27 Metastatic Bone Disease: Humerus and Scapula

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Humeral Metastases

Burden of Disease

Metastatic and myelomatous lesions of the humerus are extremely common. The true incidence is hard to determine given that patients may be less likely to display symptoms with lesions of the upper extremity and variation in the primary source of disease to affect all bones of the skeleton equally. Among the long bones, the humerus is the second most common site for symptomatic metastatic lesions [1, 2]. Similar to the axial skeleton and femur, the most common primary histologies that metastasize to the humerus are breast (30 %), renal cell (20 %), lung (10 %), and prostate carcinomas (10 %). Other primaries such as thyroid, colorectal, bladder, and hepatocellular carcinoma represent less than 10 % of humeral disease [1, 3, 4]. Myeloma accounts for about 20–25 % of symptomatic humeral lesions [3, 5] and although myeloma is not considered a bone metastasis, these lesions can be managed using similar principles.

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The anatomic distribution of humeral metastases can be divided into lesions involving the diaphysis, distal third and proximal third. Lesions of the diaphysis are most common representing 50–60 % of cases, whereas lesions of the proximal third and distal third are less common (20–30 % and <10 % of cases, respectively) [1]. Similar to the traumatological approaches used to guide management of humerus fractures, surgical management of metastatic lesions and pathologic fractures of the humerus can be approached by dividing the humerus into these broad anatomic segments (see below). However, osseous involvement or resulting pathologic fracture(s) can span the virtual boundaries outlined above and hence may require a modified approach to management.

Over the past two decades, targeted therapies for a variety of metastatic carcinomas are becoming available to patients and the survival of patients with metastatic bone disease is anticipated to increase in the future. In addition, the functional capacity of patients with metastatic disease burden continues to improve which may necessitate a more aggressive approach to treatment in certain cases. Nonetheless, the prognosis for patients that develop a metastasis to the humerus remains guarded with 1- and 2-year survival for these patients reported as between 30–40 % and 10–25 %, respectively [3, 5]. With this in mind, and in the setting of failed nonsurgical measures, operative intervention for metastatic lesions of the humerus should provide limited

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morbidity and durable fixation in the absence of bone healing and permit immediate load-bearing and rapid rehabilitation.

Non-operative Care

Because the humerus is a non-weight-bearing bone there exists greater possibility to treat symptomatic metastatic and myelomatous lesions of the humerus with radiation therapy, splinting, and/or a temporary period of activity modification. The capacity of the underlying histology to respond to adjuvant therapy (either local or systemic) must be considered, as these variables will have an impact on the local outcome if the goal requires consolidation of bone loss or healing of a pathologic fracture. As the humerus is subjected to much lower forces than the bones of the lower extremity, it is not uncommon for patients to present with a pathologic fracture without any antecedent pain. Predicting which lesions are at risk for fracture, thereby warranting prophylactic stabilization, remains difficult and any criteria to do so are ill defined. Mirels criteria [6] remains the most commonly used scoring system to evaluate metastatic lesions of the long bones for fracture risk despite a relatively low specificity [7]. These criteria were developed in a population predominantly burdened with metastatic breast cancer involving the femur and therefore this scoring system may not be generalizable to all lesions within the humerus. However, in a study by Evans et al. [8], the authors were able to show that Mirels criteria remained reproducible, valid, and more effective than clinical judgment alone in the determination of prophylactic stabilization of the humerus. Although not easily rationalized, the authors of this study were able to show improved sensitivity and specificity when a threshold score of 7 was used (as opposed to a score of 9 for femoral lesions) to predict the need for prophylactic stabilization [8]. Preventing a pathologic fracture of the humerus remains an important dialogue, as postoperative complications are more commonly seen in surgically stabilized complete fractures versus prophylactic treatment of impending fractures [3].

In symptomatic lesions of the humerus deemed low risk for fracture or in patients who are unlikely to tolerate an anesthetic or have a limited life expectancy, treatment with external beam radiation would be considered the standard of care (please refer to Chaps. 17 and 21 for more detail). The optimal radiation treatment protocol for symptomatic bony metastases is controversial [9–11], although data from systemic reviews and meta-analyses would suggest that a single fraction dose of 8–10 Gy or mutlifractionated doses of 20–30 Gy over 5–10 treatments equally improve pain outcomes. Single-fraction therapy is associated with less local toxicity but higher rates of retreatment and posttreatment fractures compared to mutlifractionated doses [12, 13]. Roughly 30–40 % of lesions treated will demonstrate some radiographic evidence of bony reconstitution after radiation therapy [14, 15]. Systemic agents, including bisphosphonates, may also have an effect on overall success of treatment.

Although nonsurgical management of many traumatic humeral fractures is considered the standard of care, this same approach for established pathologic fractures needs to be cautiously considered given the low likelihood of achieving union in many tumor histologies (Fig. 27.1a–c). In the frequently cited study by Flemming and Beals [16], nonunion and inadequate pain control were observed in 50 % and 88 % of patients, respectively. Given the limited life expectancy of metastatic carcinoma patients, the prolonged physical impairment associated with nonoperative management of pathologic humerus fractures warrants prompt surgical care. Functional bracing can be used for patients that are not systemically fit for surgical care or in some tumor types whereby healing is considered to be likely if adjuvant treatment is known to have a positive effect on osseous disease. Patients with a diagnosis of multiple myeloma who have yet to receive systemic treatment or those currently receiving active treatment may be considered candidates for a trial of nonsurgical care (Fig. 27.1d–f). Functional status, activity expectations, hand dominance, and analgesic requirements may impact on the decision to treat conservatively.

Fig. 27.1 Panels **a**–**c**: 65-year-old male patient with a metastatic adenocarcinoma lesion and associated pathologic fracture of the humeral diaphysis managed nonoperatively. Images of the fracture at presentation (**a**), 6 weeks (**b**), and 3-month follow-up (**c**) demonstrated persistent nonunion. Panels **d**–**f**: 51-year-old male patient with new diagnosis of multiple myeloma on active chemotherapy with 6-week history of upper arm and shoulder pain (**d**). 3 months following period of activity modification (**e**). 2 years after presentation having completed appropriate therapy and disease remission (**f**)

Operative Management

For the vast majority of cases, surgical management of metastatic bone disease is a palliative treatment. Therefore the primary goals of any surgical intervention in this patient population should be to provide a definitive procedure that controls local tumor burden, provide immediate and durable osseous stability, reduce pain, and enable a rapid return to activities of daily living.

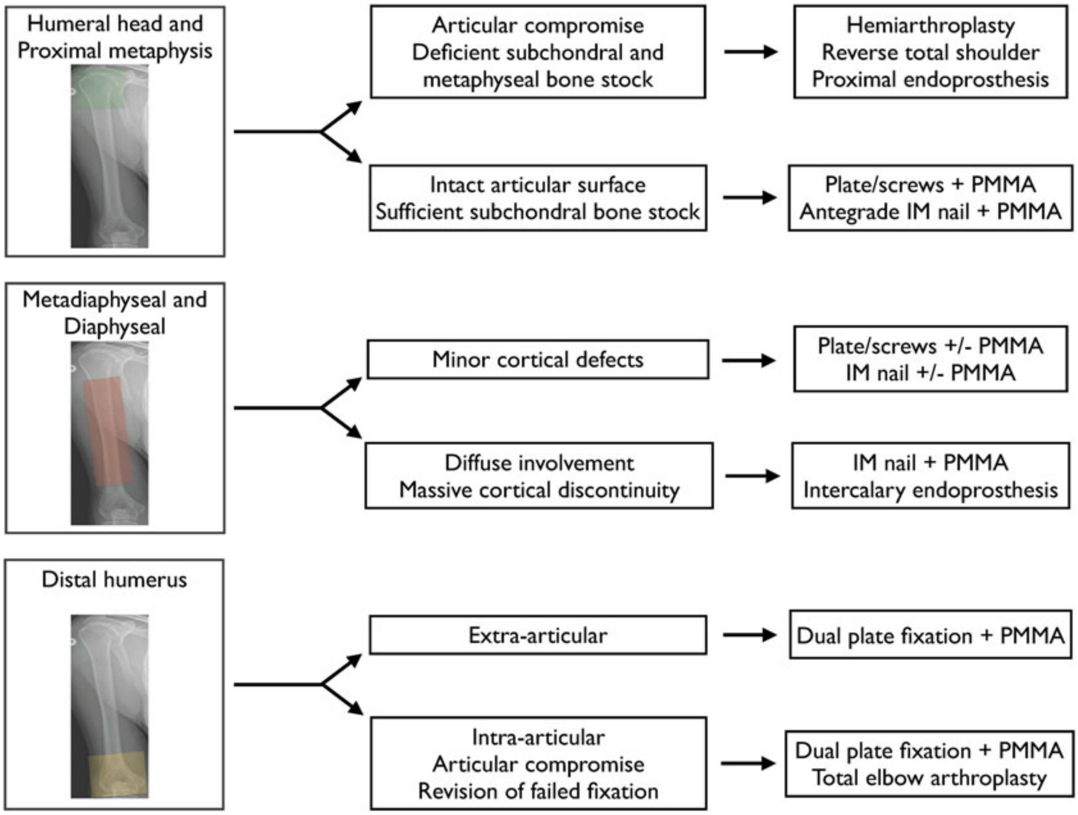

Fig. 27.2 Surgical treatment algorithm for lesions and/or pathologic fractures of the humerus based on anatomic factors

Failure to meet any one of these goals often necessitates revision surgery, prolonging recovery in individuals with an already compromised quality of life. These operative goals are no different for the humerus than for the long bones of the lower extremity. Pathologic and impending fractures of the humerus can be operatively stabilized using a variety of techniques and implants. Optimal implant and technique selection is based on a constellation of factors such as patient health status, anatomic location of the fracture and/or lesion(s), the extent of bone loss, histologic diagnosis, and surgeon preference.

To simplify these variables, surgical decision making can be stratified using anatomic landmarks. Lesions of the metaepiphyseal proximal humerus are managed using plate and screw constructs or endoprosthetic reconstructions. Diaphyseal and metadiaphyseal lesions are most amendable to intramedullary nail fixation or plate and screw fixation, while distal lesions of the humerus are best treated stabilized using orthogonal plating strategies or elbow arthroplasty techniques (Fig. 27.2). Alternatively, the indications and technical considerations for each reconstructive or stabilizing device can be evaluated in the context of pertinent patient and fracture-related variables.

Intramedullary Nail Fixation

Intramedullary nails are ideal load-sharing devices for stabilization of most impending and complete pathologic fractures of the humerus. Antegrade and retrograde interlocking humeral nails are widely available and technically simple to use. A major advantage of these devices is that the working length of the nail spans the entire bone, especially with diffuse disease (Fig. 27.3a, b). Plates can also be used to span the majority of humerus (Fig. 27.3c, d). However nails, unlike plate

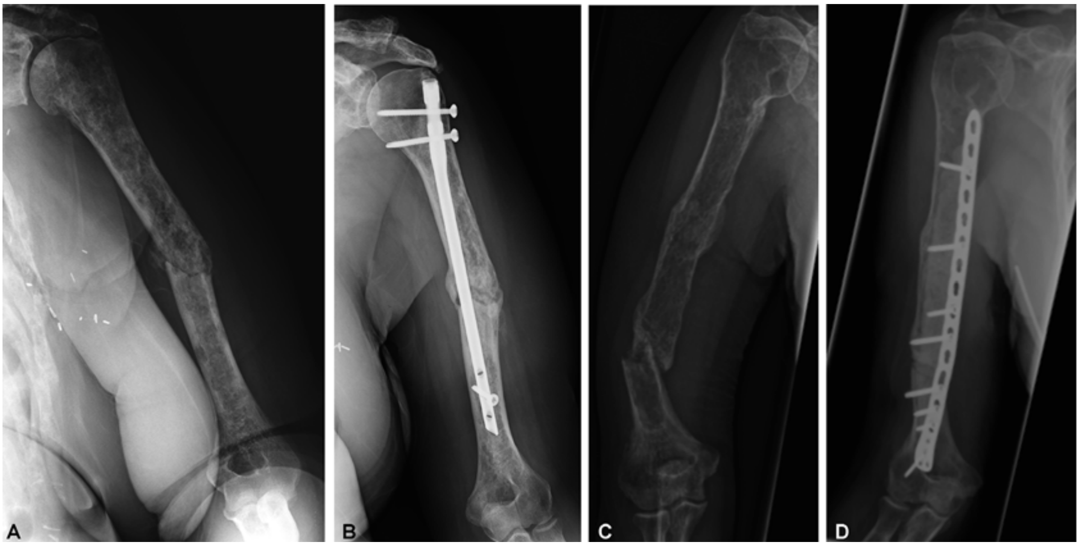

Fig. 27.3 Panels **a** and **b**: 61-year-old female with diffuse involvement of the humerus secondary to metastatic breast carcinoma (**a**). An intramedullary nail provides fixation for the entire diaphysis and proximal metaphysis with evidence of fracture healing at 3-month follow-up (**b**). Pain symptoms were dramatically improved in this patient, despite incomplete fracture union at 3 months. Panels **c** and **d**: 62-year-old female with multiple myeloma on maintenance chemotherapy and history of pathological humeral fracture(s). Patient presented with symptomatic nonunion of distal humeral diaphysis (**c**). Definitive stability achieved with long posterior locking plate augmented with cement (**d**)

constructs, are more amenable to a minimally invasive approach, which is advantageous in situations where the additional risk associated with exposure of the lesion or fracture (blood loss, nerve injury, etc.) is not warranted. Tumor debulking and cement augmentation of bone defects can still be accomplished simultaneously using additional exposures along with nailing procedures.

General indications for intramedullary nail fixation include lesions or fractures located within 2–3 cm distal of the greater tuberosity to roughly 5 cm proximal of the olecranon fossa [17]. In addition to the proximal-distal location of the lesion, 4–5 cm of intact cortical bone on either side of the nail is required for rigid fixation [18]. Proximal or distal metaphyseal defects do not preclude the use of an intramedullary nail although plate fixation or cement augmentation should be considered in these instances. Tumor debulking and cement augmentation should also complement nail fixation of diaphyseal defects >2–3 cm. Proximal and distal interlocking screws should be utilized whenever possible, especially for complete fractures [18]. When using cement augmentation, cement can be added in a more viscous state and packed around the nail after insertion or in a less mature state after reaming and immediately before the definitive device is inserted.

In appropriately selected patients, outcomes after intramedullary fixation are favorable. Durable pain relief and return to activities of daily living can be expected in >90 % of patients. Reoperation rates are less than 5 % and most commonly associated with tumor progression and prominent proximal hardware [4, 17–20] (Fig. 27.4). One retrospective case–control study demonstrated earlier functional gains and pain improvement when intramedullary fixation was augmented with cement [20], although the necessity of cement augmentation with IM nail fixation remains controversial.

There are nonetheless various pitfalls and complications associated with intramedullary humeral nails. Shoulder pain and/or decreased shoulder abduction and forward flexion is observed in 10–15 % of patients likely secondary

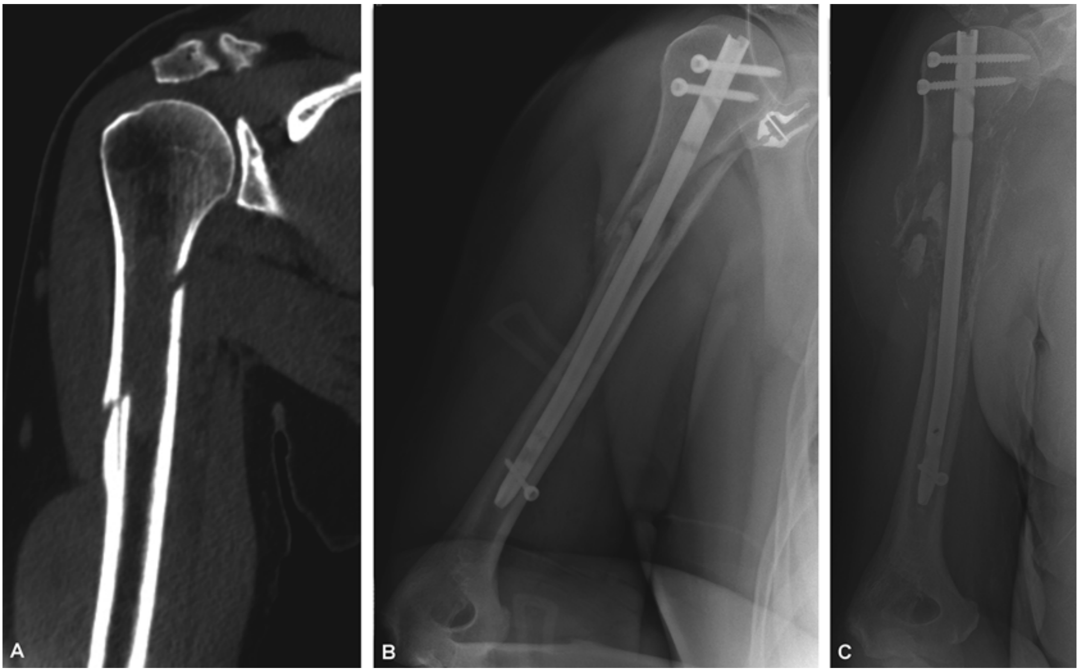

Fig. 27.4 A 59-year-old patient with metastatic renal carcinoma involving the proximal humeral diaphysis with an associated pathologic fracture as his presentation of disease (**a**). Despite tumor debulking, IM nail fixation, and postoperative radiation (**b**), the lesion and bone destruction progressed rapidly with extensive bone destruction at 6-week follow-up (**c**). Within 5 months of his fracture, this patient died of this aggressive systemic disease

to rotator cuff injury during insertion or a prominent proximal nail position [21–24]. This can be lessened by meticulous protection of the supraspinatus tendon during reaming and nail insertion. Ensuring the proximal nail or proximal locking bolts are not left proud will also minimize postoperative shoulder issues. In a recent systematic review comparing plate osteosynthesis and intramedullary nail fixation for non-pathologic fractures of the humerus, nail fixation was associated with a greater incidence of shoulder impingement (21/123 cases, 17 %), decreased range of motion, and hardware removal (9/69 cases, 13 %) [25]. These results may not be generalizable to patients with pathologic fractures and impending fractures given the lower functional demands and life expectancy of these patients. Regardless, patients should be counseled of the risk of shoulder impingement preoperatively.

Postoperative radial nerve palsies are also associated with intramedullary fixation of the humerus, with an incidence of 3–6 % reported in the literature [4, 24, 26]. Cadaveric studies have demonstrated a 30 % incidence of lateral-medial distal locking bolt abutment with the radial nerve after humeral nailing [27]. Although more commonly encountered reported during the treatment of femoral metastases, embolic pulmonary complications are associated with intramedullary preparation and nail insertion into the humerus [28]. Nail insertion after cement injection adds an additional risk for embolic debris and therefore low-viscosity cement combined with attentive cardiopulmonary monitoring should be employed in these cases [28, 29].

Plate Fixation

Plate fixation of humeral metastases is less commonly utilized than intramedullary nailing, mostly because these procedures are often more invasive and do not always protect the entire bone. Plate and screw constructs are ideal for joint preserving reconstructions of lesions involving the proximal metaphysis/humeral head and distal humerus where intramedullary nail fixation is unlikely to provide adequate fixation in abnormal bone [30]. For these anatomic locations a preoperative CT scan is helpful to determine the extent of bone loss, aiding preoperative decision making between plate and screw or arthroplasty options. Plate fixation also affords direct exposure of the lesion for tumor debulking, avoids violation of the rotator cuff, and permits direct fracture reduction. Because of the limited working length of plate and screw constructs, judicious tumor debulking followed by cement augmentation should be considered in all cases. Cement augmentation provides additional mechanical stability and improves the pull-out strength of orthopedic screws inserted into abnormal bone [31, 32]. Both locking and non-locking screws can be placed across a mature cement mantle. Plate constructs should be cautiously used in cases with diffuse involvement of the bone, massive segmental cortical defects, and uncontained periarticular lesions with compromised articular integrity. Extensive disease involving the humeral diaphysis with extension into the distal metaphysis creates a challenging problem when deciding on the most appropriate implant given the challenges of obtaining distal fixation with intramedullary constructs (Fig. 27.3c, d).

For proximal lesions, a deltopectoral approach with a distal anterolateral extension provides adequate exposure while a triceps-sparring or -splitting posterior approach should be used for distal lesions. Distal lesions of the humerus have the highest incidence of mechanical failure and revision surgery (30 %); therefore dual plating with tumor debulking and cement augmentation is recommended to provide maximal stability and longevity [3]. Locking plates compared to non-locking fixation has been shown to provide superior screw fixation in the setting of poor bone quality, which has expanded the indications of these devices to include patients with metastatic bone lesions [30, 33, 34]. Contrary to this, satisfactory results using non-locking fixation and cement augmentation in the humerus are possible [5] and should not be abandoned, especially as government and hospital cost-containment pressures increase. In either setting, plates should span the defect by at least two cortical diameters, permit three bicortical screws on either side of the lesion, and, when possible, cover as much of the entire length of the bone permitted by the surgical approach [2, 5, 30]. Percutaneous fixation to limit surgical exposure can be used, when safe, in order to extend the length of the construct.

Like intramedullary fixation, outcomes after plate and screw fixation are favorable; pain relief can be expected in 85–95 % of patients, and the majority of patients will resume activities of daily living with the affected extremity [5, 18, 34, 35]. In patients surviving more than 1 year, revision surgery is required in about 10–15 % of patients for adverse events such as infection, mechanical failure, and tumor progression [3–5, 35]. In the context of humeral metastases, plate and screw reconstructions are associated with increased blood loss, longer operative times, and a higher incidence of iatrogenic radial nerve injuries compared to the results of IM nail fixation [18, 36, 37]. An iatrogenic radial nerve palsy, even if transient, can be a significant functional impairment in this patient population, especially when survival is limited. This limited data however should be interpreted with caution as high-quality, prospective, controlled studies directly comparing fixation techniques are lacking.

Endoprosthetic Reconstructions

Endoprosthetic reconstructions of the proximal and distal humerus using modular tumor prostheses are valuable treatment options and should be considered when traditional internal fixation methods are unlikely to achieve durable stability and pain reduction. Indications for prosthetic reconstruction of the humerus include lesions of the humeral head with joint destruction and articular compromise, large segmental cortical defects, revision of failed intramedullary nail and/or plate and screw stabilizations, and defects of the distal humerus. In this context, proximal humerus resections are reconstructed using an endoprosthetic hemiarthroplasty [3, 38, 39] whereas distal humerus resections are coupled to a total elbow arthroplasty [3, 40, 41]. Because of pre- and post-operative radiation, systemic chemotherapy, and general poor bone quality, cemented fixation should be used whenever possible.

For proximal humerus reconstructions, a deltopectoral approach provides reliable access and visualization. Division of the rotator cuff insertion is frequently required and creative, although largely ineffective measures are often employed to reapproximate these tissues to the prosthesis. When possible, securing the native joint capsule around the prosthesis using a purse-string suture is thought to augment joint stability. Otherwise, a delicate balance of humeral head retroversion, head size selection, and rotator cuff tendon approximation are essential for long-term stability. Depending on the length of the bone resection needed, detachment of deltoid insertion is sometimes required. In these instances, the deltoid should be tenodesed to the pectoralis major tendon [38]. Deciding on whether to use a standard hemiarthroplasty implant, reverse shoulder or humeral megaprosthesis may depend on a number of factors including the amount of proximal bone loss, life expectancy, implant cost and access, and the potential for adequate soft tissue coverage and capture. To date, no literature has supported the use of one construct over another and shoulder stability can be adequately achieved with either. Proponents of a reverse total shoulder or allograft prosthetic composite argue improved shoulder function but the use of these somewhat more complicated reconstructions should be evaluated in the context of the patients' overall condition.

The ultimate goal of a proximal humerus endoprosthetic reconstruction is to obtain a stable shoulder, providing a platform for independent elbow and hand function. Preservation of elbow and hand function and pain reduction are principal advantages of these reconstructions. Consequently, patient satisfaction is generally favorable with these procedures. However, because the rotator cuff insertion is sacrificed with these resections, suboptimal shoulder function is common postoperatively. Despite deltoid and axillary nerve preservation, resultant forward flexion and abduction are unlikely to exceed 90 degrees. [38, 39, 42]. Patients should be counseled that a reasonable postoperative expectation is for the ipsilateral hand to reach the mouth and face [39]. Proximal migration of the prosthesis or glenohumeral instability is observed in a 20–30 % of cases [38, 39]. Because of the inherent instability of the glenohumeral articulation, most centers advocate 4–6 weeks of restricted motion in a shoulder immobilizer to allow sufficient time for soft tissue healing. Because of rotator cuff deficiency and limited overhead mobility following standard endoprosthetic reconstructions of the proximal humerus, some authors have advocated using a reverse total shoulder arthroplasty (RTSA) [43, 44]. With these implants, the center of joint rotation is moved inferior and medial, which improves deltoid biomechanics and enables greater potential for abduction and forward flexion beyond 90 degrees. Intraoperative and postoperative complications are more common with RTSA as compared to primary shoulder arthroplasties [45]; however outcomes in metastatic patients are lacking and warrant further investigation.

Metastatic lesions of the distal humerus are relatively uncommon, although complications and revisions are proportionately more common in these cases [3]. Distal humeral resections coupled to a hinged or semi-constrained total elbow prosthesis facilitate complete tumor removal and rapid restoration of elbow function [40, 41]. A total elbow arthroplasty is often sufficient for smaller lesions of the trochlea and capitellum, where larger, more destructive lesions of the distal humeral metaphysis should be reconstructed with a modular endoprosthesis or allograft prosthesis composite (Fig. 27.5). A midline posterior approach to the elbow can be used for the majority of these cases. The ulnar nerve should be dissected and mobilized prior to exposure of the joint. Joint exposure can be accomplished by a variety of techniques such as the Bryan-Morrey posteromedial approach [46], working on either side of the triceps [47], an osteo-anconeus flap [48], and triceps-splitting approach [47], depending on local anatomy and surgeon preference.

With these procedures, patients can expect a substantial improvement in pain and elbow motion. Postoperative elbow motion in the sagittal plane is sufficient for most activities of daily

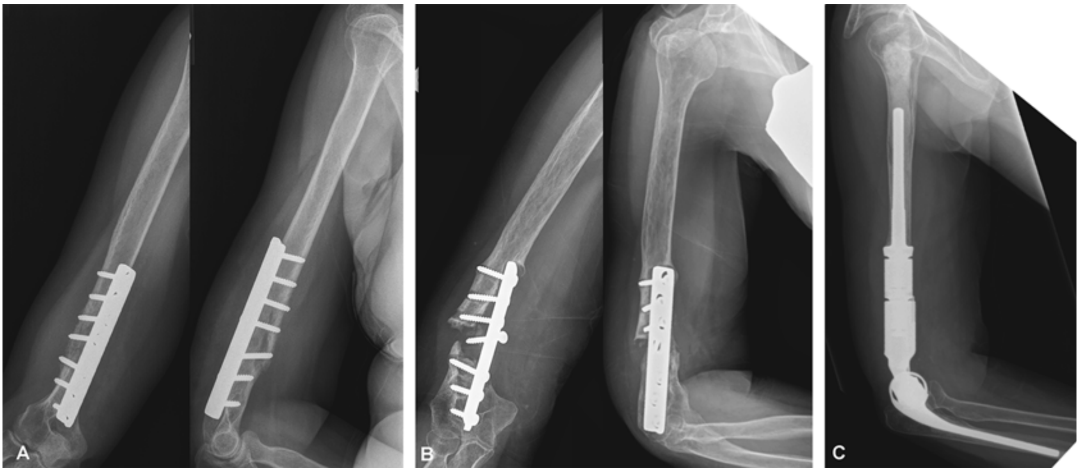

Fig. 27.5 A 65-year-old female with myeloma of the distal humerus and associated pathologic fracture was treated with plate fixation and postoperative radiation (**a**), although subsequently developed further bone resorption, atrophic bone ends, and hardware failure (**b**). As revision osteosynthesis was unlikely, a distal humerus resection was reconstructed with a distal humerus endoprosthesis coupled to a hinged total elbow arthroplasty (**c**)

living and coordinated positioning of the hand towards the mouth and face. A major limitation of total elbow arthroplasties is diminished lifting capabilities. Most surgeons advocate permanent lifting restrictions of 5–10 lbs. Early complications can be expected in 25–30 % of cases, the most common complication being iatrogenic injury to the ulnar nerve followed by infection [40, 41, 49]. Other causes of revision include triceps avulsion, local disease progression, and peri-prosthetic fractures. Implant instability is uncommon.

In situations where extensive diaphyseal bone loss is initially identified or can be expected after tumor debulking or resection, reconstruction using a cemented intercalary endoprosthesis may provide some appealing benefits (Fig. 27.6). The reconstruction allows for a limited exposure directly over the affected area of bone loss and intramedullary stem insertion. This mitigates the need for extensive exposure that may be required for long plate fixation or violation of the shoulder for proximal nail insertion. Early reports of these devices in the USA were complicated by a high rate of transient nerve palsies (likely secondary to distraction needed for implant coupling), peri-prosthetic fractures, and failure at the implant coupling interface [50]. Newer implant designs have mitigated some of these complications although aseptic loosening in one study was reported in 3/11 (27 %) patients [8]. In a separate report from Europe, the authors reported one case of aseptic loosening in eight patients at a mean follow-up of 29 months [51]. Based on these findings, the authors propose a narrow indication for these implants limited to patients with limited life expectancy and proximal or distal bone stock to allow for a minimum of 5 cm of intramedullary fixation [8].

As a general rule, relative to internal fixation strategies, functional outcomes for intra-articular proximal and distal endoprosthetic reconstructions of the humerus are inferior to conventional fixation strategies such as intramedullary nails and plate osteosynthesis [42]. With this in mind, if the joint can be saved using durable intramedullary nail or plate reconstruction, consideration of these strategies should be prioritized, although this is not always possible. Endoprosthetic implants are at higher risk for infectious complications (3–10 %), which can be disastrous in the immune-compromised host [52]. Endoprosthetic reconstructions are generally more costly than internal fixation options; however this is potentially

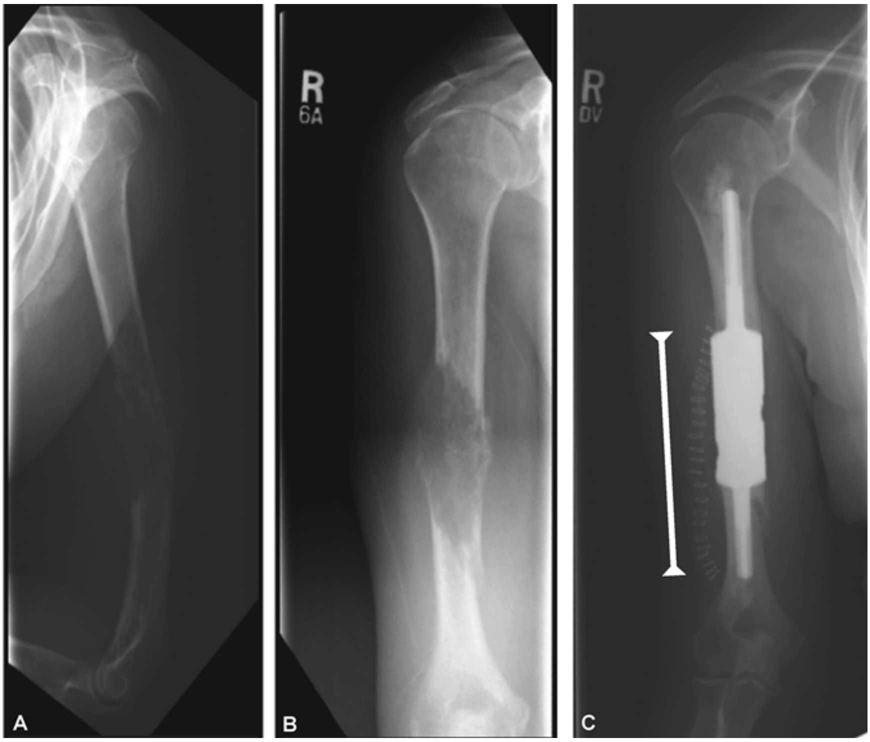

Fig. 27.6 50-year-old female with metastatic breast cancer and extensive diaphyseal bone loss (Panels **a** and **b**). Intercalary endoprosthesis was used to reconstruct the defect and allow for early motion and immediate load-bearing (**c**). Surgical exposure requires limited incision (white line) directly over osseous defect for tumor resection and intramedullary stem fixation

offset in particular lesions where alternate fixation is deemed to be high risk for failure and subsequent revision.

Scapular Metastases

Burden of Disease

Metastatic lesions of the scapula are uncommon (<3 % of all skeletal sites) [53] and reports detailing the management of these lesions in literature are scarce. In a recent report from the Scandinavian Sarcoma Group, registry data of 1195 surgically treated skeletal metastases identified 8 lesions involving the scapula [1]. This number certainly underestimates the true incidence of metastatic lesions involving the scapula but highlights the infrequency of surgical management at this anatomic location.

Non-operative Care

Given the deficiency of a standardized surgical approach for scapular metastases and the morbidity associated with surgical resection of the scapula, first-line treatment for symptomatic lesions irrespective of associated fracture status should involve radiation therapy and multimodal pain management. Failure to improve after radiation therapy or severe disability from involvement of the glenohumeral joint may justify surgical intervention.

Operative Care

Indications for the surgical management of scapular metastases include persistent debilitating symptoms after radiation, intolerable mass effect from large tumors, compromise of the glenohumeral articulation, and in rare cases where a curative resection of an isolated scapular lesion is desired. Surgical options include partial or total scapulectomies, glenohumeral arthroplasties, intra-lesional curettage with cement augmentation (cementoplasty), and radiofrequency ablation. Rarely is forequarter amputation indicated unless there is a massively dysfunctional limb as in the setting of axillary radiation-induced lymphedema or secondary angiosarcoma.

Forequarter Amputation and Scapulectomy

Forequarter amputation for metastatic disease is technically simple, and affords the most definitive removal of local disease burden. Indications for this technique are *exceedingly rare* and should only be considered when there is extensive tumor burden involving a combination of the shoulder girdle, proximal arm, and particularly the axilla and neurovascular bundle. Surgical resection can be achieved using an anterior or posterior based approach; however an anterior based resection and closure using a posterior myocutaneous flap affords the most direct exposure of critical neurovascular structures in the shoulder girdle and axilla [54, 55]. Early complications are infrequent and include seroma/hematoma formation, wound dehiscence, and skin edge necrosis [54, 56]. The posterior flap is well vascularized and healing of the myocutaneous flap is usually not a concern, unless there has been extensive undermining of the subcutaneous layer. Prosthetic use postoperatively is uncommon, especially in the metastatic bone disease population. Cosmesis, phantom limb pain, neuropathic pain, and functional limitations are major long-term issues associated with this procedure.

Scapulectomy

Total or partial scapulectomy permits aggressive resection of scapular disease while retaining the upper extremity for preserved elbow and hand function. Like amputation, the surgical indications for these procedures in this patient population are *exceedingly rare*.

Resections of the shoulder girdle are classified based on anatomic zones of scapula and glenohumeral involvement. These resection types were described for sarcoma resections; however the general principles can be applied to resections for metastatic bone disease. Type I resections are an intra-articular resection of the proximal humerus; type II resections involve resection of the inferior, non-articular half of the scapula, where the entire scapula is resected in a type III resection; and type IV resections involve an extra-articular resection of the scapula, distal clavicle, and proximal humerus [57]. In type IV resections, also known as the Tikhoff–Linberg procedure (total shoulder girdle resection), the residual humerus is suspended from the residual clavicle or in modifications of this technique the residual humerus or a metallic proximal humerus spacer can be affixed to the ribs [58].

Depending on the type, extent of resection shoulder function and the ability to palliate are variable. Elbow and wrist function is comparable to other shoulder and proximal humerus reconstruction procedures [59–61]. Shoulder cosmesis remains a common complaint in patients after this procedure; however this can be improved using inserts and shoulder padding.

Debulking, Cementoplasty, and Radiofrequency Ablation

Forequarter amputations and scapulectomies are morbid procedures associated with poor functional results. In light of this, far less invasive procedures for metastatic lesions of the scapula are the norm. As oncologic cure is rarely the goal with these procedures, debulking procedures with or without cement augmentation can provide improved pain symptoms, restore shoulder girdle function, and be performed as outpatient surgery. This technique is especially helpful in smaller lesions around the glenoid where joint preservation is desired (Fig. 27.7).

Radiofrequency ablation of musculoskeletal lesions has gained increasing popularity over the past two decades. Using this minimally invasive technology, lesions are accurately targeted using intraoperative cross-sectional imaging modalities and heated to temperatures of 60–100 °C for approximately 1–4 min using a low-voltage, high-frequency current, which is transferred to

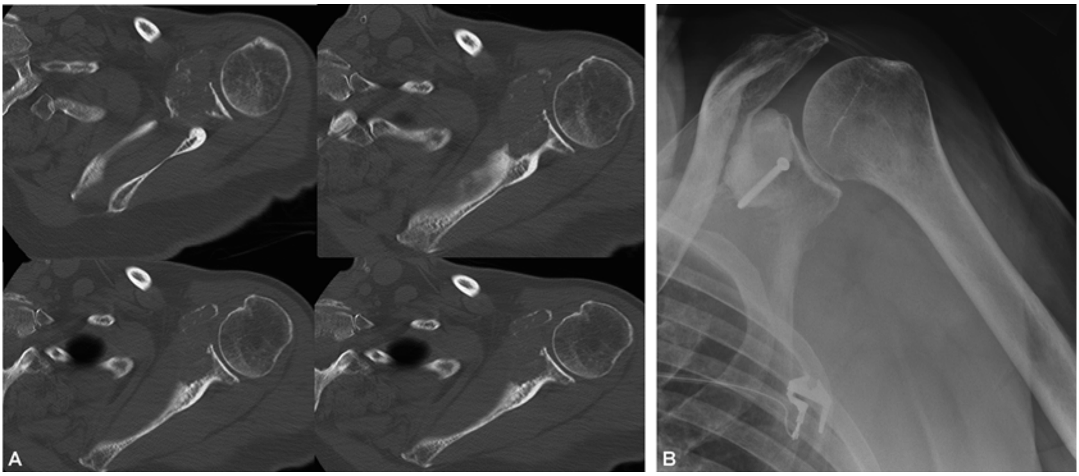

Fig. 27.7 69-year-old male presenting with severe shoulder pain secondary to a metastatic lesion of the glenoid and coracoid process (**a**). Given the limited residual glenoid bone stock available for a total shoulder arthroplasty, this lesion was treated by an open debulking procedure and cement augmentation using a screw-rebar technique (**b**)

surrounding tissues. Resistive heating around the electrodes causes immediate cell death, whereas more distal tissues are heated by thermal conduction [62]. It is generally accepted that temperatures greater than 50 °C lead to irreversible cell damage and death.

Various studies have reported favorable outcomes using this technology for symptomatic metastatic bone lesions recalcitrant to conventional external beam radiation therapy [63–65]. In one multicenter study designed with a predetermined definition of a clinically significant patient benefit, 95 % of patients experienced a meaningful reduction in maximal pain scores and a significant reduction in opioid consumption [63]. These improvements can persist beyond 3 months. Furthermore, RFA procedures can be repeated multiple times on the same lesion. In cases where lesions are in close proximity to nerves, RFA can be performed under conscious sedation to monitor nerve symptoms. In the context of metastatic lesions of the scapula, RFA is usually reserved for lesions <8 cm [64, 65] and may not be a feasible option for larger mets of the scapular body. Lesions associated with a pathologic fracture will not benefit from this technique in isolation. Further details about these concepts in general can be found in Chap. 18.

Summary

Metastatic lesions of the humerus are common and a variety of non-operative and operative treatment options are available for these patients. Unlike the femur, greater opportunity exists to manage symptomatic lesions with radiation and activity modification. Numerous surgical options are available for pathologic fractures. Scapular lesions are less common and first-line therapy should include radiation therapy. For radiorefractory cases, scapular resections are highly morbid and minimally invasive procedures such as radiofrequency ablation and cementoplasty can provide good symptomatic control.

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