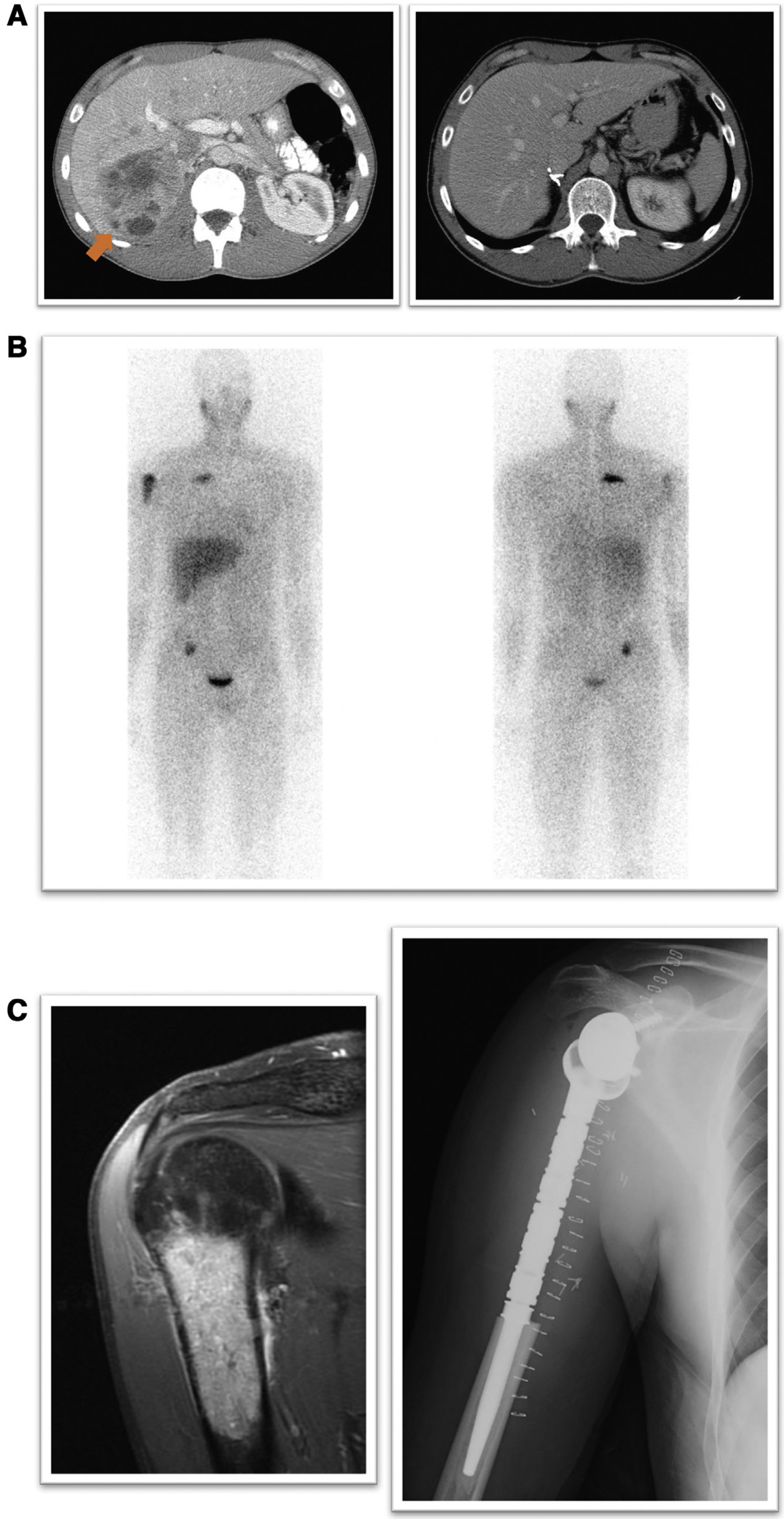

Figure 3 (A) Abdominal computed tomography (CT) with a heterogeneous right adrenal mass (arrow) that was resected with a histological diagnosis of pheochromocytoma. (B) MIBG (meta-iodobenzylguanidine) scintigraphy with deposition of the radiotracer in the humerus, rib and right iliac blade, compatible with metastases. (C) Left: MRI of the right shoulder, coronal STIR plane, with infiltration of the bone marrow of the proximal humerus. Right: surgery with placement of a humeral prosthesis. (D) CT of the hips

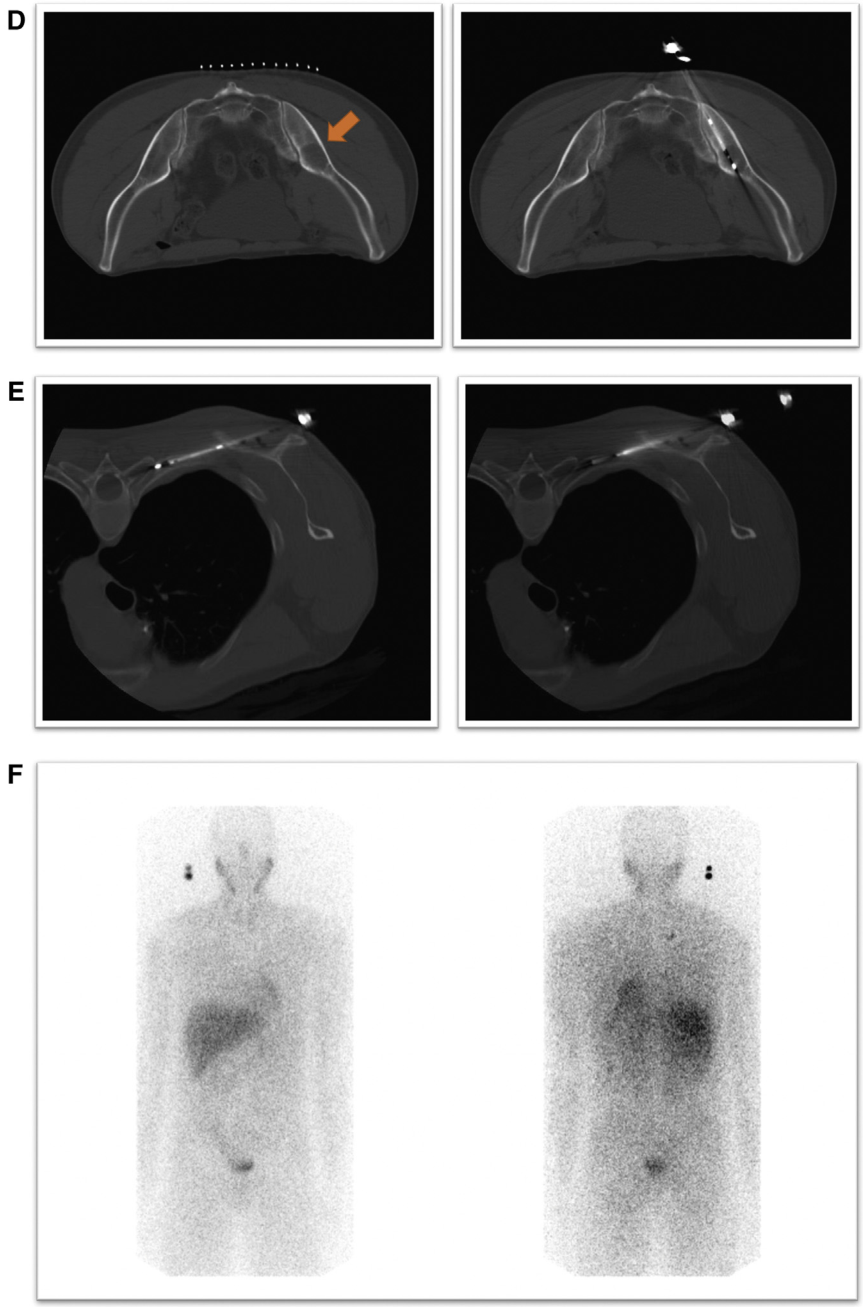

Figure 3 (*Continued*)

of helium gas increases the temperature to 33 °C, which achieves thawing.[1] Several cycles are repeated, since in the first one the ice crystals remain in the extracellular space – when they melt, the water diffuses into the intracellular space through the osmotic gradient – and in the following cycles, membrane rupture and cell death occur.[1,4] The longer the thaw phase, the greater the degree of tissue destruction.

CA is preferred in the treatment of BM with a soft tissue component or extensive lesions that affect the posterior vertebral elements, as well as for the management of osteoblastic lesions.[23]

with the patient in the prone position during microwave ablation of the metastasis in the right iliac blade (arrow). (E) Chest CT with patient in the prone position during radiofrequency ablation of the right rib metastasis. (F) MIBG (meta-iodobenzylguanidine) scintigraphy with disappearance of the radiotracer deposits..

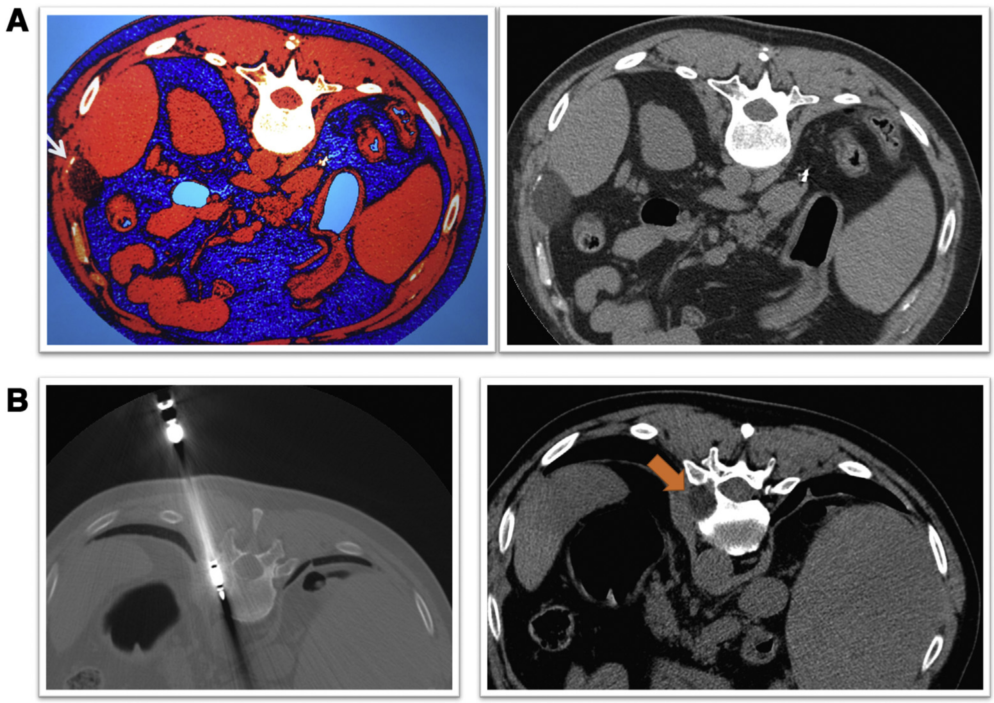

Figure 4 (A) Abdominal computed tomography in the prone position in a patient with renal cancer and rib metastasis treated with cryoablation, in which the hypodense ice ball is identified (arrow). (B) Cryoablation treatment of a vertebral metastasis (same patient) that associates a soft tissue component, identifying the hypodense ice ball (arrow).

The main advantages of CA are: precise control of the ablation area thanks to the visualisation of the hypoattenuating ice ball on CT (Fig. 4A–B) or with low signal intensity on MRI; the simultaneous activation of multiple cryoprobes so that the ice ball can be ''shaped'' according to the morphology of the tumour, allowing for the treatment of more voluminous tumours (Fig. 5A–C); and the intrinsic anaesthetic properties of the ice ball make the procedure less painful compared to other thermoablation techniques.[4] Furthermore, a possible anti-tumour immune response stimulated by CA itself has also been described.[26] Regarding the disadvantages, it is a more expensive technique (although there are studies that affirm that it could be more cost-effective than re-irradiation with radiotherapy[27]) and it is more time consuming (25—30 min).[4] Another drawback is that it does not improve bone stability, potentially weakening the bone in some cases and predisposing it to fractures.[28]

MRgFUS (magnetic resonance-guided focused ultrasound surgery) is based on the application of HIFU (high intensity focused ultrasound) guided by MRI. It is a heat-based technique that does not require any incision or needle to destroy the tumour, since it works like an ultrasound beam that is generated by the transducer placed on the patient's skin,[29] which reaches and is concentrated in the target lesion where mechanical energy is converted into thermal energy (65–85 °C),[7] inducing cell death and coagulative necrosis.[30] It does not use ionising radiation, so several lesions can be treated per session, and the treatment can be repeated in as many sessions as necessary. Any location is capable of being treated, as long as the ultrasound beam is able to penetrate, with obstacles being air, cortical bone, metallic devices, etc. Spinal injuries, for example, cannot be treated.[31] Pain treatment has been reported to be effective in 60–100% of cases. This improvement occurs quickly, in about 3 days, and is persistent, lasting more than 3 months. Currently, it is considered a second-line treatment (after radiotherapy) for the treatment of pain caused by non-vertebral or cranial bone metastases.[32]

Embolisation

The objective of transarterial embolisation is to devascularise hypervascular BM, being as selective as possible in preserving the rest of the vessels.[4] Since this technique is more effective in vascular tumours, there is more literature about the treatment of metastases from renal and thyroid cancer[33]:

- It is recommended that it be performed within 3 days prior to resection surgery (minimising the risk of significant bleeding) to reduce the risk of tumour revascularisation.
- It reduces pain and the risk of spontaneous bleeding from BM that are not candidates for surgical or percutaneous treatment.
- It reduces tumour vascularisation in case of percutaneous treatment.

A significant reduction in intraoperative blood loss (in BM from kidney tumours), as well as pain relief, has been reported in several studies. However, in up to 35% of patients[4] post-embolisation syndrome, ischaemic pain at the embolisation site, paraesthesia and subcutaneous necrosis are described.

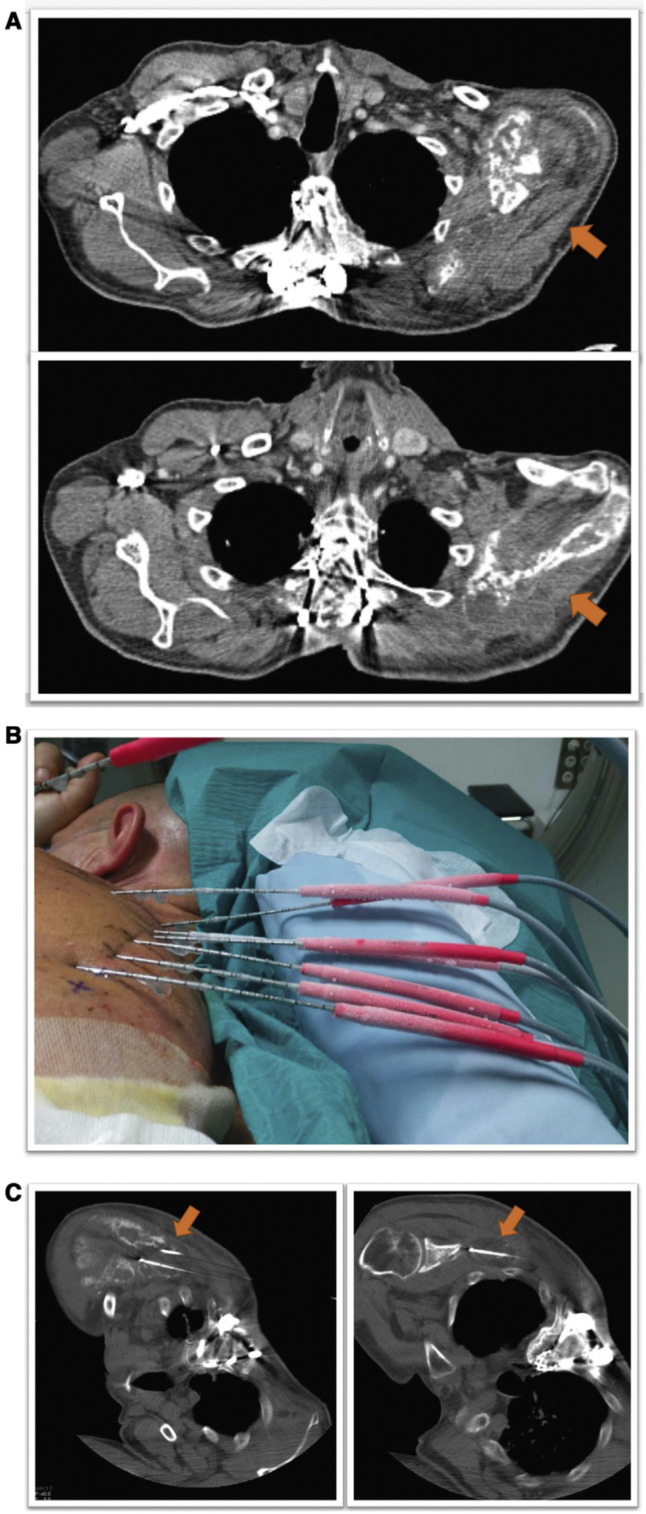

Figure 5 (A) Patient with lung cancer and multiple bone metastases. Voluminous metastasis in the right scapula with an important soft tissue component. (B) Treatment of said metastasis by cryoablation with multiple cryoprobes. (C) Chest computed tomography with patient in lateral decubitus. The cryoprobes are visualised as well as the formation of a hypodense ice ball around the distal end (arrows).

Indications and patient selection

The therapeutic plan for patients with BM must be determined by a multidisciplinary team.[22] According to the quality improvement guides from the Cardiovascular and Interventional Radiological Society of Europe (CIRSE), interventional treatment can be curative or palliative.[4]

Palliative treatment is proposed for the vast majority of patients with BM for the management of SRE (skeletal-related events): especially for those with persistent pain despite radiotherapy or with contraindication to radiotherapy, or with inadequate response to systemic treatments and/or analgesia.[22] In these cases, the main objective is to achieve a complete ablation of the tumour-bone interface,[2] although there is a growing tendency to treat the entire lesion to obtain the best results in terms of response (both pain and other symptoms).[34] These patients must have a painful or at least limited solitary bone lesion, whose imaging findings correspond to the location of the pain on physical examination, with a score on the pain scale of 4 or more points out of 10.[2,35] Likewise, it can also be offered to those patients with BM that extend to adjacent soft tissues or vertebral tumours that are growing fast towards the spinal canal.[4]

In most cases, BM are considered a systemic spread of cancer, and thermoablative techniques are not usually indicated, except if it is with palliative intent. However, data in the scientific literature suggest the existence of a limited metastatic burden, called oligometastatic disease, an intermediate state between the localised primary tumour and metastatic spread.[36,38]

Thus, *curative treatment* can be considered in selected patients with oligometastasis in limited bone disease (<3–5 potentially treatable BM, each <3 cm in diameter)[4,22,37]. Unlike with palliative treatment, ablation margins in curative treatment should extend beyond the tumour margins, as long as vital structures are not compromised.[2] Likewise, it may also be indicated in patients with a slow-growing disease, in those with stable metastatic disease with only one or a few BM that do not respond to conventional systemic treatment (oligoprogression).

Pre-procedure study

First, we must decide which is the most appropriate technique according to the characteristics of the injury that we are going to treat:

1 Vascularisation: if the lesion is highly vascular, embolisation should be indicated before ablative techniques. In addition, the ablative effect is subsequently enhanced by embolisation of vessels that could exert a ''heat dissipation'' effect. Examples are metastases from renal and thyroid carcinoma.
2 Location of the lesion to assess, for example, the use of MRgFUS (cortical, medullary bone, degree of penetration of the ultrasound beam, etc.).
3 Size: a small lesion could be treated with radiofrequency (<4 cm), while in larger lesions a higher success rate has been described using microwaves or cryoablation.

4 Cost-effectiveness: although we have not found evidence in the literature, radiofrequency and microwaves are less expensive procedures than cryoablation and MRgFUS, so they could be more cost-effective.

Subsequently, we will check coagulation (medication adjustment), kidney function, allergic history and absence of signs of infection.

During the BM interventionist procedure, it is mandatory for the anaesthetist to help in deciding which type of anaesthesia to use in each case.

After reviewing the imaging studies, the interventional radiologist must carefully plan the procedure, establishing:

1 The objective of the procedure (curative vs. palliative).
2 The need or not for biopsy (e.g. if the primary cancer is unknown, suspicion of several primary tumours, molecular study for specific therapies, etc.).
3 Non-target structures that could be at risk of iatrogenic injury.
4 Risk of fracture due to the BM itself or secondary to the procedure (e.g. by ablation or embolisation).

Protection and monitoring measures during the procedure

In general, thermoablation techniques are considered safe. However, the most common complications occur immediately post-procedure, including *cutaneous* lesions, haemorrhages, *nerve* and *cartilage* injuries or accidental ablation of adjacent non-target organs.[4,34] For this reason, a series of parameters that will influence the extent and severity of a potential neural injury must be monitored: temperature, duration, margins of the ablation zone, integrity of the cortical bone and the type of nerve fibre.[23]

Conscious sedation allows the patient to become aware of possible neurosensory deficits due to involvement of an adjacent nerve, which would require the ablation to be immediately stopped and the use of thermoprotective measures such as insufflation with CO_2 and/or heating/cooling with serum[23]. Hydrodissection is a structure displacement technique that uses non-ionic solutions such as 5% glucose serum (or saline in the case of MW) to separate structures at risk of being injured, also modifying the temperature around said structure. Intra-articular lesions have to be approached with caution, minimising the possibility of injury to the subchondral bone and articular cartilage. This can also be achieved by intra-articular injection of 5% glucose serum or CO_2.[23] Likewise, joint cartilage temperature monitoring techniques have also been described to avoid the deleterious effect on chondrocytes and especially nerve structures.[35]

Neurophysiological monitoring and nerve electrostimulation during thermoablation allow early detection of significant reductions in the amplitude and/or latency of motor and somatosensory evoked potentials in potential neurological lesions[23].

Skin injuries can also be a complication of thermoablation. To avoid this, cloths/gauze or gloves with warm saline solution can be put in place during cryoablation to minimise these injuries, while in unipolar RFA systems, more extensive skin plates can be used to reduce this risk.[23]

Table 1 Demographic data of patients with bone metastases treated at our centre.

No./sex/age	Primary tumour	Location of metastasis	Treatment
1. M 32y	Pheochromocytoma	Ribs and iliac bone	2 MW and 3 RFA
2. F 59y	Lung ca.	Sacrum	RFA
3. F 68y	Breast ca.	Sternum	RFA
4. F 51y	Breast ca.	Vertebra	RFA + cementoplasty
5. M 75y	Lung ca.	Iliac	MW
6. M 64y	Renal ca.	Vertebra	RFA + cementoplasty
7. F 53y	Lung ca.	Scapula and rib	RFA
8. F 62y	Breast and lung ca.	Sacrum	RFA
9. M 59y	Urothelial ca.	Sacroiliac	MW
10. M 69y	Prostate ca.	Lesser trochanter	RFA
11. F 57y	Breast ca.	Ischium	RFA
12. M 41y	Renal ca.	Sternum, rib, scapula, sacrum, iliac	RFA
13. F 65y	Malignant solitary fibrous tumour of the pleura	Sacrum	RFA
14. M 50y	Lung ca.	Sacrum and iliac	RFA
15. F 46y	Lung ca.	Ischium	RFA
16. F 85y	Breast ca.	Sacrum and iliac	Cryoablation
17. M 59y	Renal ca.	Rib and paravertebral	2 cryoablations
18. F 75y	Breast ca.	Sacrum and iliac	Cryoablation
19. M 70y	Prostate ca.	Vertebra	RFA + cementoplasty
20. M 66y	Lung ca.	Pubis	Cryoablation
21. F 40y	Advanced thymoma	Vertebra	RFA + cementoplasty
22. M 59y	Renal ca.	Acetabulum	RFA
23. M 83y	Prostate ca.	Vertebra	RFA + cementoplasty
24. M 73y	Lung ca.	Rib	RFA

Ca.: carcinoma; MW: microwave; RFA: radiofrequency ablation.

Finally, thermoablation can be combined with other techniques such as cementoplasty, since there is a greater risk of pathological fracture in BM.

Follow-up after interventional treatment

Pain control is the main goal of percutaneous treatment in most cases. Thus, to evaluate the response to treatment, many authors use clinical data, such as the pain scale or quality of life measurement *scores*.

Follow-up imaging is not necessary in patients with diffuse metastatic disease who have received palliative treatment, unless new symptoms appear. However, in patients with oligometastatic disease treated with curative intent, periodic follow-up is recommended for better local control of the tumour.[4] The imaging modalities of choice are, above all, MRI and positron emission tomography/computed tomography (PET-CT), recommended from the 4th or even 8th−12th week after treatment. It is important to remember that the RECIST criteria are not applicable in BM, since they are considered ''not measurable'', except in cases with an associated soft tissue component.[4]

Our experience (Table 1)

At our centre, 24 patients with BM were treated (29 CT-guided percutaneous procedures) between 2014 and 2020.

A total of 65% (19/29) of the procedures were performed under conscious sedation, while 35% (10/29) were performed under general anaesthesia. The procedures were carried out in collaboration with the anaesthesia department. All procedures were carried out guided by CT, 100% of them being satisfactory without immediate complications.

Among the patients, 33% (8/24) had BM from lung cancer, 25% from primary breast cancer (6/24), 17% from renal cancer (4/24), 12.5% from prostate cancer (3/24) and 12.5% from other tumours (including metastasis from pheochromocytoma) (Fig. 6). This last patient with pheochromocytoma, required pre-procedure medication using alpha- and beta-blockers with a target blood pressure of 110—120 mmHg systolic and 60—70 mmHg diastolic, without symptoms of hypoperfusion or orthostaticism.[39]

In 46% of the cases the treatment was curative, while in 54% it was palliative.

Overall, 69% (20/29) of the procedures performed were radiofrequency ablations, while 17% (5/29) were cryoablations, and 14% (4/29) were MW ablations.

Some 14% of the thermoablations were performed in association with a cementoplasty.

Most of the patients experienced a significant improvement in pain after treatment.

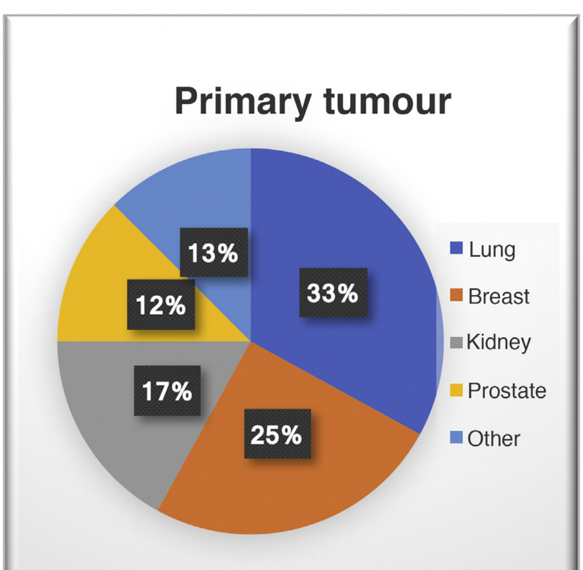

Figure 6 Most common locations of the primary tumour in patients with bone metastases treated at the centre.

Conclusion

Interventional radiology, especially percutaneous ablation (sometimes combined with cementoplasty), plays an increasingly important role in local treatment, generally palliative, of BM (pain management and prevention of pathological fractures), although in selected patients it can be performed with curative intent (e.g. in patients with good baseline condition and oligometastasis).

Among the thermoablation techniques RFA, MW and CA stand out. RFA offers rapid and effective ablation with minimal risk of bleeding for tumours smaller than 3 cm. MW ablation achieves heating of a greater tissue volume than RFA with less cooling effect. CA offers safe and effective ablation with easy monitoring of the ablation site through CT or MRI (ice ball), and less periprocedural pain, as well as the possibility of treating larger lesions (multiple cryoprobes). However, it is a more expensive and time-consuming technique.

The success of BM ablation lies in an adequate selection of the patient (the participation of a multidisciplinary team is important); a pre-procedure study, assessing the characteristics of the lesion to be treated, as well as other parameters; adequate protection measures and intraoperative monitoring to avoid complications, and finally, post-procedure follow-up.

Authorship

1. Responsible for study integrity: SCX.
2. Study concept: JMV, ABH.
3. Study design: JMV, SCX.
4. Data collection: SCX.
5. Data analysis and interpretation: SCX.
6. Statistical processing: SCX.
7. Literature search: SCX, JMV, ABH.
8. Drafting of the article: SCX.
9. Critical review of the manuscript with relevant intellectual contributions: JMV, ABH.
10. Approval of the final version: JMV, ABH.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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