·Clinical Research·

Prosthetic replacement of the proximal humerus after the resection of bone tumors

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[Abstract] Background and Objective: After using chemotherapy to treat patients with malignant bone tumors, amputation, which was the typical intervention in the 1980s, has been substituted with limb-sparing surgery. This article reported the surgical indications, operative methods, operative effects, and complications of prosthetic replacement of the proximal humerus after the resection of bone tumors. **Methods:** Between April 2004 and December 2008, prosthetic replacement was performed in 18 patients with proximal humerus tumors, including 7 patients with osteosarcoma, 5 patients with chondrosarcoma, 3 patients with giant cell tumor (GCT) of the bone, 1 patient with GCT of the bone combined with an aneurysmal bone cyst, and 1 patient with metastatic bone tumors. Using the Enneking staging system, 7 osteosarcomas and 3 chondrosarcomas were at stage IIb, and 3 GCTs and 2 chondrosarcomas were at stage Ib. The patient with metastatic bone tumors reported severe pain. **Results:** Follow-up ranged 5–61 months (mean, 29 months) and showed that 1 patient with osteosarcoma died 19 months after surgery. Local recurrence presented in 1 patient with GCT, 1 patient had inner infection in the area of surgery, and 2 patients had shoulder subluxation after the operation. There was no prosthetic loosening in any patient. The abduction angle of the shoulder was 8°–35°, and circumgyrate angle was 18°–25°, with flexion 35°–90° and extension 25°–42°. According to the functional score developed by the International Society of Limb Salvage, scores ranged from 18 to 29 points, with an average of 24 points. **Conclusions:** Prosthetic replacement for the patients with bone tumors in the proximal humerus is an appropriate procedure with satisfactory therapeutic outcomes. However, many complications should be noted and long-term curative effects are presently uncertain.

Key words: Proximal humerus, bone tumor, prosthesis, prosthetic replacement

The proximal humerus is a common site for malignant bone tumors. At one time, these tumors were primarily treated with amputation, which resulted in the complete loss of hand function. Since the 1970s, due to progress in both chemotherapy and joint prosthetic technology, limb salvage surgery has gradually become the main surgical procedure. Currently, tumor resection and prosthetic replacement are widely used in our country as well as others. The surgical procedure helps preserve most hand function and yields favorable efficacy. But so far, no large-scale case study has been reported. In this study, we performed a retrospective analysis on 18 patients with proximal humerus tumors treated with prosthetic replacement in relation to the published research, to investigate the indications, surgical approaches, efficacy, and complications of prosthetic replacement in treating patients with proximal humerus tumors.

Clinical data

General data

We performed a retrospective analysis on 18 patients with proximal humerus tumors treated with prosthetic replacement at the shanghai Sixth People's Hospital, Shanghai Jiaotong University between April 2004 and December 2008. Among this group of patients, 9 were men and 9 were women. They aged between 16 years and 64 years, with a median age of 37 years. As for the pathology, tumors were rated as osteosarcoma of proximal humerus in 7 patients, chondrosarcoma in 5 patients, aggressive and recurrent giant cell tumors (GCT) of bone in 3 patients, GCT accompanied by aneurysmal bone cysts in 1 patient, metastatic leiomyosarcoma in 1 patient, and chondroblastoma in 1 patient. Based on the Enneking staging system, 7 osteosarcomas and 3 chondrosarcomas were rated as stage IIb, and another 2 chondrosarcomas, 3 GCTs, and 1 GCT

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accompanied by aneurysmal bone cysts were rated as stage Ib. In 1 patient with chondroblastoma, the proximal humerus was severely damaged. In 1 patient with a single metastatic tumor, the patient experienced severe pain. According to the comprehensive treatment strategies for osteosarcoma, 7 patients with osteosarcoma and 1 patient with metastatic leiomyosarcoma received neoadjuvant chemotherapy, with 2 cycles of chemotherapy before and after surgery, respectively.

Before surgery, the scope of tumor resection was determined based on magnetic resonance imaging (MRI) and X-ray examinations and the clinical and pathologic features, and the humeral head (joint) prosthesis was customized for each patient (Figure 1A, B). Regarding the margin of resection, for GCT and benign tumors, the margin around the resected tumor was 2 cm from the distal end of the tumor, and for malignant tumors, the margin ranged from 2 cm to 4 cm, depending on the level of malignancy of the tumor.

Surgical approaches

With conduction anesthesia on the cervical and the brachial plexus, the patient was in a supine position, with the affected shoulder elevated by pads. The surgery started with an incision on the anteromedial surface of the shoulder joint and proceeded via the acromioclavicular joint and the coracoid process, and along the groove between the deltoid muscle and the pectoralis major muscle. The cephalic vein was carefully protected. Then blood vessels and the nerve plexus in the fossa axillaris, including the musculocutaneous and axillary nerves, were isolated and protected. Soft tissue and the ends of the muscles were dissected at 1 cm to 2 cm from the distal end of the tumor capsule. The articular capsule was dissected and the surgical margin was determined (that is, a frozen section biopsy was conducted during surgery to ensure a safe surgical margin). The marrow cavity was expanded and filled with bone cement. Then the humeral head prosthesis was installed. A 30° –40° inward supination of the humeral head was carefully maintained (Figure 1C). The rotator cuff was reconstructed and sutured to a special hold in the neck of the humeral head. A negative-pressure drainage tube was put into place. After surgery, the affected limb was immobilized with a Darco neck-waist sling. Physical therapy for the hand, wrist, and elbow was started after surgery, and physical therapy for the shoulder started 4 weeks later.

Postsurgical treatment

At 24–72 h after surgery, the negative-pressure drainage tube was removed. Patients were encouraged to start active motion of the hand, wrist, and elbow. At 1 week after surgery, patients could start to swing the shoulder joint. At 3 weeks to 4 weeks after surgery, lifting and abduction of the shoulder joint could be gradually started. Functional exercise should be started as soon as possible even with mild tolerable pain for the patients. In 7 patients with osteosarcoma and 1 with metastatic tumors, 2 cycles of postsurgical adjuvant chemotherapy were given.

Figure 1 Prosthetic replacement of the proximal humerus in a 20-year-old man with osteosarcoma in his right proximal humerus

A, before surgery, bone destruction in the proximal humerus; B, MRI before surgery: the tumor was 10 cm in length as measured by T1-weighted image; C, the prosthesis was well in place after the surgery.

Results

The patients were followed-up for 5–61 months, with a mean of 29 months. At 19 months after surgery, 1 patient with osteosarcoma died of lung metastasis. One patient with GCT developed recurrence after surgery and underwent disarticulation of the shoulder. Recurrence was not seen again thereafter. Deep infection was seen in 1 patient after surgery. The infection was not under control even after debridement, so a second surgery was planned. In 2 patients, the prosthesis was not in a good place and showed semiluxation, which was gradually corrected by

physical therapy. In this group of patients, no loose prostheses were seen. After prosthetic replacement, the ranges of motion of the shoulder joints were as follows: extension 25°–42° (mean 25°); anteflexion 35°–90° (mean 72°); abduction 8°–35°; and rotation 18°–25°. According to the postsurgical functional scoring system of the International Society of Limb Salvage, limb function was evaluated on 6 aspects, including pain, mental acceptance, and hand functions, such as mobility, weight-lifting, and flexibility. The scores ranged from 18 to 29, with a mean of 24. The score was > 25 in 12 patients, accounting for 66.6% of all patients.

Discussion

The proximal humerus is a common site for malignant bone tumors. Before the 1970s, malignant bone tumors in the proximal humerus, particularly osteosarcoma, were routinely treated with shoulder disarticulation, which resulted in complete loss of upper limb functions. With the progress in neoadjuvant chemotherapy, imaging, diagnostic techniques in pathology, and joint prosthesis technology, tumor resection and prosthetic replacement of the shoulder joint have become optimal treatments for early- or mid-stage primary malignant bone tumors, aggressive GCT, and single metastatic tumors. After limb-salvage surgery with a prosthetic replacement, the appearance of the limb is completely salvaged for patients, and elbow, wrist, and most of the shoulder functions are maintained, significantly improving the quality-of-life for patients.[1] Prostheses for shoulder joint replacement include proximal humeral prosthesis, prosthesis of the entire shoulder joint, and complex prosthesis. In this study, all patients were given proximal humeral prosthesis. Before surgery, the length of the tumor was measured by MRI and the prostheses were custom-tailored.

Before resection of the proximal humeral tumors and the prosthetic replacement of the humeral head, it is necessary to individualize both the prosthesis before surgery and the surgical treatment during the surgery, with rigorous compliance to the indications for this surgery. Whether the surgery is actually indicated for a patient has direct influence on the outcome of the surgery and the occurrence of postsurgical complications. For malignant tumors of the proximal humerus, tumor resection plus the subsequent prosthetic replacement is indisputable. For GCT of bone, a traditional surgical approach is curettage and grafting, where the postsurgical 5-year recurrence rate is 50%–60%.[2] We believe that, for aggressive GCT and recurrent GCT, tumor resection and prosthetic replacement should be seriously considered, because local curettage alone often leads to recurrent tumors and a second surgery.

Based on our experience and published literature,[3] we believe that indications for the resection of proximal humeral tumors and the prosthetic replacement of the proximal humerus are: (1) stage-I and -IIb malignant tumors and stage-IIb malignant tumors that are sensitive to chemotherapy, important blood vessels and nerves are not affected, and the tumor can be completely resected; (2) aggressive GCT and recurrent GCT; (3) a single metastatic bone cancer, where the primary lesion has already been resected or controlled; (4) good local conditions that allow for reconstruction after tumor resection, and that the patient is in good condition, both locally and generally, and demands limb salvage; and (5) benign tumors, including aneurysmal bone cyst that has caused severe damage in the proximal humerus. The contraindications include: (1) poor conditions or the infection of local soft tissue, or tumor involvement of major blood vessels and nerves; and (2) patients with poor general conditions, multiple metastasis, or advanced tumors.

To ensure compliance with the indications for the prosthetic replacement for proximal humeral tumors, the pathologic diagnosis for these patients should be established before surgery. For chemotherapy-sensitive malignant tumors, neoadjuvant chemotherapy should be given to eliminate micro-lesions, minimize tumor volume, stiffen the tumor, and promote the formation of a pseudocapsule. In this study, 7 patients with proximal humeral osteosarcoma and 1 patient with metastatic tumors were given neoadjuvant chemotherapy after diagnosis. MRI-based evaluation after chemotherapy is essential in that it helps obtain a safer surgical margin in limb-salvage surgery, as well as salvaging more normal soft tissue.[4] The comparison of MRI images before and after chemotherapy can help evaluate chemotherapeutic efficacy and provide evidence for options and modifications of chemotherapy regimens after surgery.

Before limb-salvage surgery, several factors should be evaluated, including whether the tumor can be completely resected, whether soft tissue can be reconstructed, the restoration of postsurgical function in the patient, and possible complications. A safe surgical margin is the only way to minimize the rate of local recurrence. Among the early-stage cases of our study, one patient with GCT developed local recurrence, which might be related to the fact that the surgical margin was not rigorously extended. With regard to blood vessels and nerves around the tumor, presurgical MRI is also necessary in that it illustrates the 3-dimensional relationship between the tumor and the blood vessels. During surgery, blood vessels and nerves should be carefully isolated. For patients on this study, the surgical margin was determined based on MRI findings and the specific conditions during the surgery. In addition, tissue was obtained for frozen section from the residual marrow cavity and from the margin of resected soft tissue to ensure a margin of safety.

During the resection of the tumor, the rotator cuff, the articular capsule, and the glenoid labrum that are not affected by the tumor should be preserved to the extent possible, and the rotator cuff should be sutured to a special side-hole on the neck of the proximal humeral prosthesis. Reconstruction of the rotator cuff is related to the amount of soft tissue resected. If the rotator cuff, the glenoid labrum, and most of the deltoid muscle have to be resected during surgery, a restrictive shoulder joint prosthesis should be used for the reconstruction to ensure the stability of the shoulder joint. For patients who undergo an excessive resection of local soft tissue, reconstruction can be performed using rotating skin flaps from the latissimus dorsi or the pectoral muscles to ensure that the prosthesis is well covered by soft tissue. In the prosthetic replacement of the shoulder joint, we

must emphasize the stability of the shoulder joint, which is also a prerequisite for good function in the affected limb after surgery, whereas the stability of the shoulder joint can only be ensured by excellent tissue reconstruction during surgery.[5]

Various complications can be seen after prosthetic replacement for proximal humeral tumors. The most common complications include the following. (1) An unstable shoulder joint, mostly because soft tissue has been excessively resected during surgery, particularly when the rotator cuff is resected and thus the prosthesis goes without an essential stabilizing structure. During surgery, it is important to preserve soft tissue to the extent possible while ensuring that the tumor is resected with a safe surgical margin. The balance of muscular strength should be reconstructed. Conversely, when installing the prosthesis, the caster angle of the humeral head should be maintained at 30°–40°.[1] The shaft of the prosthesis should be afixed into the marrow cavity. An unstable shoulder joint can lead to joint dislocation and subluxation. Patients in this study presented unstable shoulder joints to various extents. Among them, 2 patients experienced postsurgical joint subluxation, which was gradually corrected by postsurgical physical therapy. With physical therapy and conservative treatment, most dislocations and semiluxations are correctable. (2) Local recurrence is the most severe complication after prosthetic replacement and leads to the immediate failure of surgery. To avoid this, we must ensure rigorous compliance with the indications before surgery and ensure that patients with chemotherapy-sensitive tumors, such as osteosarcoma, are given neoadjuvant chemotherapy. When dissecting the affected segment of the bone, a safe surgical margin should be ensured. Frozen section biopsy during surgery is helpful in determining whether the tumor is completely resected. (3) Loose prostheses after shoulder joint replacements are rare. No loose prostheses were seen in our study. This may be related to the fact that the upper limb is not a weight-bearing limb. (4) Deep infection is another severe complication after prosthetic replacement and tends to result in the failure of the replacement. Asayamongkolkul *et al*.[6] reported that 2 out of 59 cases of prosthetic replacement for proximal humeral tumors developed deep infections. With local debridement and lavage, as well as reconstruction with rotating skin flaps from the latissimus dorsi to increase soft-tissue coverage on the prosthesis, the infection was ultimately cured in both cases and the prosthesis was thus maintained. In our study, 1 patient developed deep infection at 10 months after surgery. After local debridement and constant lavage, the postsurgical infection remained, so the patient was given a second surgery. The infection was related to the poor condition, prolonged surgery, and poor postsurgical drainage of the wound. Once it occurs, such infection is hard to cure. Therefore, it is advisable to ensure rigorous compliance to standardized operation procedures during surgery and to use vancocin postsurgically as a prophylaxis against infection. (5) Nerve injury may occur. In some patients, the nerve undergoes a stretch injury during surgery. In our study, 1 patient experienced mild numbness, but patients otherwise were free from this complication.

After prosthetic replacement for proximal humeral tumors, the affected shoulder joint will be less functional. The function of the affected limb after surgery is related to the following factors:[7] (1) the scope of the resection of the tumor and the surrounding soft tissue; (2) the method of reconstruction and the control over the caster angle of the humeral head during surgery; and (3) systemic rehabilitative exercises after surgery. When resecting the tumor, the unaffected rotator cuff and the articular capsule should be preserved to the extent possible. When the tumor is removed, excellent reconstruction of the tendons and muscular tissue should be emphasized in surgery. In addition, rehabilitative exercise for the affected limb should be started soon after surgery. On the day of surgery, patients can start activity and exercise in all the joints other than shoulder joint after the surgery is completed. At 3–4 days later, exercise including flexion, extension, and swinging of the shoulder joint can be started. At 4 weeks after surgery, lifting activity of the shoulder joint can be encouraged, and so on. Systemic and standardized rehabilitative exercise that starts right after surgery is an important guarantee for the restoration of excellent function in the affected limb and is also an effective strategy to correct postsurgical semiluxation of the shoulder joint.[1]

In relation to the published literature for proximal humeral tumors, prosthetic humeral head replacement provides complete tumor resection, lower incidence of recurrence, and fewer early complications, which make it a prime choice as a method of reconstruction after the resection of malignant tumors and aggressive or recurrent GCTs in the proximal humerus. For this procedure, it is important to ensure rigorous compliance with its indications and to prevent the occurrence of complications.

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