Transarterial embolization of bone metastases

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Abstract

Embolization of bone metastases is most commonly performed for hypervascular tumors prior to surgical resection. When employed in this fashion embolization can significantly decrease perioperative hemorrhage and improve surgical outcomes. In addition, embolization of bone metastases may lead to local tumor control and decreased tumoral associate bone pain. Careful techniques and choice of embolic material is required when performing embolization of bone lesions to ensure low procedural complications and high rates of clinical success. The indications, technical considerations, and complications associated with embolization of metastatic hypervascular bone lesions will be discussed in this review with subsequent case examples.
Introduction

In cancer patients, disease that has metastasized to the skeleton often portends a poor prognosis with potential significant morbidity characterized by severe pain, impaired mobility, pathologic fractures, bone marrow aplasia, and hypercalcemia. Treatment focuses on slowing progression and improving quality of life by reducing pain and improving mobility.

Indication for surgical treatment of bone metastases most commonly includes a present or impending pathologic fracture and prophylactic fixation surgery. However, these surgical procedures are associated with prolonged operating times and large intraoperative blood loss, especially in hypervascular tumors. Given these risks, pre-operative embolization of bone metastases was developed with the goal of minimizing intraoperative blood loss and reduced surgical complications. Since that time embolization of bone lesions has expanded in its use and indications. The indications, materials, technical considerations, and complications associated with embolization of bone lesions will be discussed in this review. The focus of this review will be on embolization of hypervascular bone metastases and not primary osseous malignancy, as metastases are significantly more common. However, it is worth noting that similar techniques can be applied to embolization of primary bone lesions.

Indications

The most common indication for embolization of a bone metastasis is to decrease intraoperative hemorrhage during surgery which can result in improved simplicity of the surgical resection. Less frequent indications include relief of pain and for local tumoral control.

Given the high intraoperative blood loss associated with hypervascular bone metastases, pre-operative embolization is most commonly performed for these type of tumors which include metastatic renal cell carcinoma, thyroid cancer, melanoma, leiomyosarcoma, and prostate cancer. Renal cell carcinoma metastases are the most common. Less commonly, embolization of primary bone lesions and metastases have been performed to decrease lesion associated pain. The operator’s goal for this indication is to devascularize tumor in order to alleviate symptoms via tumor shrinkage. More recently, cryoablation has demonstrated promising results when employed for control of lesion associated pain and may be more clinically effective in this regard when compared to embolization.

Pre-procedure

Pre-procedure planning should include a history and physical examination focused on elucidating specific sites of pain and identifying locations of planned surgical resections. Evaluate the planned access site pulses (common femoral or radial artery) and visualize the overlying skin at site of the planned embolization. Note neuromuscular status, skin color, capillary refill, and presence or absence of overlying wounds.

Pre-procedure cross-sectional imaging is often obtained to confirm arterial supply and identify critical adjacent structures. CT angiography is preferred by the authors given its ability to
delineate arterial supply and anatomic details while avoiding the limitations of inappropriate MRI protocoling. However, more recently at our institution pre-procedure arterial-phase cross-sectional imaging has been omitted and replaced by intra-procedural cone-beam CT. In addition to convenience, cone-beam CT has the added benefit of ensuring adequate timing of the contrast bolus for appropriate visualization of the targeted arterial anatomy.

**Technique**

Prior to performing embolization operators should carefully consider vascular supply of at-risk vital structures. For example, within the lower extremity consideration should be given to arterial supply to the vasa nervorum of the sciatic nerve which most commonly arises from the medial circumflex femoral artery.\(^7\) If a spine metastases will be treated, careful evaluation for spinal cord vascular supply is mandatory.

Arterial access is most often determined based on favorable anatomy (i.e., lack of atherosclerotic disease) and the location of the targeted tumor(s). For upper extremity lesions the authors prefer lower extremity common femoral artery access. This is due to the anatomy of arterial branching points within the extremities to be commonly oriented from proximal to distal. Approaching these branching points from a proximal to distal approach facilitates greater ease of cannulation and decreases excessive device manipulation that may damage or spasm targeted arteries. For similar reasoning the preferred access sites when procedures involve the lower extremities includes the contralateral retrograde common femoral artery, the ipsilateral antegrade common femoral artery, or the left radial artery. If the embolization is being done pre-operatively, arterial access in the same extremity should be avoided since surgeons will often perform extensive manipulation of the proximal joint. Access site complications may be potentially higher and undetected from these intraoperative movements.

During treatments involving the upper extremities the operator should take particular care near the aortic arch and great vessels due to the theoretical complication of inciting an ischemic stroke from catheter manipulation in this region.\(^10\) For this reason the authors prefer to use a 4 or 5 French (Fr) Glidcath (Terumo, Tokoyo, Japan) for navigating through the aortic arch as we have found the catheter to be the most atraumatic while having a high degree of success in cannulating the targeted vessel. When patient anatomy results in difficulty cannulating an arch vessel a neurointerventional specific catheter is utilized, such as the headhunter (Merit, South Jordan, UT).

After access to the targeted region is accomplished, power-injection angiography is performed. In the upper extremity a rate of 4 ml per second for a total of 15-20 ml of contrast is usually sufficient. When choosing contrast injection rate and amount in the lower extremity distance between the catheter and the targeted lesion must be considered. For proximal lesions a rate of 4 ml per second for a total injection amount of 15-20 ml is usually sufficient. For more distal lesions a larger amount of contrast is required, usually 20-30 ml. Angiography is then repeated with performance of a cone beam CT which obtains excellent arterial and soft tissue anatomy which aides in identification of all arterial supply to the targeted tumor. An appropriate delay time on the cone beam CT will allow perfusion of the entire tumor to be visualized. This delay
time can be chosen by the obtaining the time elapsed for maximal tumor enhancement on the preceding digital subtraction angiogram. Post-processing of the cone beam CT with 3D reconstruction and maximum intensity projections is particularly helpful in this regard and allows the operator to determine the optimal working obliquity when canulating targeted vessels.

Selection of branching arteries is performed with a microsystem to decrease the risk of non-target embolization. Targeted vessels in this procedure tend to be particularly small in caliber and therefore 2.0-2.4 French (Fr) microcatheters are often required. Depending upon anatomy and vessel size the authors’ preferred microcatheters are the 2.4 Fr Direxion shaped tip (Boston Scientific, Marlborough, MA) and the 2.0 Fr Progreat alpha (Terumo, Tokoyo, Japan). Microwires that are most commonly used include the Fathom 14 (Boston Scientific, Marlborough, MA), and the Synchro soft microwire (Stryker, Kalamazoo, MI). Once access into the targeted vessel is obtained, 100-200 mcgs of nitroglycerin can be given intra-arterially to reduce spasm and facilitate a more complete embolization.

Embolization of targeted vessels is then performed. Hypervascular osseous tumors frequently have several arterial feeders. Embolization of a single artery is inadequate, and will result in collateralization via the larger feeding arteries. Therefore, we intentionally select and treat the smaller arteries first, with treatment reserved for the largest arterial feeder at the end. All arteries should be treated in a single session if possible. Choice of embolic is largely operator dependent but the authors recommend permanent particulate agents. Liquid agents, such as glue or Onyx (Medtronic, Dublin, Ireland), carry an increased risk for non-target embolization with the anatomy often found in the extremities. Gelfoam (Pfizer, New York, NY) is an attractive choice for an embolic agent for this procedure given its temporary nature of lasting approximately 2-4 weeks. Unfortunately, its practicality is limited given the need to deliver the embolic within small microcatheters that are often required to cannulate the targeted vessels. This limits the ability to safely deliver Gelfoam (Pfizer, New York, NY) due to decreased operator control, increased chance for reflux, and a high likelihood of occluding small microcatheters.11

With regards to choice of other particulate agents, previous investigations have shown no difference between the use of non-spherical polyvinyl alcohol (PVA) particles and trisacryl gelatin microspheres.12 If cost is a consideration PVA particles could be utilized. The authors’ preferred particulate embolic are calibrated microspheres given their tightly regulated sizing which has been observed by the authors to lead to greater reliability. When sizing particulate embolics the operator must carefully evaluate initial angiographic imaging to assess for the presence of non-target supply and for the presence of intra-tumoral shunting. In the absence of arterial shunting particle sizes utilized are often between 75µm – 200 µm. The most commonly used particles and size by the authors is 100 µm Embozene (Varian, Palo Alto, CA). If shunting is present larger particles are chosen to ensure entrapment of particles within the tumor, such as 100-500 µm. The targeted goal for embolization is a significant reduction in tumoral blush with preservation of non-tumoral supply. A goal of complete stasis is ill advised in these procedures given the increased likelihood of complications including non-target embolization in an area of often high-risk anatomy (i.e. upper extremities). When performing prior to planned surgical resection, it is not imperative to achieve complete devascularization. While this remains the goal, it should not be done at the expense of significant non-target embolization. The use of microcoils is not routine in our practice due to the possibility of impeding or complicating surgical resection.
with likely little clinical benefit. If microcoils are being considered it is recommended to discuss first with the surgeon performing the subsequent tumoral resection.

**Post-procedure**

Embolization of bone metastases is often associated with significant post-procedure pain. Therefore, embolization should be performed within close proximity to the planned surgical resection to minimize patient suffering. Embolization at our institution is arranged to be performed in the late afternoon the day before surgical resection is to be performed the following morning. Patient controlled analgesic (PCA) pumps are routinely arranged for in preparation for the significant post-procedural pain while the patient awaits surgical resection.

Complications from embolization of bone metastases is similar to other embolization procedures and overall the procedure is associated with low complication rates.\(^\text{13}\) The most common complication is postembolization syndrome due to tumor necrosis and presents with symptoms of pain, fever, and fatigue. Other complications include access site complications, infections, pain, and complications related to sedating medications. More rare complications are most commonly associated with non-target embolization, such as skin ulcerations or limb ischemia. Transient paralysis has been reported in the literature and is thought to be secondary to non-target embolization of vascular supply to an adjacent nerve.\(^\text{14}\)

**Conclusion**

Interventionalists are well trained in embolization procedures throughout the vascular system. As such, expanding one’s embolization repertoire to include the bone has the potential to provide significant clinical benefit to patients with bone metastases, a deliberating disease that carries a poor short-term prognosis. The most common indication for embolization of bone tumors is for pre-operative embolization for metastatic hypervascular bone lesions (renal cell carcinoma or thyroid cancer) and when utilized for this indication the perioperative bleeding is significantly reduced resulting in decreased complexity in surgical resection.


**Case 1.** A. Right elbow radiograph in a patient with metastatic renal cell carcinoma with a bone metastasis causing near complete destruction of the right olecranon. B. Right upper extremity digital subtraction angiogram (DSA) via right common femoral artery access with a 5 Fr angled Glidcath (Terumo, Tokyo, Japan) demonstrates hypervascular tumor centered in the olecranon. C. Intra-procedure maximum intensity projection from a cone-beam CT well delineates vascular tumoral supply. D. DSA after selection of the right internal ulnar collateral artery with a 2.0 French Progreat alpha microcatheter (Terumo, Tokyo, Japan) and Fathom 14 microwire (Boston Scientific, Marlborough, MA) demonstrates tumoral vascular supply. Note is made of rapid visualization of the brachial artery which was secondary to intra-tumoral shunting (arrow). E. Post embolization angiogram demonstrates near complete absence of previously seen tumoral blush after multiple sites of embolization. Within the right internal ulnar collateral artery embolization was performed with 100-300 µm Embospheres (Merit, South Jordan, UT) due to the presence of arterial shunting. Remaining sites of embolization was accomplished with 100 µm Embozene (Varian, Palo Alto, CA). Intraoperative blood loss after radical olecranon resection and reconstruction was 200 ml.
Case 2. A. CT of the right hip in a patient with metastatic renal cell carcinoma with bone metastasis involving the right proximal femur with an impending pathologic fracture. B. Right lower extremity digital subtraction angiogram (DSA) after obtaining contralateral retrograde left common femoral artery access demonstrates a large hypervascular tumor corresponding to the right femoral metastatic lesion. C. DSA after selection of the lateral circumflex femoral artery branch with a 2.0 Fr Progreat alpha (Terumo, Tokyo, Japan) with a Fathom 14 microwire (Boston Scientific, Marlborough, MA) confirms tumoral supply. D. DSA after selection of a second lateral circumflex femoral artery branch also confirms tumoral supply from this location. E. DSA after embolization performed with 75 μm Embozene (Varian, Palo Alto, CA) at each location demonstrates near absence of previously seen tumoral blush. Intraoperative blood loss during resection and reconstruction was 300 ml.