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Proximal humeral resection

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1. Introduction

Proximal humeral resections constitute frequent surgical procedures in orthopaedic oncology.[1] They may be carried out for bone sarcomas, locally aggressive benign bone tumours (i.e. giant cell tumour of bone [GCTB], humerus rarely affected [2]), soft tissue sarcomas of the bone/extending into the bone and bone metastases. Key considerations in proximal humeral resections include the following:

- Preservation of the axillary nerve
- Preservation of the deltoid muscle/rotator cuff
- Intra- vs. extraarticular proximal humeral resection

These key issues determine reconstruction techniques (anatomical vs. reverse shoulder arthroplasty) expected postoperative function, need for/possibility of tendon transfers and necessity of soft tissue coverage with (local) flaps. In the following, the reconstruction with (custom-made) megaprostheses is described, bearing in mind that other reconstruction options are available, including osteoarticular allografts, allograft-prosthetic composites), cement spacers, free vascularised fibula grafts and the claviculo-pro-humero technique.[3, 4]

According to Malawer et al. [5], resections around the shoulder girdle can be divided into 6 types:

- Type I: Intra-articular proximal humerus resection
- Type II: Partial scapulectomy
- Type III: Total scapulectomy
- Type IV: Extra-articular scapular and humeral head resection

- Type V: Extra-articular humeral and glenoid resection
- Type VI: Extra-articular humeral and total scapular resection

Depending on whether the abductors can be retained or have to be removed, a subtype A (abductors retained) and B (abductors resected) can be differentiated.[5]

2. Clinical presentation

Patients with primary malignancies of the proximal humerus frequently present with pain (at rest and during night) and local swellings. In case of primary malignancies of bone, plain radiography is usually sufficient (**Fig. 1A–B**) to detect an underlying malignancy and prompt further imaging (especially MRI scans; **Fig. 1C–E**).

3. Treatment strategy

The biopsy approach for suspected proximal humeral malignancies should be directed minimally lateral to the deltoidopectoral groove not to contaminate the cephalic vein, but to allow for later safe resection of the biopsy tract alongside the surgical specimen. Following adequate neoadjuvant treatment (if necessary), plain radiography, contrast-enhanced MRI-scans and CT/MRI angiography scans have to be carefully evaluated for intraarticular tumour extension, extraosseous tumour components and contact with/infiltration of major neurovascular structures. The relation of the tumour to its surrounding structures determines the surgical strategy, i.e. whether an intra- or extraarticular resection has to be carried out, and whether the deltoid and axillary nerve can be preserved.

4. Surgical steps

Step by step: positioning, approach, resection, reconstruction, closure, postoperative management.

1. *Patient positioning*: For intra-articular resections of the proximal humerus (type I), patients are best positioned in a supine position with the arm placed in abduction for better visualisation of the axillary structures. In case of an extra-articular resection, a semi-lateral or lateral decubitus position may be chosen, with free draping of the affected arm.
2. *Surgical approach*: The incision should involve the biopsy tract that is usually placed in the anterior third of the deltoid muscle, just lateral to the deltoidopectoral interval. Depending on whether an intra- or extraarticular resection is performed, the incision is extended proximally up to the coracoid process (intraarticular resection) or over the clavicle towards the superior-dorsal aspect of the scapula

(extraarticular resection). At the upper arm, the incision is placed antero-medially and extends as far as necessary distally to allow for save osteotomy of the proximal humerus.

Resection: The biopsy site is included in the resection specimen. In case of an **intraarticular resection** allowing for preservation of the axillary nerve and (parts of the) deltoid muscle, the approach is between the remaining deltoid and pectoralis major muscle, leaving the cephalic vein intact, if possible. Next, the pectoralis major muscle is transected at its proximal humerus insertion and retracted medially, exposing the neurovascular bundle, the pectoralis minor muscle, the coracoid process with the conjoint tendon (short head of biceps muscle, coracobrachialis muscle) and the subscapularis muscle. For an intraarticular resection, the rotator cuff is now sectioned and the musculotendinous transition, and the tendon of the long head of the biceps muscle released from the superior glenoid. The inferior glenohumeral ligament is partially resected from the inferior glenoid. As far as the tumour extension allows, the deltoid muscle is carefully dissected and the axillary nerve preserved. At this point, osteotomy of the humerus may be carried out to increase mobility of the specimen and visualisation of the circumflex humeral as well as tumour-feeding vessels that require ligation to allow retraction of the neurovascular bundle away from the proximal humerus. Before osteotomy is performed, the neurovascular bundle should be identified at the level of the osteotomy, and – depending on the height of the osteotomy – the radial nerve bluntly dissected off the humerus in its groove between the medial and lateral heads of the triceps. The latissimus dorsi muscle, teres major muscle and long head of the triceps muscle are sectioned – if possible – at their tendinous part or in their muscular portion to leave a soft tissue envelope on the extraosseous tumour component. The dissection is completed by releasing the brachialis, biceps and coracobrachialis muscles anteriorly, and triceps muscle posteriorly from the humerus. The specimen can now be removed.

For **extraarticular** resections, the shoulder joint capsule must not be opened. After detachment of the pectoralis muscle from its humeral insertion (or medial to it, depending on the extraosseous tumour component) and medial retraction, the pectoralis minor is likewise transected at retracted medially, allowing for exploration of the axillary neurovascular bundle. The conjoint tendons are released from the coracoid process, and the musculocutaneous nerve is preserved, if possible. In extraarticular resections, extraosseous extension of the tumour often requires sacrifice of the axillary nerve and deltoid muscle. In this case, large skin flaps are created around the deltoid muscle. The lateral portion of the clavicle is osteotomized (slightly medial to the coracoid process), and the subscapularis

muscle transected. The circumflex humeral arteries are – depending on the extraosseous extension of the tumour – identified and ligated, enabling retraction of the neurovascular bundle away from the tumour. Via the supero-posterior extension of the skin incision, the supraspinatus, infraspinatus, teres major and latissimus dorsi muscles are transected, maintaining a safety margin to the glenohumeral joint. The osteotomy of the scapular neck is carried out medially to the coracoid process. Similar to an intraarticular resection, early osteotomy of the humerus facilitates dissection at the glenohumeral joint. The dissection is completed by dissecting and dividing the brachialis, biceps and coracobrachialis muscles anteriorly, and the triceps muscle posteriorly at their appropriate levels, ensuring that a safety soft tissue envelope around the extraosseous tumour component is maintained. Again, care must be taken to safe the radial nerve that should be bluntly dissected from the humerus in its groove between the medial and lateral head of the triceps muscle.

3. *Reconstruction*: There are different reconstruction techniques available. As outlined above, reconstruction with a (custom-made) megaprosthesis is herein described. Following thorough irrigation of the surgical field, the humeral shaft is reamed adhering to the manufacturer's instructions. After the humeral stem has been implanted, a shoulder hemi-prosthesis or reverse shoulder arthroplasty system, with the latter requiring preparation of the glenoid, is implanted. A reverse shoulder arthroplasty should be chosen in patients with an intact axillary nerve, preserved deltoid muscle and sufficient residual glenoid.[3, 6, 7] A shoulder hemiarthroplasty may be considered in older patients, those with resection of the axillary nerve and deltoid muscle, and following extra-articular resection. To reduce the risk of shoulder instability, a Trevira-tube (or similar) should be used to secure the humerus to the glenoid/remaining scapula, and re-attach tendons/muscle stumps to the prosthesis. In case the deltoid muscle had to be resected alongside the proximal humerus, a local latissimus dorsi flap can reduce the risk for postoperative infections.
4. *Closure*: After the tumour prosthesis has been implanted and soft tissues closed around the implant, a 10 G or 12 G suction drainage is inserted (that should be removed early postoperatively). The skin is meticulously closed, and sterile dressings are applied.
5. *Postoperative management*: Especially after extensive resections around the proximal humerus, the initial goal is to achieve adequate stability in the shoulder joint, wherefore immobilisation in a Gilchrist bandage is recommended for 6 weeks.

5. Technical Pearls

- Careful evaluation of preoperative MRI images (and sometimes also CT/MRI-angiography images) helps in determining whether an intra- or extraarticular resection can be safely carried out, and whether the main neurovascular structures can be preserved.
- Osteotomy of the humerus at an early stage improves preparation and visualisation at the glenohumeral joint.
- After ligation of the circumflex humeral vessels, the neurovascular bundle can be retracted medially.
- Local tendon transfers can improve shoulder function, e.g. a latissimus dorsi or teres major transfer.[7]

6. Avoiding and Managing Complications.

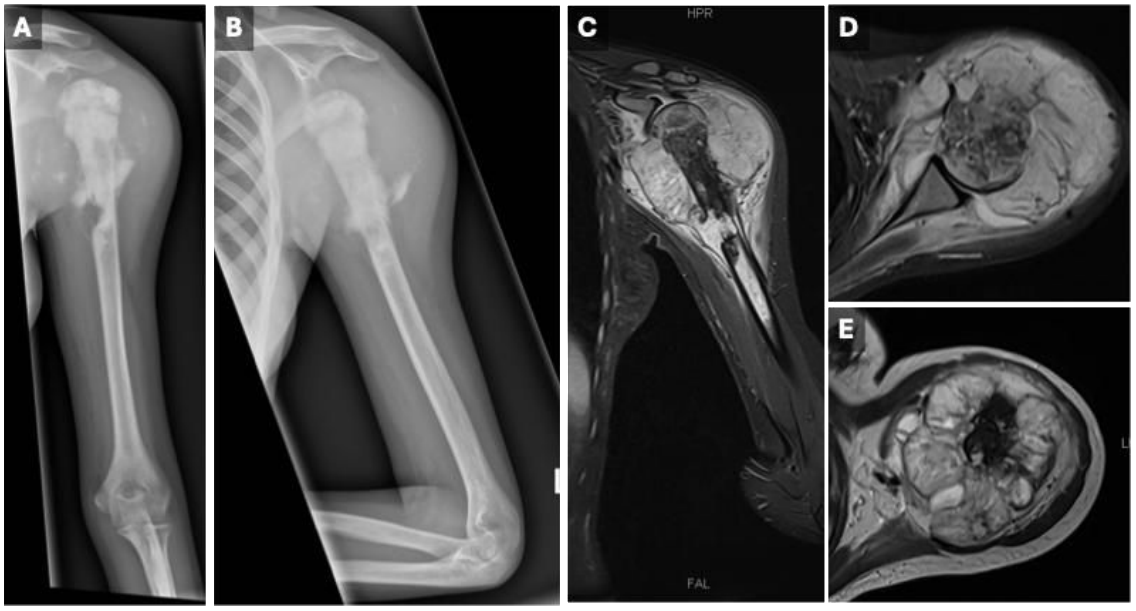
The risk of shoulder instability can be reduced by using constrained implants, using a Trevira tube (or similar) and meticulously securing the proximal humeral component to the glenoid/remaining scapula and tendons/muscle stumps. Especially in resections necessitating sacrifice of the rotator cuff and deltoid muscle, a latissimus dorsi flap (with or without a skin island) can improve soft tissue coverage and reduce the risk for postoperative infections.

7. Comments from the expert

Do not set patient's (and yours) expectations too high: abduction and elevation will depend on several factors like resection extent, axillary nerve preservation, and the potential need for postoperative immobilization to achieve a stable joint. If you are rarely doing shoulders, you might think about inviting a non-oncological shoulder expert to your operating team.

8. Infography

Fig 1: Plain radiography (A, B) and MRI scan (C–E) of a high-grade osteosarcoma in a 14-year-old patient with intra-articular extension. Following neoadjuvant chemotherapy, an extra-articular resection and reconstruction with a custom-made implant was carried out.



9. Bibliography

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