Osteoid osteoma: a review of treatment by percutaneous radiofrequency ablation

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Over the past two decades, ablation techniques have become widely accepted for treating a range of bone and soft tissue tumours. Radiofrequency tissue ablation is now considered the treatment of choice for osteoid osteomas (OO), with guidance on treatment published by The National Institute for Health and Clinical Excellence (NICE).1

OO is a small, solitary, benign skeletal tumour of unknown aetiology first characterised by Jaffe in 1935,2 accounting for approximately 10-13% of all benign bone tumours.3 Between 75-90% of cases occur between the ages of five to 25 years. Males are more commonly affected than females. Histologically, the lesion consists of an ovoid or sphere-shaped ‘nidus’ composed of a variable calcified meshwork of bone trabeculae. The nidus is highly vascular with a peripheral nervous supply and is usually surrounded by dense cortical and periosteal bone. Clinically there is severe local pain that is typically worse at night, which is classically relieved by non-steroidal anti-inflammatory drugs or aspirin. Cases involving the spinal column account for 10-25% seen and often cause muscular spasm resulting in painful scoliosis.4

Lesion detection

The classic radiographic features are of a radiolucent nidus with distinctive dense reactive sclerosis.5 The nidus is often not distinctly visible on the background of dense cortical thickening. OO can be radiographically occult and the diagnosis only made on cross-sectional imaging. They can be classified as being either outside the joint capsule (extra-capsular), or within the joint capsule (intra-capsular), both having little or no growth potential, rarely exceeding 15mm in diameter. Extra-capsular lesions are cortical based and most often arise in the shafts of long bones such as the femur and tibia, causing focal cortical thickening (figure 1). Intra-capsular osteoid osteomas are less common. Typically these cause a mono-arthritis with reactive synovitis and effusion, often without a significant cortical reaction.6

CT remains the gold standard for the detection of OO due to its ability to distinguish between the nidus and surrounding sclerosis.7 The amount of sclerosis is highly variable, with intra-articular lesions often having little or no sclerosis. In cases where the spinal column is involved, CT is invaluable in visualisation of the nidus, particularly those seen within the spinal pedicles and laminae (figure 2). The vascular groove sign on CT is the presence of a vessel leading into the nidus and is a moderately sensitive, yet highly specific, sign that is visualised when using multi-detector computed tomography (MDCT) scanning protocols of 1mm slice thickness.8 The vascular groove sign was present in 79.6% of lesion located in long bones in one study.9

Despite its ability to produce multiplanar cross-sectional images of the body with superior soft tissue contrast, MRI is limited in providing an accurate diagnosis of OO.10 It offers a reduced ability to delineate the nidus when compared to CT, with one study reporting that the nidus was visualised in only 65% of cases.11 Dynamic MRI, however, has been found to improve the visualisation of the nidus in cases where it is poorly visualised on CT and may be used for planning the interventional procedure in difficult cases.12 MRI has a particularly useful role in the delineation of intra-articular osteoid osteomas, showing synovitis and effusions.10 The presence of bone oedema should raise the possibility of an osteoid osteoma (figure 3).13

Treatment

The lesion produces excess amounts of prostaglandins (PGE2 and 6-Keto-PGF1a) triggering a local inflammatory response and vasodilatation of the surrounding vessels.14 To counter-act these responses, non-steroidal anti-inflammatory drugs (NSAIDs) or aspirin are useful pain management.

Historically, surgical resection was the recommended treatment for OO involving complete en-bloc resection of the nidus and surrounding bone.15 The main disadvantage of open surgery is that the nidus can be difficult to locate and this often leads to a wider resection of bone than required. Therefore, en-bloc resection should only be considered for difficult or recurrent lesions after failed percutaneous therapy.16 Despite having a high success rate in resolution of pain, there are numerous risks associated with open surgical resection, including infection and fractures.17 In cases where the lesions are located in the spinal column there is a risk of neurological compromise.18

Percutaneous procedures have been used to treat OO by physical removal (resection biopsy) or by destroying the lesion using ablative techniques such as cryoablation, laser thermo-coagulation and radiofrequency ablation (RFA).19 RFA was considered the preferred treatment due to the low number of complications and short recovery time.20 Numerous studies have shown RFA to be a safe and effective technique for OO treatment.

Radiofrequency ablation of osteoid osteomas

RFA produces an alternating current of high frequency radio waves (>10kHz) through an electrode probe tip that causes local tissue damage (thermo-coagulation) by dissipating its energy as heat.21 The use of MDCT technology with low dose CT fluoroscopy allows for exact location of the nidus in relation to the overlying skin with a reduction of radiation dose received by the patient. Recommendations are that low mAs protocols should be followed, to prevent patients receiving a high estimated maximum entrance skin dose (ESD).22

Skin markers are used to plan the entry point with the ideal needle tract only crossing a single compartment, while care is taken to avoid neurovascular structures.23 The shortest path is not necessarily the ideal route. A needle or a
drill is used to create a small entry in the bone, providing a tract for placement of a bone biopsy needle. CT fluoroscopy mode enables faster image reconstruction, near-continuous image update and in-room image viewing and table control (figure 5). Biopsy is not always feasible with histological confirmation rates ranging from 36 to 100%. During the placement of the needle, patients with OO are likely to experience an increase in their respiratory and cardiac rate as the nerve supply around the tumour is highly sensitive and contact causes pain, triggering a change in vascular pressure. Once a sample of the nidus has been drilled or removed it creates a hollow space into which the electrode probe can be positioned with the use of spot CT imaging through the outer cannula. The outer cannula is then drawn back slightly, away from the tip to prevent heat transmission that may result in skin burns.

Following electrode probe placement, thermal heating is applied to the nidus. The operator controls the coagulation temperature and time used to ablate the lesion. There are no definite parameters for length and temperature of ablation, with studies reporting using ablation times of 4-6 minutes with temperatures of 85-90°C, while some have used ablation times of 8-10 minutes and higher coagulation temperatures of 80-110°C. If a coagulation temperature of above 45°C is applied to tissue for a length of 60 minutes irreversible cellular damage occurs. If temperatures of between 60-110°C are used there is 'near instantaneous' coagulation of tissue and necrosis (death) to the cells within the nidus. Using temperatures above the traditionally recommended 85-90°C, the success of complete nidus coagulation may be improved. Similar techniques such as laser thermo-coagulation use thermal methods to destroy the lesion, however, the temperatures used during laser treatments can be difficult to regulate, reaching temperatures as high as 240°C, resulting in damage to the surrounding bone tissue.

Factors that may affect coagulation include lesion size and those adjacent to vulnerable structures, such as close to skin or neurovascular structures. Each lesion should be assessed individually and the coagulation time adjusted to suit each case. The risk of failure decreases with age, possibly due to periosteum being more vascular in children and therefore affecting heat distribution within the nidus. For lesions 10mm or larger there is seen to be an increased risk in treatment failure. The 'treatment zone' defines the amount of tissue around the electrode probe that may be treated. The length of the probe tip is used to calculate the size of the treatment zone. The electrode probe used for RFA of OO is typically 5mm and will ablate tissue in a 10mm spherical area. If the lesion measures more than 10mm a second probe placement can extend the treatment zone, improving success rate.

Expected outcomes
The clinical success of the procedure is defined as an absence of pain on clinical follow-up. Techniques and success rates vary considerably between institutions, with reported success rates ranging between 76% and 100%. Complications
RFA is a safe technique for the treatment of OO. Reported complication rates are universally low, in the region of 1-2%. Possible complications include superficial skin burns, skin/fat necrosis, infection and broken needles. With surgical intervention, complications of rates between 20-45% have been reported including fractures, haematoma and nerve damage.

Clinical follow-up
Most patients have pain for one to two days following the procedure, with technical success manifesting as resolution of pain after one week. Normal daily activity is usually possible after 48 hours without the need of a cast or splint. The necrosis within the nidus caused by RFA is replaced by haemorrhage with sclerotic bone formation expected over 2-27 months. Follow-up imaging is not usually undertaken unless there is persistent or recurrent pain, as the imaging features may be slow to resolve. Complete, or almost complete, ossification of the treated nidus on CT correlates with successful treatment. Absence of this ossification pattern, however, does not correlate with treatment failure. CT is therefore not useful to identify the activity of the nidus following treatment. Furthermore, on MRI residual bone oedema may be present in cases where symptoms have resolved.

Conclusion
In summary, OO is a small benign skeletal bone tumour mainly affecting children and young adults, typically causing severe localised pain. Initial treatment currently recommended is non-steroidal anti-inflammatory (NSAIDs) or aspirin, which focuses on pain management. Prior to the development of radiological intervention techniques, surgical intervention was performed. Despite it having a high success rate in resolution of pain, there are numerous risks associated and therefore less invasive techniques have been developed. RFA was first discussed in the early 1990s and has gained popularity, becoming the treatment of choice for OO worldwide. This is due to its high success rates, quick recovery and low complication risks. It has allowed musculoskeletal radiologists to expand within their role in the treatment of this tumour, as the technique can be easily learned. The development of CT technology is enabling greater imaging quality which is allowing for not only greater detection of the lesions, but more accurate and safer treatment of the lesion, with the patient receiving a lower radiation dose.

References

Figure 1
(Left) Femoral shaft osteoid osteoma. Radiograph of the right femur demonstrating focal cortical thickening (arrows). No distinct nidus is visible. (Right) CT with coronal reformat demonstrating a small nidus (arrow) with dense surrounding sclerosis.

Figure 2
Lumbar spine osteoid osteoma. A small lucent nidus is present in the lamina (arrow) with surrounding sclerosis. The lesion demonstrates the ‘vascular groove’ sign.

Figure 3
Intra-articular osteoid osteoma. Coronal STIR sequence showing mono-arthritis of the right hip with an effusion and synovitis (arrows). There is diffuse bone marrow oedema in the femoral neck. The nidus was situated at the anterior aspect of the femoral neck (see figure 4), and not clearly demonstrated on MRI.

Figure 4
Proximal femoral osteoid osteoma. Planning CT scan showing skin markers. The nidus is indicated by the arrowhead.

Figure 5
CT fluoroscopy. Three contiguous images are presented showing the position of the biopsy needle at the anterior cortex of the femur.