Cementoplasty to Cryoablation: Review and Current Status

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ABSTRACT

Recent advances in percutaneous image-guided techniques have empowered interventional radiologists with diverse treatment options for the management of musculoskeletal lesions. Of note, there is growing utility for cementoplasty procedures, with indications ranging from stabilisation of bone metastases to treatment of painful vertebral compression fractures. Likewise, cryoablation has emerged as a viable adjunct in the treatment of both primary and secondary bone and soft tissue neoplasms. These treatment options have been progressively incorporated into the multi-disciplinary approach to holistic care of patients, alongside conventional radiotherapy, systemic therapy, surgery and analgesia. This review article serves to outline the indications, technical considerations, latest developments and evidence for the burgeoning role of cementoplasty and cryoablation in the musculoskeletal system, with an emphasis on pain palliation and tumour control.

KEY WORDS

Musculoskeletal, interventional radiology; interventional oncology, cementoplasty, cryoablation
INTRODUCTION

Over the last few decades, various percutaneous image-guided ablation and stabilization techniques, including cryoablation and cementoplasty, have emerged in the management of musculoskeletal lesions. There is growing utility of these procedures especially in the context of malignancy, where bone pain is one of the most common types of pain, and the skeleton is the third most frequent site of metastases[1]. This is compounded by the prevalence of bone metastases, with the annual age-adjusted incidence rate of newly diagnosed bone metastasis approximately 18.8 per 100,000 in the United States[2].

Currently, radiotherapy is considered as the preferred treatment option for palliation for uncomplicated metastatic bone pain. However, radiotherapy alone does not contribute to bone stability[3], [4]. Other limitations of radiotherapy include radio-resistance of some tumours, risk of radiation related fracture especially to weight-bearing bones, osteitis, osteonecrosis as well as a radiation dose limits for one body site[5], [6]. Additionally, radiotherapy has a delayed pain relief onset, typically 4 weeks and occasionally up to 15 weeks[7].

Surgery is only indicated as first-line treatment for selected metastatic bone lesions, such as slow-growing tumours and patients with relatively good prognosis[8]. Surgical decompression and instrumentation has a primary role in the management of acute spinal instability, and spinal cord compression with neurological deficits [4]. While opioids are recommended for management of cancer-related bone pain, they are associated with multiple common side effects and sometimes suboptimal pain relief[9], [10].

Given the limitations of traditional strategies, this review article serves to provide an update on the increasing role of cementoplasty and cryoablation in the musculoskeletal system, with an emphasis on pain palliation and tumour control.

CEMENTOPLASTY

Percutaneous cementoplasty is a minimally invasive technique comprising of cannula placement within a bone lesion with subsequent cement injection [11]. The cement, usually polymethylmethacrylate (PMMA), hardens in consistency after about 10 to 20 minutes. Cement polymerization and hardening involves an exothermic reaction, with temperature peaks of up to 75 °C, and play an accessory analgesic role through the destruction of adjacent nociceptors [12].

INDICATION

When considering cementoplasty for bone metastases, a multi-disciplinary team including interventional radiologists, radiation oncologists, medical oncologists and orthopaedic surgeons should be engaged. Cementoplasty is typically considered in the following clinical scenarios: persistent pain or imaging evidence of tumour progression despite maximized radiation therapy, contraindications to radiation therapy, lack of patient desire for radiation therapy, and/or inadequate treatment response to systemic therapies and analgesia [13], as well as prophylactic stabilization for impending pathological fractures in the axial skeleton[14].

Pre-procedural cross-sectional imaging is essential to determine the number and site of lesions, needle size and approach, as well as measurements for ablation zone (if performed). MRI imaging features may also be useful to guide patient and vertebral level selection; levels with marrow oedema correlating with pain should be targeted for optimal pain relief [15]. Careful review of prior imaging, with a low threshold for repeating the patient’s cross-sectional imaging are advised, especially if new or significantly worsening symptoms are reported since the latest imaging was
performed. In the authors’ experience, pre-procedural imaging is usually current, preferably within a few days of procedure, and at most within a month from procedure.

Severity of the spinal instability is an important consideration and can be evaluated via various scoring systems including the Spinal Instability Neoplastic Score (SINS). Surgical consultation for potential tumour resection or debulking with stabilization is suggested for patients with a SINS of 7 or higher. Spinal metastases resulting in central canal stenosis are typically managed with surgical intervention.

In the spine, suitable patients for vertebroplasty include those with chronic pathological fractures refractory to radiotherapy or other conservative measures, acute vertebral fractures with less than 6 weeks of symptoms, and painful pathological vertebral fractures without spinal cord compression or significant neurological deficit. The most appropriate timeframe for substantial pain relief may be 2 to 4 weeks from onset of injury, as suggested by a meta-analysis. However, treatment in the initial 4 weeks of vertebral fractures may lead to a higher risk of complications including cement leakage. In the authors’ experience, vertebroplasty can be performed before or after radiotherapy, and readily coordinated during multi-disciplinary discussions.

Cementoplasty is contraindicated in patients with coagulopathy, unstable spinal lesions, presence of local or systemic infections, allergy to bone cement, and asymptomatic vertebral compression. Vertebral plana with 90% or greater height loss and extensive osteolytic destruction especially at the posterior cortex of the target vertebral body are relative contraindications.

TECHNIQUE

In the authors’ experience, cementoplasty is usually tolerated well under conscious sedation with local anaesthesia; general anaesthesia can also be considered for certain patients. Patients are positioned according to the site of target lesion; in conventional vertebroplasty this usually means a prone position with padding under the thorax and ankles. Local anaesthesia is administered along the puncture site and expected cannula trajectory, infiltrating the subcutaneous tissues, muscles and pain-sensitive periosteum.

For vertebroplasty of a lumbar segment, a transpedicular approach is preferred where the upper outer aspect of the pedicle is accessed. The cannula is directed medially through the pedicle and into the anterior third of the vertebral body to the midline inferiorly. This optimizes cement distribution to ideally include most of the vertebral body with cement crossing the midline (Figure 1). A costotransverse approach for the thoracic vertebra is also feasible due to smaller pedicle sizes. Bipedicular access may be considered in some scenarios including suboptimal positioning of a single cannula, or severe central vertebral height loss preventing cannula placement along the midline. Other novel access routes, including transoral access of C2 and a trans-discal approach, have been reported.

Aside from vertebroplasty, other percutaneous vertebral augmentation procedures include balloon kyphoplasty and vertebral stenting. During kyphoplasty, a balloon-like device is inflated inside the vertebral body, and its expansion restores vertebral body height, creating a cavity into which cement is then injected. Patient positioning and vertebral body access is similar to conventional vertebroplasty. A reamer is inserted over the access cannula, through which the stenting device or inflatable balloon are inserted. Once deployed, an intravertebral cavity is created with partial restoration of vertebral height.
Cementoplasty has also been performed at extra-spinal positions, notably the sacrum, acetabulum and long bones. For percutaneous sacroplasty (Figure 2), both a short-axis or long-axis cannula placement technique can be adopted depending on the size and extent of the fracture or lesions. The short-axis technique is better suited under CT guidance, with the cannula advanced perpendicular to the dorsal surface of the sacral ala. However, the volume of injected cement at each cannula may be limited, necessitating placement of additional cannulas or adopting a more oblique approach[28].

For percutaneous acetabuloplasty (Figure 3), either a posterior or anterior approach can be adopted. Cement is deposited along the acetabular roof and posterior column, as they form part of the load-transmission axis. Displaced fractures with acetabular protrusion are contraindications due to risk of intra-articular cement leakage.

Other novel techniques described include the usage of curved or directional needles for cementoplasty of the acetabulum and vertebral bodies[29], [30].

IMAGING GUIDANCE

In the authors’ experience, cannula placement is usually performed under fluoroscopy, cone-beam CT or conventional CT, sometimes with the assistance of advanced navigation software and real time multiplanar reformats, depending on resource availability and operator preference. CT is preferred for cervical and upper thoracic spinal access due excellent spatial resolution of adjacent soft tissue structures. CT gantry angulation or needle guidance software are useful adjuncts in difficult to access lesions. Ultrasound is useful in certain situations such as visualizing critical neurovascular structures close to the cannula trajectory. Fluoroscopic guidance for cement injection is preferred to visualise real-time cement flow and distribution.

As musculoskeletal interventional oncology procedures become increasingly complex, many procedures are performed under a combination of CT and fluoroscopic guidance. This allows acquisition of excellent spatial resolution on the axial plane with CT, and real-time visualization cement injection or embolization under fluoroscopy. The newest cone-beam CT units have incorporated artificial intelligence capabilities including deep learning algorithms that allow guidance of bone access cannulas without requiring fluoroscopy, markedly reducing radiation dose[31]. MRI guidance has also emerged, allowing target identification in soft tissue lesions while avoiding ionizing radiation [32], [33], although its usage is limited by costs and availability.

EFFECTIVENESS

VERTEBRAE

Previous trials such as VERTOS I and II trials demonstrated benefit of vertebroplasty over conservative management for osteoporotic vertebral fractures [34], [35]. However, two large prospective multicentre studies and a subsequent Cochrane review failed to show a difference in pain improvement compared to a sham procedure, which involved injection of local anaesthetics but without cement deposition[36], [37], [38], [39]. The VERTOS IV trial replicated this conclusion in acute fractures up to 9 weeks[39]. Major criticisms with these trials include a heterogeneous and less than ideal patient selection, heterogeneous and methodological flaws in the calculation of response to pain, underpowered study and varying and suboptimal cement volume injected. In addition, the sham procedure of periosteal local anaesthesia at the dorsal pedicle was considered active treatment with significant effects on medial branch and sinuvertebral nerve blockade[40].
Subsequently, the VAPOUR trial showed benefit over placebos in patients with acute fractures and symptom duration of less than 6 weeks [41].

A follow-up of patients recruited for the VERTOS II and IV trials revealed statistically significant more patients had a high pain score at 12 month-follow up in the sham and conservative group, as compared with the vertebroplasty group[42]. Patients with moderate fracture deformity were also less likely to have high pain scores if they were treated with vertebroplasties [42].

Pathological vertebral compression fractures are second most common indication for vertebroplasty. A retrospective observation study of patients with metastatic compression fractures who underwent vertebroplasty reported improvement of visual analog scale (VAS) pain score from 5.8 to 2.7; patients with posterior column involvement and paravertebral extension reported greater pain relief [43]. The efficacy of vertebroplasty on pain reduction and disability improvement is also well documented in multiple myeloma patients, with sustained results on long term follow-up (5 years) [44]. Pain relief can be substantial; a study documented median VAS scores decreasing from 9 to 1 post-vertebroplasty [45]. Vertebroplasty is also a potentially effective percutaneous technique to treat symptomatic intraosseous haemangiomas, with lasting results[46].

Currently, the overall consensus is that vertebral augmentation is appropriate for painful vertebral compression fractures refractory to conservative therapy, as well as for select neoplastic vertebral lesions[47]. The authors are concordant with these recommendations. In the authors’ experience, vertebral augmentation for symptomatic neoplastic vertebral lesions with multi-disciplinary input tends to yield favourable results. In addition, there are potentially additional benefits of vertebroplasty aside from pain relief and mortality which require further research[48].

SACRUM

Percutaneous sacroplasty is established to be a safe procedure, and provides good short-term and long-term outcomes for patients with painful insufficiency sacral fractures or pathological sacral lesions[28], [49]. A multicentre study of 243 patients reported mean VAS scores improving from 9.2 to 1.9 for sacral insufficiency fractures and 9.0 to 2.6 for sacral lesions, at 1 year follow-up interval[28]. However, patients with displaced or unstable sacral fragility fractures would benefit more from surgical fixation[50].

PELVIS – In extraspinal bone metastases, cementoplasty is commonly performed to reinforce the acetabular roof and restore load transmission across the acetabulum. There is growing evidence demonstrating percutaneous cementoplasty as a safe and effective choice for patients with painful osteolytic pelvic bone metastases, significantly reducing pain and disability while preserving gait function[51], [52], [53]. Most recently, Park et al. evaluated percutaneous cement injection in 178 patients with pelvic bone lesions, which achieved significant pain reduction with mean numerical pain scores decreasing from 6.1 (pre-treatment) to 2.1 (1-month post-treatment), while maintaining gait function in 68% of recruited patients [54].

LONG BONES – The role of cementoplasty for metastases in long weight-bearing bones is still debated, due to the presence of complex loading forces (tensile and torsion) in addition to compression. Initial studies reported a one-year pathological fracture rate of 40.6% after cementoplasty of proximal femoral metastases [55]. A systematic review by Cazzato et al reported
standalone cementoplasty in the long bones is effective to achieve pain alleviation and to improve mechanical function, but fracture is the most frequent complication [53].

More recently, a systematic review compared the efficacy between cementoplasty alone versus cementoplasty augmented with fixation devices for impending pathologic proximal femoral fractures. Both appeared effective for pain relief and had a similar post-intervention fracture rate (5% for cementoplasty alone versus 7% for augmented cementoplasty), with no statistically significant differences [56]. Given current evidence, cementation of the long bones can be considered for palliation of immobile patients who are unsuitable surgical candidates.

KYPHOPLASTY

Kyphoplasty is purported to combine the benefit of analgesia with the restoration of vertebral body height [24], [57]. By restoring vertebral body height and improving spinal sagittal balance, kyphoplasty prevents increased loading of the spinal anterior column and reduces the risk of additional compression fractures [58]. Both kyphoplasty and vertebroplasty conferred a significant mortality benefit over conservative management, with the adjusted number needed to treat to save 1 life at up to 5 years estimated at 11.9 and 23.8, for conservative management versus kyphoplasty and vertebroplasty respectively [59].

For spinal metastases, both vertebroplasty and kyphoplasty significantly improved pain, disability and health-related quality of life, with no technique substantially superior to the other [58], nor had significant difference of pain relief [60]. However, balloon kyphoplasty may also decrease cement interdigitation into the surrounding trabecular matrix, potentially compromising anchorage and bone consolidation [61]. In addition, balloon kyphoplasty is postulated to cause further tumour dissemination due to the balloon inflation [62]. It is also costlier than vertebroplasty.

VERTEBRAL AUGMENTATION WITH IMPLANTS

Other techniques of vertebral augmentation include devices such as vertebral body stenting, SpineJack system (Figure 4) [59], Osseofix, Vertelift and KIVA system [63]. A prospective randomized study comparing implantable titanium vertebral augmentation devices versus balloon kyphoplasty for painful osteoporotic vertebral compression fractures reported greater pain relief, improved height restoration and lower incidence of adjacent fractures of the former, with similar results for adverse events and degree of functional improvement [64].

OSTEOSYNTHESIS

Unlike cement, screw fixation is its resistance to tensile, torsion, and shearing forces [65]. Percutaneous image-guided screw fixation (Figure 5) has been recently introduced for stabilization and consolidation of minimally displaced or impending pathologic fractures (Mirel Score 8 or greater) predominantly in the pelvis and proximal femur, and can be combined with cement augmentation (percutaneous internal cemented screws) [66], [67], [68], [69]. These studies reported significant improvement in pain and functional scores, with Pusceddu et al reporting a decrease in mean VAS scores in 27 patients from 7.1 (pre-treatment) to 1.4 (six months post treatment) [68]. Few major complications were reported; Deschamps et al reported two cases of secondary proximal femur fractures [66]. A study using cone beam CT guidance for placement of 75 percutaneous screws in pelvic bone metastases including steep angulations reported no adverse events [70].
The decision for percutaneous synthesis is multifactorial, taking into account factors such as the patient’s pre-morbid status, expected life expectancy and lesion location. Percutaneous osteosynthesis is generally reserved for non-surgical patients, for timely pain palliation and mobilization[66], [71]. In addition, more research is required to establish the long-term efficacy and safety profile.

COMPLICATIONS

Complications can be broadly divided into needle access-related and cement-related complications. Needle manipulation or errant placement may result in traumatic injury to critical structures including arteries, nerves or tendons[72], [73]. Careful consideration and an appropriate imaging modality are key to optimize visualization of critical structures along the needle trajectory. In the event of muscle or nerve injury, the preferred treatment option is non-steroidal anti-inflammatory agents or steroids. Vascular injury may require a vascular surgery consult and surgical repair[74].

As with all invasive procedures, infection is a potential complication and routine aseptic technique with pre-procedural single dose of intravenous antibiotics that cover skin flora is usually adequate. Tumour seeding associated with needle manipulation is rare, with a few case reports published[75], [76].

Cement leakage occurs more frequently during the treatment of pathological vertebral compression fractures compared to osteoporotic fractures[77]. Cement leakage into the peri-vertebral veins, paravertebral soft tissues or intervertebral discs is commonly encountered, occurring in approximately 70% of cases, and is usually asymptomatic [78]. Posterior cement leakage into the spinal canal is rare but can lead to spinal cord compression[79]. Intra-foraminal leakage may be responsible for radiculopathy. In the hip joint, chondrolysis and osteonecrosis may result from intra-articular cement leakage, potentially requiring arthroplasty[80].

Cement intravasation via the periosteal venous plexus has been reported with incidence of up to 25%[73], while intravasation to the azygous vein portends a higher risk of pulmonary emboli[81]. Similarly, cement injection may result in the displacement of bone marrow into the venous plexus, with potential fat embolism[82]. It has been recommended to limit cement injection volume to less than 30ml or six vertebral segments per session to minimize symptomatic fat embolism[83].

CRYOABLATION

Cryoablation is a percutaneous thermal ablation technique where tumour tissue is cooled to extremely low temperatures achieved via placement of probes filled with liquid nitrogen or a compressed gas (usually argon) into the target lesion[84]. Alternating cycles of rapid freezing and gradual thawing result in tumour cell death, via a complex mechanism involving the formation of intracellular ice crystals, endothelial damage to local tumoural blood supply, inducing ischemia and devascularization [85]. A temperature lower than −20 °C results in complete cell death, while about 80% of cells are destroyed in the 0-20°C zone [86].

INDICATION

Cryoablation has an expanding role in the management of primary and secondary bone tumours. For primary bone tumours, cryoablation has been included in the European Society of Medical Oncology (ESMO) guidelines as a local adjuvant to curettage for atypical cartilaginous tumours and giant cell tumours, and palliative treatment for recurrent extracranial chordomas[87]. Cryoablation has also
been reported as a viable alternative to radiofrequency ablation for osteoid osteoma (Figure 6) [88], the current preferred treatment modality [89], including a recent retrospective study of 50 patients which achieved a 96% overall clinical success rate[90].

For bony metastases, the United States National Comprehensive Cancer Network guidelines have included percutaneous thermal ablation as a palliative treatment option for metastatic bone pain. [91]. The updated American College of Radiology appropriateness criteria includes percutaneous thermal ablation as a viable initial treatment option for symptomatic pathological vertebral compression fractures [92].

While there is no current evidence favouring the use of one ablation technique over another for the palliation of metastatic bone disease[93], cryoablation has certain advantages. Compared to other ablation techniques, cryoablation has an intrinsic analgesic effect, with less pain for the patient during and immediately after treatment [94], [95]. Cryoablation can be repeated if indicated, and operators can use multiple cryoprobes simultaneously to customize the size and shape of the ablation zone[96]. In addition, a radiofrequency-unsafe cardiac pacemaker is not a contra-indication to cryoablation.

While there is no clear consensus presently, oligometastatic and oligoprogressing disease with bone metastases with a size <2 cm and no cortical erosion have been associated with a better local tumour control after ablation [97], [98]. Lesions to be considered for ablation should also clearly associated with focal pain of at least moderate intensity (pain score above 4), with insufficient response to treatment options including analgesics or radiotherapy [99].

Lesions that are less than 1 cm to important neural structures or organs are usually excluded. Large vessels often have a “heat sink” property which protects the vessels but also lead to an irregular and unpredictable ablation zone[100]. Osteoblastic lesions are usually not amenable to ablation because of difficulty in probe deployment, but may be occasionally possible if deployed adjacent to the lesion with no adjacent critical structures, such as the iliac wings [19].

A myriad of applications of image-guided cryoneurolysis have been reported, from the head and neck region, intercostal, coeliac plexus, spine, inguinal neuralgia, pudendal neuralgia, Morton’s neuroma, and other peripheral nerves[101], [102].

Contraindications to cryoneurolysis are similar to peripheral nerve blocks, including infection (both local and systemic), anti-coagulation, bleeding disorders, cold urticaria, and Raynaud’s syndrome[103]. Cryoneurolysis is also contraindicated when the target nerve contributes an important motor function, for example the femoral nerve which may cause quadriceps muscle weakness and limits ambulation[103]. Nevertheless, the risk of motor compromise may be acceptable in terminal illness and severe symptoms, and necessitates an individualized approach.

**TECHNIQUE**

Similar to other percutaneous ablation techniques, cross-sectional images are scrutinized to plan an appropriate needle trajectory, as well as number and type of cryoprobes necessary to mould the ablation zone. Cryoablation is usually well tolerated under conscious sedation.

Reported protocols for cryotherapy vary widely, ranging from a single cycle of 120 seconds to repeated cycles of 10 minutes, with intervening active or passive thawing[102]. Since the margin of the ice ball indicates 0 °C, the boundary of the ice ball should extend beyond the lesion itself by at
least 5–8 mm to assure complete tumour ablation [95], [104], [105]. To achieve the best outcome in pain reduction, the interface between normal bone and tumour should be targeted [106].

Some cell damage also occurs beyond the O’C ablation zone, and should be accounted for during planning and probe positioning. Various thermal protection techniques can also be employed, including hydrodissection, pneumo-dissection or usage of neuromonitoring devices.

For cryoneurolysis, it is critical to induce Sunderland 2 peripheral nerve injury (myelinolysis and axonolysis) in order to achieve clinical success and predictable outcomes. Cryoneurolysis provides longer pain relief compared with that of local injections or temporary catheter infusions, and a lower risk of formation of neuromas compared with that of heat-mediated ablation or surgical transection[102]. In addition, as axons regenerate at a rate of 1-2mm per day, the duration of analgesia is related to the distance between the cryoneurolysis site and source of pain[107]. A diagnostic injection of long-acting local anaesthetic, with or without accompanying steroid, may provide critical diagnostic information prior to the actual procedure [108].

IMAGING GUIDANCE

CT and MRI are preferred as techniques of guidance because it is possible to visualize the ablation zone (commonly referred to as “ice ball”), ensuring complete coverage of the lesion while reducing complications to adjacent critical structures[109], [110].

Ultrasound can also guide targeting of superficial structures and visualization of ice ball formation, with the added benefit of real-time doppler assessment of vascular structures. However, the ice ball is sono-opaque and obscures visualization of deep structures, and utility of ultrasound is limited in deep-seated lesions or in patients with large body habitus[102].

EFFECTIVENESS

BONE TUMOURS

There is mounting evidence of cryoablation for bone metastases both for palliation purposes (Figure 7), as well as curative aim in oligometastatic disease[97], [111], [112], [113], which is defined as 1–5 metastases where all metastatic sites are considered safely treatable[114]. Most recently, the MOTION trial reported rapid and durable pain relief for patients with metastatic bone disease, as well as improved quality of life and maintained functional status over 6 months[112]. Percutaneous cryoablation as an alternative or adjunct therapy for selected patients with plasmacytomas has also been reported[115].

SOFT TISSUE TUMOUR

Soft tissue sarcomas are rare tumours with multiple subtypes, the most common of which are liposarcomas and leiomyosarcomas[116]. There is emerging evidence of cryoablation as a feasible and safe treatment option for these tumours especially in recurrent or metastatic disease [117], [118]. Other tumour subtypes treated by cryoablation include abdominal wall endometriosis[119], neurofibromas[120] and gastrointestinal stromal tumours[121].

This is especially so for extra-abdominal desmoid fibromatosis (Figure 8) [111]. Previously, treatment consists of a combination of surgery and radiotherapy[122]. The current first-line treatment for symptomatic desmoid tumours is based on medical therapies including tyrosine kinase inhibitors and chemotherapy (including methotrexate) [123], with respective systemic side effects.
Recent studies have demonstrated cryotherapy as a safe and effective treatment modality for extra-abdominal desmoid tumours, with efficacy similar to those managed via conventional approaches in the short to medium term[124], [125].

CRYONEUROLYSIS / CRYORHIZOTOMY

Percutaneous image-guided neurolysis (Figures 9 to 12) is a safe, efficient and relatively cost-effective means of managing refractory pain, which may arise from direct tumour invasion or iatrogenic to surgical and radiation therapy[101]. Unlike heat-mediated ablation, cryoablation does not disrupt the acellular epineurium or perineurium, reducing risk of neuroma formation and potentially allowing nerve regeneration[126]. Cryoneurolysis is also not associated with systemic toxicity occasionally encountered with chemical nerve ablation[127].

VASCULAR MALFORMATION

Cryotherapy has also been evaluated as a treatment option for vascular malformations, in particular venous malformations (Figure 13) and fibroadipose vascular anomalies, either as a first-line treatment[128] or second-line treatment after sclerotherapy[129]. A systematic review of cryoablation in the treatment of venous malformations (55 lesions) reported promising results in terms of lesion size decrease and symptom improvement, with weighted mean postprocedural decrease in lesion size of 92.0%, weighted mean reduction in pain score of 77% and complete resolution of symptoms (35/55) (63.6%) [130].

COMPLICATIONS

Bone tumour cryoablation is safe, with a reported 2.5% rate of major complications, most commonly secondary fracture (1.2%). Major complications are associated with age greater than 70 years and use of more than three cryoprobes [131].

The most important potential complication of thermal ablation of skeletal metastases remains non-target thermal injury to the spinal cord or adjacent neural structures. These are usually transient and typically managed with local injection of steroids and long-acting anaesthetic agents[13]. Knowledge of neuroanatomy is crucial and can prevent inadvertent thermal injury[132]. Thermal injury to the vital organs and skin should be minimized by implementing thermal protection strategies such as hydrodissection or pneumo-dissection.

Other complications vary depending on the site of ablation. When treating lesions near the skin, skin necrosis is a consideration. Caution should be taken when treating lesions near joint to avoid joint effusion, synovitis and osteonecrosis.

Other potential side effects of cryoneurolysis include bleeding, bruising, and rarely infection[103]. If the target nerve is superficial, skin and hair in the adjacent region may affected including hyperpigmentation, depigmentation, and alopecia, particularly near the eyebrow when treating the supraorbital nerve[133].

COMBINED

Indications

Percutaneous cementoplasty and thermal ablation have synergistic properties. Given a potential complication of pathological fracture due to cryoablation-induced necrosis, adjunct cementoplasty
has successfully been performed and demonstrated durable pain relief and stabilization (Figure 14) [134], [135], [136]. Cementoplasty has little to no antitumoural effect and has been reported to transiently increase the level of the cancer circulating cells in the minutes following injection [137], ablation prior to cement injection may be indicated in cases of local tumour control, tumour debulking to prevent complications such as a growing lesion near a nerve, improve quality of consolidation and decrease tumour seeding.

Effectiveness

Other ablation techniques such as radiofrequency ablation and microwave ablation with concurrent stabilization have also yielded effective results [138], [139], [140], [141], [142]. In the authors’ experience, temperature-controlled radiofrequency ablation (“co-ablation”) of vertebral metastases provided satisfactory results in selected patients whom have limited pain relief despite prior radiotherapy and opioid titration (Figure 15); similar results have been reported for pelvic and acetabular metastases [143].

To date, there is limited data comparing the effectiveness of combined cryoablation and cementoplasty procedures versus other combined ablation-stabilization techniques, partly due to the complexity of conducting randomized trials regarding individualized therapy for palliative procedures [144].

It is also difficult to evaluate the exact benefit of combined ablation and cementoplasty versus cementoplasty alone, especially for bony lesions without extraosseous component [140], [145]. In a retrospective study of 35 patients, Wang et al reported a better analgesic effect, increased cement injected and lower cement leakage rates from combined RFA and vertebroplasty, compared to vertebroplasty alone [146].

CONCLUSION

There has been substantial advancements and mounting evidence of safety and efficacy in percutaneous image-guided procedures for the musculoskeletal system, including cementoplasty and cryoablation techniques. These enable the interventional radiologist to offer a diverse repertoire of options in a multi-disciplinary approach to patient management, especially cancer patients with bony metastases.
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