Interventional Radiology in Skeletal Metastasis

Anirban De[1] and Winston Rennie[2]

1. Specialist Registrar in Radiology; 2. Consultant Radiologist, University Hospitals of Leicester NHS Trust

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Abstract
Metastasis is the most common cancer of the bone. These lesions cause significant pain and morbidity. Palliative treatment has been the mainstay in managing these patients. However, the introduction of minimally invasive techniques and the concept of filling metastatic bone lesions with acrylic cement has revolutionised the management of these patients. Such techniques are usually performed under conscious sedation, thus reducing the risks of general anaesthesia in this group of patients, who are often unfit for major surgery. This article presents a review of the different intervention techniques performed by the radiologist in patients with skeletal metastasis. We have reviewed the techniques of vertebroplasty, acetabuloplasty, sacroplasty and some of the different ablation procedures.

Keywords
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Correspondence: Winston Rennie, Consultant Radiologist, Department of Radiology, Leicester Royal Infirmary, Infirmary Square, Leicester, LE1 5WW, UK.
E: winston.rennie@uhl-tr.nhs.uk

Metastatic cancer is the most common malignant disease of the bone.[1] Breast and lung carcinomas account for more than 80% of metastatic bone disease.[2] Metastasis to the bone causes significant pain and morbidity to the patient early in the course of the disease.[3] It can lead to fractures and reduced mobility, thus reducing performance status and causing depression and anxiety.[4–6] Palliative treatment is the mainstay of treatment in these groups of patients. It includes radiotherapy, chemotherapy, analgesics and palliative surgery.[7] However, there have been significant advances in the management of patients with bone metastasis. The introduction of minimally invasive techniques and the concept of filling metastatic lesions with acrylic bone cement via minimal access have revolutionised the management of patients. Such techniques are usually performed under conscious sedation, thus reducing the risks of general anaesthesia in this group of patients who are often unfit for major surgery. In this article we present a review of some of the interventional techniques performed by the radiologist.

Percutaneous Vertebroplasty
Of the secondary skeletal metastases, the spine is the most frequent site, accounting for up to 40%, with the breast, prostate and lungs being the most common primaries.[8,9] The thoracic spine is the most common site, followed by the lumbar and cervical regions.[9,10] Percutaneous vertebroplasty was first described by Galibert et al.[11] in 1987. The procedure essentially consists of an injection of low-viscosity bone cement (surgical methyl methacrylate polymer [PMMA]) via a large-bore needle into a vertebral body under image guidance.[12] Over the past decade, percutaneous vertebroplasty has been used extensively for pain relief and bone strengthening of weakened vertebral bodies due to disease process.[11,13,14] The main aim of vertebroplasty is to provide pain relief by strengthening and stabilising painful vertebral body compression fractures.[12] There is no clear consensus on the mechanism of pain relief, but it is thought to be due to immobilisation of the fracture site and support of the innervated cortex. It has also been hypothesised that the heat produced when the PMMA solidifies deadens the sensory nerve fibres. Percutaneous vertebroplasty is commonly performed in the thoracic and lumbar vertebrae, and, rarely, in the cervical vertebrae.

Indications
The main indications for percutaneous vertebroplasty are vertebral body compression fractures due to osteoporosis/osteopenia, myeloma, osteolytic metastasis, Kummell's disease and aggressive vertebral haemangiomas.[12,15] All of these disease processes result in painful vertebral-body collapse, leading to significant morbidity and deterioration of quality of life, mental health and survival.[16] Pain associated with vertebral compression fractures often becomes chronic with incomplete healing, ultimately resulting in spinal deformity and kyphosis.[16] This shifts the centre of gravity anteriorly, resulting in more pronounced flexion and further deformity and vertebral fractures.[16] Vertebroplasty aims to reduce pain and strengthen the vertebral body, thus preventing further deformity.[16] Radiotherapy is indicated in the spine when the cause is due to tumour and metastasis, but the effect is often delayed, during which time there is significant risk of instability of the vertebral column and neural compression – hence the role of vertebroplasty in metastatic disease in particular.[15]

Contraindications
Absolute contraindications to percutaneous vertebroplasty include coagulation disorders and fractures with posterior element

involvement.[12,15] There should always be spinal surgical back-up in case emergency decompression surgery is warranted due to epidural bone cement leakage.[15] The patient should be able to lie prone for the duration of the procedure (usually one to two hours) and there should be adequate patient monitoring facilities.[12] Neurological symptoms related to vertebral body compression or tumour extension increases the risk of cement leakage following injection and should be dealt with very cautiously.[16] Severe vertebral compression fractures (more than one-third of original height) may prove technically challenging.

Pre-procedure Planning

Radiological and clinical assessment is mandatory pre-procedure planning prior to performing vertebroplasty. Radiographs are assessed for the extent of vertebral collapse, pedicular involvement, posterior cortex involvement and bone tumour extension or retropulsion of fragments into the epidural space or neural foraminal involvement.[12,15] A computed tomography (CT) scan is useful for such assessment. Magnetic resonance imaging (MRI) with short T_1 inversion recovery (STIR) imaging is useful to detect areas of recent fractures and adjacent soft-tissue oedema, which helps to clinically correlate the level of the patient's pain and symptoms.

Technique

Written and informed consent is obtained. In our institution, a formal pre-assessment clinic is conducted where the procedure and probable risks are explained to the patient. Vertebroplasty is performed as a day-care procedure and the patient is discharged the same day. The procedure is performed with the patient in a prone position under fluoroscopy guidance, although the use of CT for needle positioning has been documented.[14,17] It is usually performed under conscious sedation using fentanyl and midazolam,[12] with additional local anaesthetic (lignocaine) to the skin. Continuous monitoring of vitals is conducted. Strict asepsis and skin preparation is undergone. Following a small skin incision, an 11 or 13G bone-biopsy needle is introduced percutaneously and through the pedicle under fluoroscopy guidance, the position being checked with frontal and lateral fluoroscopy imaging.[12] The tip of the needle is advanced to within the anterior one-third to one-quarter of the vertebral body.[12] Such an approach is transpedicular, although a posterolateral approach has also been documented. The transpedicular approach has a lower risk of nerve injury and cement leakage into the paravertebral tissues.[15] After the needle is positioned and the stylet is removed, contrast is used through the needle to check whether there is direct communication with any vein.[12] Venography helps to assess the risk of cement leakage outside the vertebral body. The polymethymethacrylate powder is then mixed with barium sulphate (or tungsten or tantalum) to increase its opacity.[12,15] A toothpaste-like consistency is obtained and the bone cement is injected under fluoroscopy control.[12] The injection is stopped immediately if there is any evidence of venous, epidural or foraminal leakage of cement.[12,15]

Complications

There may be transient worsening of pain and fever following the procedure due to the heat generated by the polymerisation of the bone cement.[15] Leakage of bone cement into the epidural or foraminal space can cause neurological complications, and emergency decompression is required. The complication rate of this is variable among the different studies, but it is uncommon.[12] Leakage of the polymer may also cause pulmonary embolism. The overall risk of significant complications of percutaneous vertebroplasty is around 1%, but it can be up to 5% in patients with malignancy rather than simple osteoporotic fractures. Infection and vertebral body fracture are other recognised complications.[12]

Results

Pain relief is the most significant benefit of vertebroplasty, especially in patients with metastasis and myeloma, as pain in these conditions is often resistant to medications.[15] Relief of pain and increased mobility is usually observed within 24 hours of the procedure.[12] Significant pain relief is observed in approximately 70% of patients with metastasis.[12,15] Vertebroplasty is considered an efficacious method of pain relief, stabilisation of the spine and improvement of quality of life in patients with vertebral compression fractures.[12,15]

Acetabuloplasty

Osteolytic metastasis around the acetabulum is a cause of significant drug-resistant pain and morbidity in patients with cancer.[18] Such lesions weaken the pelvis, cause pathological fractures and result in limping and disability.[1,18] Radiotherapy is often ineffective as pain control in these patients. Acetebular reconstruction is a major surgical procedure and is associated with a high rate of complications.[19,20] Minimally invasive techniques such as percutaneous acetabuloplasty provide pain relief, restoration of function and improved quality of life with fewer complications and less morbidity than major acetabular reconstruction.[1] The technique was first described by Cotten et al. in 1995.[21] The procedure involves the percutaneous injection of bone cement into the acetabulum of patients with acetabular metastatic disease. A multidisciplinary team approach is necessary and pre-procedural CT and MRI should be evaluated. The technique can be performed under general, spinal or local anaesthesia. The patient is positioned supine or lateral decubitus. Strict asepsis is maintained. Under fluoroscopy guidance, Kirchner wires are introduced into the correct position and adequately sized cannulae are placed over them for cement injection. The injection of cement is monitored continuously with fluoroscopy to prevent leakage of cement outside the bone.[18] A variety of acrylic polymeric cements are available for intra-osseus injection. Similar to vertebroplasty, materials are added to the cement to make it radio-opaque.[1] Acetabuloplasty is mainly indicated for pain relief, bone strengthening and prevention of pathological fractures. It is usually indicated for injection of the weight-bearing surface of the acetabulum, the acetabular roof. Bleeding disorders and acetabular fractures are contraindications.[1,18] Pain relief, improved mobility and functional restoration have been reported in a majority of patients.[1] In some studies, satisfactory results were obtained in up to 80% of patients. Recognised complications of percutaneous acetabuloplasty include cement leakage into the hip joint, venous leakage of cement resulting in thrombophlebitis of lower limbs and pulmonary embolism, transient post-procedure fever and renal failure.[1,18] Percutaneous acetabuloplasty is thus an effective minimally invasive technique that improves quality of life in patients with acetabular osteolytic metastasis.[18]

Sacroplasty

Percutaneous sacroplasty is essentially vertebroplasty in the sacrum. The role of sacroplasty for insufficiency fractures due to osteoporosis is well-documented in the literature, but there have been fewer reports of its role in sacral metastasis.[22,23] Sacral metastasis, like metastasis elsewhere in the spine, causes significant and drug-resistant pain. Palliative radiotherapy can reduce pain, but the effect is delayed and does not correct sacral instability.[24] Surgical intervention involves significant post-operative recovery period and morbidity.[24] Sacroplasty is less invasive and is an effective means of pain reduction. Similar to vertebroplasty, it is believed that injection of acrylic bone cement (polymethyl methacrylate) reduces pain by stabilising and strengthening the sacral vertebral body, reducing further fractures, and by the thermal effect of cement on the nerve fibres.[24] The exothermic effect during polymerisation of bone cement is believed to have a necrotic effect, thereby reducing tumour bulk.[25] Although sacroplasty is similar to vertebroplasty, it is technically more challenging. Locating the needle tip is more difficult owing to the sacral curvature, as documented in the literature.[24] Pre-procedural CT and MRI scans are performed. Conscious sedation and local anaesthesia are used[26] with continuous monitoring of vitals. The patient is kept in a prone position.[27] Fluoroscopy guidance alone can pose difficulties in visualising the sacral foramina.[24] CT guidance provides better definition of the sacrum, but is limited by lack of realtime imaging during the cement delivery.[24] A combination of fluoroscopy and CT is a better combination.[22] Following strict asepsis and a small skin dermatotomy, a 13G needle is advanced under radiology guidance.[24,27] The number of needles required to obtain adequate cement filling is variable depending on the lesion and operator. Polymethy methacrylate is mixed with barium to make it radio-opaque. Continuous fluoroscopy is performed during cement injection to prevent leakage of the cement. Pain relief has been reported between one day to two weeks following the procedure.[26,27] The procedure has been reported to be effective in up to 80% of patients.[26] The probable complications are leak of cement into the venous system leading to pulmonary embolism and neural complications due to extension of cement in the neural foramina.[26]

Ablation Techniques

Ablation is a method of local destruction of tumour cells that can be achieved by the local instillation of chemicals (such as ethanol or acetic acid) or local administration of some form of energy pulse (radiofrequency [RF], laser, microwave, ultrasound or cryoablation).[28] We present here some of the ablation techniques performed in our institute.

Radiofrequency Ablation

The role of RF ablation in liver malignancy is well-known, and is now useful in painful osseous metastasis,[28] which was first described by Dupuy et al.[29] RF ablation is based on the principle of producing local heating and tissue necrosis by using an alternating current from an electrode.[7] It has been proposed that RF ablation reduces pain by the destruction of sensory nerves in the bone cortex and by reduction of the lesion volume.[27] It also destroys tumour cells, which produce cytokines responsible for pain.[30,31] The bone lesion is located by means of CT.[28] The electrode is percutaneously placed by means of CT guidance. The procedure can be performed under conscious sedation and local anaesthesia. Many studies have shown good results with this technique. Pain reduction usually occurs within the first week, and in many, within the first 24 hours.[28] The probable complications of the procedure are infection, haemorrhage, dermal burns and post-procedure fevers. The procedure is contraindicated in the spine due to the proximity of neural structures.[28]

Coblation

RF ablation produces large amounts of local heat, thus limiting its usefulness in areas close to nerves and articular surfaces. Coblation is a technique that uses RF energy to create focused plasma by activating sodium ions in normal saline.[32,33] The activated plasma causes tumourolysis and dissolution of the local tissue, but at much lower temperatures than conventional RF ablation. This results in more targeted tumour ablation, sparing the surrounding normal tissue. Coblation is a well-established technique in nasal surgery. It has also been used in spine intervention.

Conclusion

The skeleton is one of the most common sites for metastasis. Metastasis to the bone can result in significant pain, which is often resistant to standard and conventional methods of treatment. Intervention radiology provides a new method of pain relief in this group of patients with bone metastasis. It provides minimally invasive access, which is often suitable in these already ill patients, where surgery is difficult. Such interventional techniques have shown good results. With advances in imaging and increased awareness and training in these minimally invasive techniques, it holds good promise for the future management of pain in patients with skeletal metastasis. ■

Anirban De is a Specialist Registrar in Radiology at the University Hospitals of Leicester NHS Trust. He is in his third year of radiology training. He graduated from Calcutta Medical College, then completed his basic surgical training in Wrexham in North Wales, during which time he obtained membership of the Royal College of Surgeons (MRCS).

Winston Rennie is a Consultant Radiologist at the Leicester Royal Infirmary, where he set up the vertebroplasty programme and other day-case radiology-guided interventional programmes. He has had many articles published about musculoskeletal radiology and is a reviewer for reputable journals in both the UK and the US.

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