

Endoprosthetic Reconstruction for Malignant Bone and Soft-Tissue Tumors

Apichat Asavamongkolkul MD*,
Saranatra Waikakul MD*, Rapin Phimolsarnti MD*,
Piya Kiatisevi MD**, Prasert Wangsaturaka MD*

* Department of Orthopedic Surgery, Faculty of Medicine, Siriraj Hospital, Mahidol University

** Orthopedic Institute, Lerdsin Hospital

Background: Nowadays, the results of the management of malignant bone and soft-tissue tumors have been dramatically improved because of the advance in imaging, chemotherapy, radiation therapy, and surgical techniques. Patients can have longer survival times with limb-salvage surgery. Several techniques of reconstruction have been advocated and gained more popularity following malignant tumor resection by using allograft, tumor prostheses, composite allograft prosthesis, or arthrodesis.

Objective: To report the preliminary results of 32 endoprosthetic reconstructions following malignant bone and soft-tissue tumor resection. The oncologic results, functional outcomes, and complications from the surgery were assessed in the present study.

Material and Method: Since September 1988, the authors have performed 188 limb-salvage surgical operations for the treatment of musculoskeletal tumors at Siriraj Hospital. From March 1994 to July 2006, 32 endoprosthetic reconstructions were performed on 30 patients following malignant bone or soft-tissue tumor removal. There were 16 males and 14 females with a mean age of 28 years (range 10-73). The diagnosis was conventional osteosarcoma in 16 patients, parosteal osteosarcoma in two patients, chondrosarcoma in two patients, leiomyosarcoma in two patients, failed allograft in two patients and one patient each of periosteal osteosarcoma, Ewing's sarcoma, Gorham's disease, synovial sarcoma, malignant fibrous histiocytoma, metastatic renal cell carcinoma, and prosthetic loosening. Wide excision was performed with a mean length of 18.5 cm (range 10-41). Five proximal femurs, 17 distal femurs, 1 total femur, 3 proximal tibias, 1 intercalary tibia, 4 proximal humerus and 1 distal humerus were used for reconstruction. Modular replacement systems (MRS, Stryker/Howmedica/Osteonics) were the most common prostheses used in the present series.

Results: The mean follow-up time was 26 months (range 6-128.7). Sixteen patients are continuously free of the disease, two are alive with the disease, two had no evidence of the disease, nine died of the disease, and one patient died from complication of hypertension. The mean Musculoskeletal Tumor Society functional analysis for upper extremity reconstruction was 93% (range 86.7-100) and for lower extremity was 89% (range 63.3-100). Two patients (6.7%) were determined to be a failure. Revision due to aseptic loosening was performed in one patient (3.3%) and one hip disarticulation was done related to local recurrence (3.3%). One patient with sciatic nerve palsy and two seromas was found and successfully treated in the present study.

Conclusion: Endoprosthetic reconstruction could yield satisfactory results as a wide excision and limb-salvage for patients with malignant bone and soft-tissue tumors. Most patients in the present report had good to excellent functions following surgery and few complications occurred in the present report.

Keywords: Limb-salvage surgery, Endoprosthetic reconstruction, Malignant bone tumor, Malignant soft-tissue tumor

J Med Assoc Thai 2007; 90 (4): 706-17

Full text. e-Journal: <http://www.medassocthai.org/journal>

Correspondence to : Asavamongkolkul A, Department of Orthopaedic Surgery, Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand. Phone: 0-2419-7968, Fax: 0-2412-8172. E-mail: siaas@mahidol.ac.th

Before the advent of adjuvant protocols and limb-salvage reconstruction, malignant bone and soft-tissue tumors of the extremities were traditionally treated by amputation. A 5-year survivorship of patients with high grade malignant bone tumor was about 0 to 20%⁽¹⁾. With the advance of imaging, systemic adjuvant chemotherapy, and techniques of limb-salvage reconstruction, most patients with malignant musculoskeletal tumors can be treated by limb-salvage surgery without adverse effect on their survival⁽²⁻⁵⁾. At present, patients who present with a non-metastatic high-grade malignant tumor of an extremity can be cured in approximately 70% of cases^(6,7). Simon et al compared the results of limb-salvage surgery with those of amputation in 227 patients who had an osteosarcoma of the distal femur. The authors concluded that doing a limb-salvage procedure in lieu of amputation did not shorten the disease-free interval or compromise the long-term survival of these patients. Cosmesis and function, however, were much better, with the preservation of knee motion and the ability to ambulate⁽²⁾.

Reconstruction following bone or soft-tissue tumor resection can be performed with arthrodesis^(8,9), allograft⁽¹⁰⁾, allograft-endoprosthetic composite (APC)⁽¹¹⁾, and endoprosthesis^(12,13). There are pros and cons to each option, some of which are dependent of the specific joint involved, the patient's life style, socioeconomic status, and surgeon's preferences. With the successful experience of endoprosthetic reconstruction in primary malignant tumors, many authors use this reconstruction in the treatment of metastatic bone tumors and other non-oncologic conditions⁽¹⁴⁻¹⁶⁾.

This particular reconstruction has been introduced for preservation of the limbs of patients with malignant tumors who are skeletally immature^(17,18). Between 1994 and 2006, the authors did 32 endoprosthetic reconstructions following malignant tumor resections, allograft and implant failures in 30 consecutive patients. On the basis of this preliminary experience, the principles of endoprosthetic reconstruction with emphasis on surgical technique, patients' functional and oncological outcomes, and complications of the procedures are presented.

Material and Method

Since September 1988, the authors have performed 188 limb-salvage surgical operations for the treatment of musculoskeletal tumors at the Department of Orthopedic Surgery, Faculty of Medicine, Siriraj Hospital. From March 1994 to July 2006, 32 endoprosthetic reconstructions were performed on 30 patients

following malignant bone or soft-tissue tumor removal. There were 16 males and 14 females with a mean age of 28 years (range 10-73). The diagnosis was conventional osteosarcoma in 16 patients, parosteal osteosarcoma in 2 patients, chondrosarcoma in 2 patients, leiomyosarcoma in 2 patients, failed allograft in 2 and one each of periosteal osteosarcoma, Ewing's sarcoma, Gorham's disease, synovial sarcoma, malignant fibrous histiocytoma, metastatic renal cell carcinoma and prosthetic loosening. Wide excision was performed with a mean length of 18.5 cm (range 10-41). Five proximal femurs, 17 distal femurs, 1 total femur, 3 proximal tibia, 1 intercalary tibia, 4 proximal humerus and 1 distal humerus were used for reconstruction. Four designs of prostheses were used: The Howmedica modular replacement systems (MRS, Stryker/Howmedica/Osteonics) were used in 20 patients, the United Oncology systems (United Orthopedic Corporation) were used in nine, Protek (Synthes) were used in two and the Johnson and Johnson system was used in one. The patients' data is demonstrated in Table 1. Before the surgical resection and reconstruction, patients with conventional osteosarcoma, leiomyosarcoma, Ewing's sarcoma and malignant fibrous histiocytoma received the standard preoperative and postoperative adjuvant therapy as a regimen in use at the time of their treatment.

Operative technique

The surgical approach used longitudinal incisions providing best access for an anatomic dissection of the neurovascular bundles to reflect them away from the lesion. Biopsy sites were ellipsed and kept in continuity with the lesion. All resections were carried out through normal appearing tissues in the intra-articular and intra-compartmental manner, with the intent to achieve a wide surgical margin. Generally, the technique of limb-salvage surgery using endoprosthetic reconstruction is like other reconstructions and has three steps: tumor resection, endoprosthetic reconstruction, and soft tissue reconstruction. The site-specific reconstruction techniques and considerations were published and described in detail^(19,20). With the patient under relative hypotensive anesthesia, all prosthetic components were cemented after meticulous cleaning of the medullary canal with saline. Patients received one pre-operative intravenous dose of a cephalosporin antibiotic that was continued for 72 hours or until the drains were removed. Suction drains, which were placed in a periprosthetic space before closure, were removed routinely once the drainage diminished

Table 1. Diagnoses, Sites of Reconstruction, Staging and Current Patient status (n = 30)

Diagnosis (N)	Sites										Staging ²¹				Alive	Dead
	PH	DH	PF	TF	DF	PT	IT	IA	IB	IIA	IIB	III	NA			
Osteosarcoma (16)*	1	-	1	1	11*	2	-	-	-	1	14	1	-	9	7	
Parosteal Osteosarcoma (2)	-	-	-	-	2	-	-	-	2	-	-	-	-	2	-	
Chondrosarcoma (2)	-	-	2	-	-	-	-	-	-	-	2	-	-	-	2	
Leiomyosarcoma (2)	-	-	-	-	2	-	-	-	-	-	1	1	-	2	-	
Periosteal Osteosarcoma (1)	-	-	-	-	-	-	1	-	1	-	-	-	-	1	-	
Ewing's sarcoma (1)	1	-	-	-	-	-	-	-	-	-	1	-	-	1	-	
Gorham's disease (1)	1	-	-	-	-	-	-	-	-	-	-	-	1	1	-	
Synovial sarcoma (1)	-	1	-	-	-	-	-	-	-	-	1	-	-	1	-	
MFH (1)	-	-	1	-	-	-	-	-	-	-	1	-	-	1	-	
Metastatic RCC (1)	-	-	1	-	-	-	-	-	-	-	-	-	1	-	1	
Failed allograft (2)	1	-	-	-	-	1	-	-	-	-	-	-	2	2	-	
Aseptic loosening (1)	-	-	-	-	1	-	-	-	-	-	-	-	NA	NA	-	
Total (30)	4	1	5	1	16*	3	1	-	3	1	20	2	4	20	10	

N = Patient number, MFH = Malignant fibrous histiocytoma, RCC = Renal cell carcinoma

PH = Proximal humerus, DH = Distal humerus, PF = Proximal femur, TF = Total femur, DF = Distal femur, PT = Proximal tibia, IT = Intercalary tibia, NA = Not applicable

* 1 Patient with synchronous osteosarcoma had 2 distal femoral reconstructions

to less than 50 ml. in a 24-hour period. No patients received prophylactic anticoagulants.

Rehabilitation regimens were surgical site specific. Patients with proximal humeral reconstructions were treated with a shoulder immobilizer for 2 to 3 weeks, after which physical therapy was introduced to maximize active and passive range of motion (ROM) of the shoulder and elbow (Fig. 1). The patient with distal humeral reconstruction was immobilized in a posterior long arm slab for 2 to 3 weeks, then active and passive ROM of the elbow and forearm was introduced (Fig. 2). Patients with total femur replacement or proximal femoral replacements were kept in bed with the extremity in abduction for 2 to 4 weeks. An abduction brace immobilization and partial weight bearing was recommended

for ambulation for 3 months (Fig. 3, 4). The limbs of patients with distal femoral replacements were placed in a continuous passive motion machine in the recovery room and maintained that way during the patients' stay in the hospital. Ambulation generally was begun on the third postoperative day without the use of a knee immobilizer (Fig. 5). The affected extremity of each of the three patients with proximal tibia replacements was placed in a long leg cast for 3 weeks before ROM physical therapy was commenced which concentrated on knee extension exercises to prevent a knee extensor lag (Fig. 6). One patient with intercalary tibia replacement was immobilized in a posterior short leg slab for 2 weeks, then active and passive ROM of the knee and ankle was begun. Patients with distal femoral, proximal

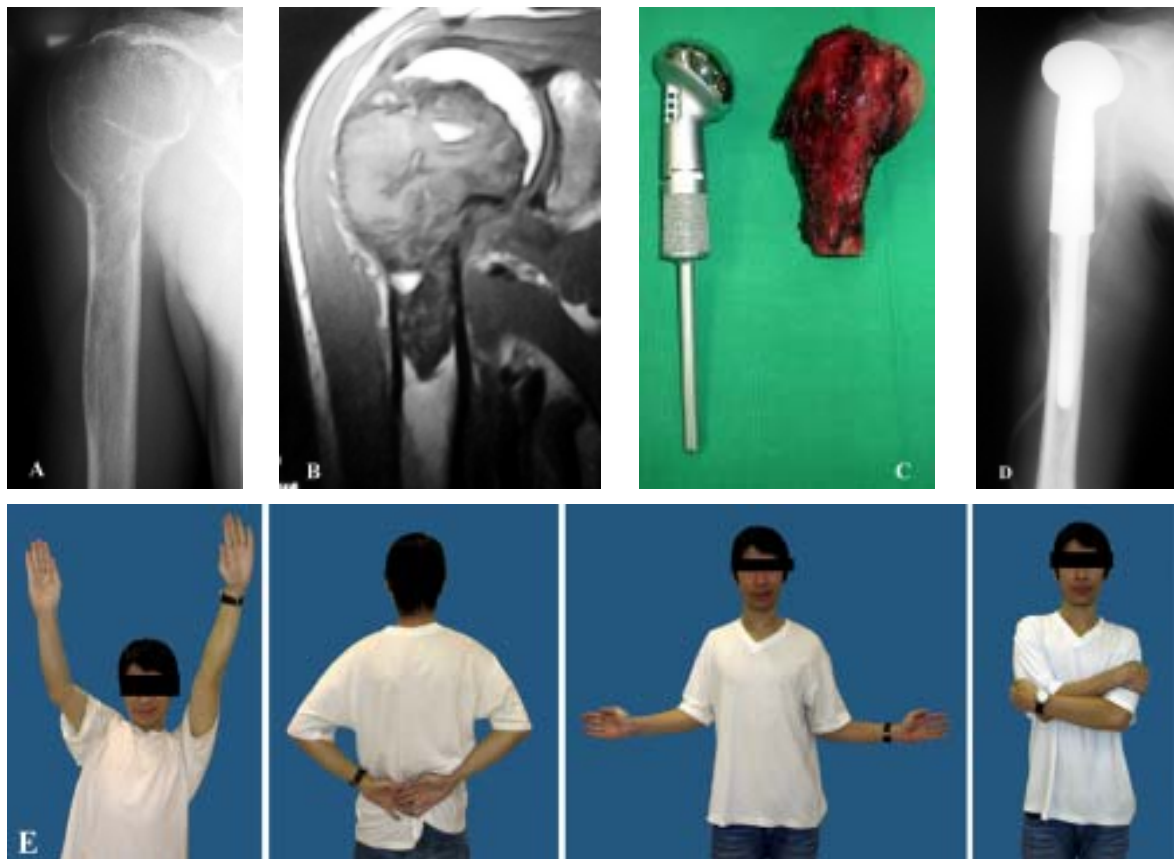


Fig. 1 (A) The radiograph of a 29-year-old patient with Gorham's disease on his proximal humerus
 (B) The T-1 weighted coronal sequence MR image demonstrates the lesion confined at head, neck and proximal shaft of the humerus with soft tissue extension outside the cortex
 (C) The photograph shows the gross tumor after resection and the modular proximal humeral endoprosthesis
 (D) The postoperative radiograph of the proximal humerus shows excellent cement fill around the stem of the humeral prosthesis
 (E) This clinical photograph shows the 1-year postoperative functional result of a proximal humeral replacement

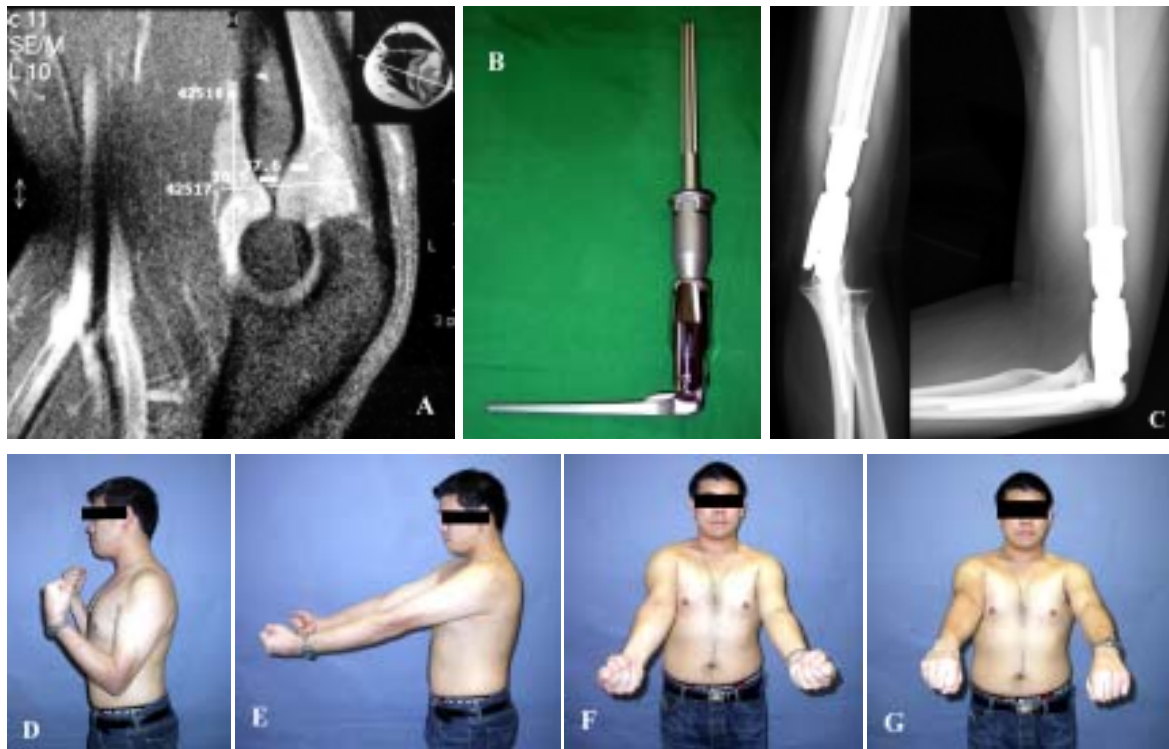


Fig. 2 (A) The T-1 weighted gadolinium sagittal sequence MR image of a 27-year-old patient demonstrates a synovial sarcoma involved at the olecranon fossa area
 (B) The photograph shows a modular distal humeral endoprosthesis
 (C) The postoperative radiographs of the elbow shows good alignment of the prosthesis
 (D) The clinical photograph shows full elbow flexion with the distal humeral replacement shown in C
 (E) The patient in this clinical photograph shows full elbow extension
 (F) The patient in this clinical photograph shows full supination
 (G) The patient in this clinical photograph shows full pronation



Fig. 3 (A) The radiograph of a 73-year-old patient shows a pathological fracture at the subtrochanteric and shaft area of the femur after interlocking medullary nailing
 (B) The intra-operative photograph demonstrates the proximal endoprosthesis reconstruction after tumor resection
 (C) The postoperative radiographs shows good replacement with excellent cement fill around the stem of the proximal femoral endoprosthesis

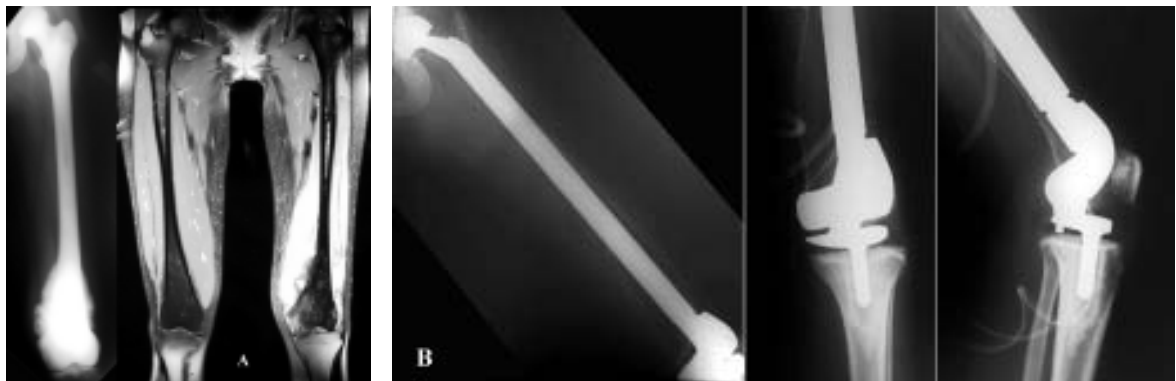


Fig. 4 (A) The radiograph and the T-1 weighted gadolinium coronal sequence MR image of a 23-year-old patient demonstrates extensive lesion of the osteosarcoma involving the whole shaft of the femur
 (B) The postoperative radiographs of the whole femur and knee of the patient are in Figure A

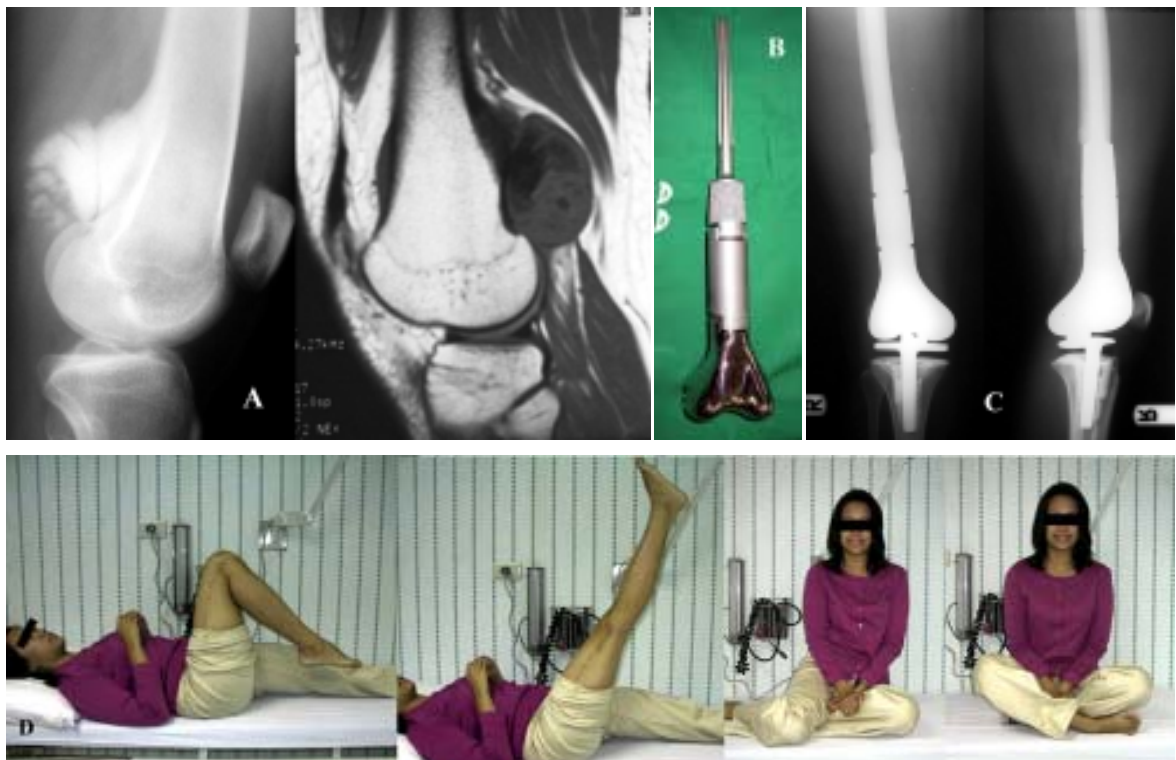


Fig. 5 (A) The radiograph and the T-1 weighted sagittal sequence MR image of a 20-year-old patient with a parosteal osteosarcoma of the posterior aspect of the supracondylar area of the femur
 (B) The photograph shows a modular distal femoral endoprosthesis
 (C) The postoperative radiographs show good alignment of the distal femoral endoprosthesis
 (D) This clinical photograph shows the 3-year postoperative functional results with full range of motion of the knee and Thai-style sitting



Fig. 6 (A) The radiograph and the T-1 weighted coronal sequence MR image of a 34-year-old patient with osteosarcoma on his proximal tibia demonstrates the lesion confined at the medial aspect of epiphyso-metaphyseal of the proximal tibia with soft tissue extension outside the cortex
 (B) The photograph shows a gross tumor after resection and the modular proximal tibial endoprosthesis
 (C) The postoperative radiograph of the tibia shows excellent cement fill around the stem of the proximal tibial prosthesis
 (D) This clinical photograph shows the 1-year postoperative functional result of a proximal tibial replacement

tibia and tibial intercalary reconstructions were allowed to bear full weight immediately after surgery with crutches (Fig. 7). The patients were reviewed every three months for the first 2 years after operation, then every six months for 3 additional years and annually thereafter. All patients underwent functional analysis according to the Musculoskeletal Tumor Society functional rating system and were followed up to death, amputation, or revision surgery.

The functional outcome was assessed in all patients using the Musculoskeletal Tumor Society functional rating system⁽²²⁾. This system uses a 30-point scale to weight each of six parameters equally; these are pain, functional limitation, emotional acceptance, which are used for both upper and lower extremity reconstruction. Three more parameters used for upper

extremity reconstruction are hand positioning, manual dexterity and lifting ability. For lower extremity reconstruction, the three parameters are walking distance, use of support and gait. Failure of endoprosthetic reconstructions was defined as revision of any or all components of the implant, removal of the prosthesis or amputation of the limb. The records were inspected for the onset and causes of the failure leading to revision, removal of implant or amputation.

Data were presented as number and percent, mean and range. Some patients were demonstrated by Figures.

Results

The mean follow-up time was 26 months (range 6-128.7). Sixteen patients are continuously free



Fig. 7 (A) The radiograph and the T-2 weighted axial sequence MR image of a 35-year-old patient demonstrates a periosteal osteosarcoma on his shaft tibia
 (B) The photograph shows the modular intercalary tibial endoprosthesis with a custom-made distal tibial stem
 (C) The postoperative radiograph of the tibia shows excellent cement fill around the stem of the prosthesis
 (D) This clinical photograph shows the 1-year postoperative functional result of an intercalary tibial replacement

of the disease, two are alive with the disease, two had no evidence of the disease, nine died of the disease, and one patient died from complications of hypertension. Two patients alive with the disease have bilateral lung metastases and have supportive treatment. The mean Musculoskeletal Tumor Society functional analysis for upper extremity reconstruction was 93% (range 86.7-100) and for lower extremity was 89% (range 63.3-100). Patients with proximal humerus replacement had a mean functional score of 91.7% (range 86.7-100). A patient with distal humerus reconstruction had an excellent functional score (100%). Patients with proximal femoral replacement had a mean functional score of 89.3% (range 73.3-100). A patient with total femoral reconstruction had a fair functional score (63.3%). Patients with distal femoral replacement had a mean functional score of 88.2% (range 66.7-100). Patients with proximal tibia reconstruction had a mean func-

tional score of 98.9% (range 96.7-100) and a patient with intercalary tibial replacement had an excellent functional score (100%). Most patients were classified with good and excellent functional results according to the Musculoskeletal Tumor Society functional analysis.

Two patients (6.7%) were determined to be a failure at the time of last follow-up. The rate of revision was 3.3% (1) and of amputation 3.3% (1). Overall, there were five complications in the present study. One (3.3%) local recurrence occurred at the distal femur of the patient with osteosarcoma. This patient underwent hip disarticulation at 11 months after the reconstruction. She had a thoracic wedge resection of the metastatic lung lesions and recently has had no new disease relapse. One aseptic loosening was found at the distal femoral stem in the patient with parosteal osteosarcoma who developed this complication following the

first operation after 128.7 months. She was successfully revised with the new modular distal femoral prosthesis and could resume her previous profession. An incomplete sciatic nerve palsy (3.3%) happened in the patient with a 33-centimeter resection of the distal femur. This patient has used only an ankle-foot orthosis when he walks. Two (6.7%) seromas were found in the patients with distal femoral reconstruction. They were successfully treated by only one minor surgery in each patient.

Discussion

The oncological objective of malignant bone or soft tissue tumors resection is to achieve local tumor control. Patients who have adequate wide margin tumor excision by limb-salvage surgery or amputation will have a low-risk of tumor recurrence and good prognosis. Multi-institutional studies have also shown no major difference in the rates of survival of patients who have limb-salvage and of those who have amputation for osteosarcoma in an extremity^(2,23). Limb-salvage surgery might be considered in tumors without major neurovascular structure involvement. An amputation must always be considered if wide margins cannot be obtained with a limb-salvage procedure or if the resultant limb function would be worse with limb salvage and reconstruction than with amputation and prosthesis. The principles of limb-salvage surgery for bone or soft tissue malignant tumors are wide adequate margin excision and reconstruction of bone or soft tissue after tumor removal. In the present study, the authors have used one custom-made and 31 modular replacement systems for reconstruction after resection of the neoplastic disease and other conditions in multiple bony locations of the extremities. Initially, custom-made prostheses were used. The pre-operative design and manufacturing processes required 8 to 10 weeks; this caused a significant delay in the timing of tumor resections. A second drawback of custom-made prostheses was the difficulty in determining the actual length and width of the resected bone on the basis of imaging modalities alone⁽²⁴⁾. The modular prostheses have been introduced for prosthetic reconstruction since the mid 1980s. This system enables the surgeon to measure the actual bone defect at the time of surgery and select the most appropriate components to use in reconstruction. Now, surgeons can have this modular prostheses imported within 4 to 6 weeks. True custom-made components are now only needed for cases of unusual stem diameters or lengths or in other uncommon scenarios. Another key design feature in-

cludes extensive porous coating on the extra-cortical portion of the prostheses for bone and soft tissue fixation, which can lower the incidence of aseptic loosening⁽²⁵⁾.

The function after limb-salvage surgery of patients with bone and soft-tissue tumors has been demonstrated to be better than those with amputation both in the upper and lower extremities. In the upper extremities, an extra-articular resection of the proximal part of the humerus results in a function that is markedly superior to that after a forequarter amputation. In addition, an arthrodesis of the shoulder using an allograft gives a better functional result than does a flail extra-articular resection of the humerus. In terms of energy expenditure during gait and the function of the patients who have limb-salvage around the knee following osteosarcoma resection, the results appear to range from best to worst in the following: mobile replacement of the knee, rotationplasty, or arthrodesis of the knee and above-the-knee amputation^(3,25). Endoprosthetic reconstruction has the substantial benefits of early weight bearing and mobilization, excellent cosmesis and patient acceptance. The functional analysis of the patients in the present study could be acceptably compared with that seen in other studies^(3,5,13,19,26). Although, the goals of limb-salvage surgery are preservation of the functional limb and improvement of the quality of life, the patients and their families must realize that none of the reconstructions will enable them to have a functionally normal limb, and that they will be partially disabled.

Local recurrence remains a concern whether limb salvage or amputation is chosen as a means of local control. Local recurrence after limb salvage has been reported to range from 3 to 10%^(13,19,26,27). A large multi-institutional study accepted that the local recurrence rate of a limb-salvage procedure for osteosarcoma should not be more than 10%, which was also approximately the rate for patients who had had an amputation⁽²⁶⁾. The local recurrence in the present series of 3.3% was within the range of previous studies.

Complications and failures in endoprosthetic reconstruction are not uncommon. The most common complications are infection (3 to 13%)^(4,19,28), aseptic loosening (5 to 16%)^(4,28,29), polyethylene component failure (5.4%)⁽²⁷⁾, prosthetic fracture and local recurrence. The rate of prosthetic failure ranged from 13 to 16.6% and the rate of amputation was 2.4 to 5%^(13,19,24,27). The causes of amputation were related to local tumor recurrence or deep infection. In the present series, two prostheses (6.7%) were determined to be a failure

caused by aseptic loosening and local recurrence. One amputation (3.3%) was performed in the patient who suffered from tumor recurrence. There was no deep infection in the present study. One incomplete sciatic nerve palsy and 2 seromas occurred which were successfully treated by minor surgery.

Another important factor that should be discussed is the comparison of cost-effectiveness for this specific limb-salvage technique with other reconstruction techniques and amputation. Grimer et al demonstrated that a limb-salvage resection with endoprosthetic reconstruction clearly is more cost-effective than amputation⁽³⁰⁾. The reason for this finding is that most patients with primary bone malignant tumors are young and active. If treated by amputation, they probably will require a sophisticated artificial limb that has to be replaced at regular intervals, and may include the use of an artificial sport limb, swimming limb and spare limb. In addition, most patients will have stump problems develop that will necessitate recasting of the socket. Presently, there is no comparative study of the cost-effectiveness between endoprosthetic reconstruction and massive allograft, which is the most common limb-salvage reconstruction in our institute. From the study in the presented limb-salvage patients, there were twice as many complications in massive allograft reconstruction than other non-allograft reconstruction⁽³¹⁾. Patients with massive allograft reconstruction needed more surgical operations after the first reconstruction. The most common complications occurring after massive allograft are fractures, non-union, infections and joint instability. Patients with this type of reconstruction need a certain period of immobilization and gait-aid equipment after reconstruction, which delays joint movement or weight bearing gait, and may cause some degree of joint stiffness. These disadvantages and further complications, might lead to more expense in this type of reconstruction. Further study should be conducted to confirm these important cost-effective benefits in the future.

Conclusions

Endoprosthetic reconstruction following malignant bone and soft-tissue tumor resection can be used in a variety of anatomic locations for selective patients. Current modular designs eliminate the need for a true "custom-made" prosthesis in most situations and enable intra-operative adjustments to be made. From the findings in the present study, patients' functions and cosmesis are routinely quite good with a relatively low rate of complications for tumor endoprostheses.

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ผลการผ่าตัดเก็บรยางค์โดยวิธีบูรณาการด้วยข้อเทียมสำหรับการรักษามะเร็งกระดูกและเนื้อเยื่ออ่อน

อภิชาติ อัครวมงคลกุล, สารเนตร ไวกกุล, ระพีพันธ์ พิมลสานต์, ปิยะ เกียรติเสวี, ประเสริฐ วังสุตรค

ภูมิหลัง: ในปัจจุบันการรักษามะเร็งกระดูกและเนื้อเยื่ออ่อนมีผลการรักษาดีขึ้นเนื่องจากการวิวัฒนาการของภาพรังสี การให้ยาเคมีบำบัด การฉายรังสีรักษา และวิธีการผ่าตัดที่ดีขึ้น ผู้ป่วยที่เป็นโรคเหล่านี้สามารถมีอัตราการรอดชีวิตที่สูงขึ้น รวมทั้งยังสามารถได้รับการผ่าตัดเก็บรยางค์ที่มีพยาธิสภาพและใช้งานได้ดี วิธีการผ่าตัดบูรณาการเพื่อเก็บรยางค์ภายหลังผ่าตัดก่อนเนื้องอกที่เป็นมะเร็งกระดูกและเนื้อเยื่ออ่อนมีอยู่หลายวิธี เช่น การใช้กระดูกปลูกถ่ายจากผู้ป่วยบริจาค และการใช้ข้อเทียม เป็นต้น

วัตถุประสงค์: เพื่อศึกษาผลการรักษาภายหลังผ่าตัดเก็บรยางค์และบูรณาการกระดูกที่มีพยาธิสภาพด้วยข้อเทียม จำนวน 32 ข้อ จากผู้ป่วย 30 ราย ผู้ศึกษาได้รายงานผลการรักษาของผู้ป่วยทั้งในแง่การพยากรณ์โรค และการทำงานของรยางค์ที่ได้รับการผ่าตัด รวมทั้งโรคแทรกซ้อนภายหลังการผ่าตัด

วัสดุและวิธีการ: มีการผ่าตัดเก็บรยางค์และบูรณาการด้วยวิธีต่าง ๆ ภายหลังผ่าตัดเนื้องอกกระดูกและเนื้อเยื่ออ่อนที่โรงพยาบาลศิริราช ตั้งแต่ปี พ.ศ. 2531 จำนวน 188 ครั้ง ระหว่างเดือนมีนาคม พ.ศ. 2537 – กรกฎาคม พ.ศ. 2549 พบว่ามีการผ่าตัดเก็บรยางค์และบูรณาการด้วยวิธีการใช้ข้อเทียม 32 ข้อ จากผู้ป่วย 30 ราย พบผู้ป่วยเพศชาย 16 ราย เพศหญิง 14 ราย โดยมีค่าเฉลี่ยของอายุผู้ป่วย 28 ปี ผู้ป่วย 16 รายได้รับการวินิจฉัยว่าเป็น osteosarcoma, parosteal osteosarcoma 2 ราย, chondrosarcoma 2 ราย, leiomyosarcoma 2 ราย ผ่าตัดเปลี่ยนกระดูกปลูกทดแทนจากผู้บริจาคและมีปัญหาแทรกซ้อน 2 ราย มีการวินิจฉัยว่าเป็น periosteal osteosarcoma, Ewing's sarcoma, Gorham's disease, synovial sarcoma, malignant fibrous histiocytoma, metastatic renal cell carcinoma และ prosthetic loosening ในผู้ป่วยอย่างละราย ค่าเฉลี่ยความยาวของเนื้องอกที่ได้รับการผ่าตัดออก 18.5 ซม. ตำแหน่งของการผ่าตัดพบว่าเป็นที่กระดูก femur ส่วนต้น 5 ราย กระดูก femur ส่วนปลาย 17 ราย กระดูก femur ทั้งท่อน 1 ราย กระดูก tibia ส่วนต้น 3 ราย กระดูก tibia ส่วนกลาง 1 ราย กระดูก humerus ส่วนต้น 4 ราย และกระดูก humerus ส่วนปลาย 1 ราย ข้อเทียมส่วนใหญ่ที่ใช้ในการศึกษานี้เป็นแบบ modular replacement systems

ผลการศึกษา: ค่าเฉลี่ยของระยะเวลาที่ติดตามผู้ป่วยนาน 26 เดือน (ช่วง 6-128.7) ผู้ป่วย 20 รายยังมีชีวิตอยู่ 9 ราย เสียชีวิตจากโรคมะเร็ง และ 1 ราย เสียชีวิตจากปัญหาแทรกซ้อนเนื่องจากความดันโลหิตสูง ผลการใช้งานวัดค่าโดยวิธีของ The Musculoskeletal Tumor Society พบว่าค่าทำงานโดยเฉลี่ยของรยางค์ส่วนบนอยู่ที่ 93 เปอร์เซ็นต์ (ช่วง 86.7-100) ค่าทำงานโดยเฉลี่ยของรยางค์ส่วนล่างอยู่ที่ 89 เปอร์เซ็นต์ (ช่วง 63.3-100) ผู้ป่วย 2 ราย (6.7 เปอร์เซ็นต์) ได้รับการผ่าตัดข้อเทียมเดิมออกมาเนื่องจาก aseptic loosening และมีรอยโรคเกิดซ้ำใหม่เฉพาะที่โดยผู้ป่วยที่มีรอยโรคเกิดซ้ำใหม่เฉพาะที่ต้องได้รับการผ่าตัดขาออกตั้งแต่ระดับข้อสะโพก ผู้ป่วย 1 ราย มีการสูญเสียการทำงานของเส้นประสาท sciatic และผู้ป่วย 2 ราย พบมีปัญหาน้ำเหลืองคั่งบริเวณแผลและได้รับการผ่าตัดจนหายดี

สรุป: การผ่าตัดเก็บรยางค์และบูรณาการด้วยวิธีการใช้ข้อเทียมภายหลังผ่าตัดมะเร็งกระดูกและเนื้อเยื่ออ่อนให้ผลการรักษาที่ดีโดยผู้ป่วยสามารถใช้งานรยางค์ที่เคยมีพยาธิสภาพได้เป็นอย่างดี รวมทั้งมีปัญหาแทรกซ้อนน้อย
