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Original Article

Outcomes of combined chemotherapy, extensive resection, and metal prosthesis reconstruction of the proximal tibia and distal femur in Chinese patients with stage IIB knee malignant tumour: a long-term followup

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Abstract: Background: Complication rates reported for contemporary knee reconstruction limb salvage surgery (LSS), an alternative to amputation patients with bone tumours of the proximal tibia and distal femur, have not been extensively explored in China. Objective: Functional outcomes, survival, prosthesis failure, and complication rates were investigated in Chinese patients with malignant or aggressive tumours of the knee joint. Methods: A retrospective study was conducted of 47 patients with knee joint tumours (M:F, 23:24; mean age 27±6 years; range 15 to 39 years) treated with pre- and post-operative chemotherapy combined with extensive tumour resection and metal prosthesis replacement. Patients were followed from March 1998 to March 2008, until death or limb salvage failure. LSS efficacy, survival, prosthetic failure, and complications were evaluated by Musculoskeletal Tumour Society (MSTS) scoring. Results: Patients were followed up for a median of 89 months. Mean operative bleeding and surgical time were 600±154 (300-1500) mL and 2.8±0.6 (1.5-3.5), respectively. No early infections were reported; however, 8 (17.0%) and 3 (6.3%) patients developed superficial infections or deep tissue infections, respectively, and 9 (19.1%) developed deep vein thrombosis. Prosthetic loosening, breakage, and removal was reported in 7 (14.9%), 2 (4.3%), and 3 (6.3%) patients, respectively. Only 1 (2.1%) patient required subsequent amputation. A total of 12 (25.5%) developed recurrence, and 23 (48.9%) died during the follow-up time. Mean MSTS was 78±12%. Conclusions: Combined chemotherapy, extensive resection, and metal prosthesis reconstruction optimized functional recovery. However, potentially life-threatening complications, infections, and recurrence limited its broad implementation.

Keywords: Knee, limb salvage, complication, tumour, chemotherapy, prosthesis, resection, metal prosthesis

Introduction

Cancers of the knee joint, including multiple myeloma, osteosarcoma, Ewing's sarcoma, and chondrosarcoma (e.g., bone cysts, giant cell tumour, enchondroma), are the most common form of bone cancers, occurring in 2 to 7 of every 100,000 members of the global population in either the more common benign (noncancerous) or uncommon malignant (cancerous) forms [1]. Only 6% of childhood malignancies occur due to primary bone tumours, though 60% of primary bone tumours affect patients younger than 45 years, peaking in patients aged 15 and 19 years [2]. Though wide tumour resection followed by endoprosthetic and biological reconstruction is the most common surgical therapy for primary bone tumours in the knee joint region [2], recent evidence has suggested that prosthetic limb salvage surgery (LSS) following resection may be an effective treatment option for bone and soft tissue tumours around the knee; however, complication rates remains high [3]. Thus, there is a need to more completely explore prosthetic LSS of the knee joint and potential engineering and surgical strategies to limit complication rates.

In previous decades, amputation was a primary treatment for aggressive and potentially malignant lower extremity musculoskeletal tumours; however, contemporary advancements in adjuvant chemotherapy, imaging, and surgical prostheses have increased the prevalence of LSS, offering superior gait efficiency and return to normal living compared with amputation [4]. Furthermore, LSS patients report less detrimental changes in quality of life compared to amputees [4]. Despite the apparent advantages of LSS, up to 27.2% of patients report deep infection, 23.3% report mechanical failures of the prosthesis, and only 68.6% survive to 5-years [5]. To improve the success of these surgeries employing contemporary prostheses, improvements in prosthesis engineering and patient selection are required to overcome the relatively high occurrence of deep infection and mechanical failure [5].

In China, LSS has only recently been employed as a routine measure for treatment of primary malignant or symptomatic bone tumours, with wide implementation and success rates of these procedures lagging somewhat behind most of the developed world [6, 7]. Furthermore, the effectiveness and economy of prosthesis and surgery selection for Chinese patients remains widely debated, owing in part to recent changes in Chinese healthcare [7]. Additionally, many Chinese healthcare centres face the additional burden of simultaneously treating patients with diverse types of primary bone tumours, with additional limitations due to available beds and other resource limitations, making LSS patients more than 6 times as likely to experience complications in Chinese facilities as conventional amputation patients [7].

To provide a basis for improving prosthetic treatment of diverse types of primary bone tumours of the knee in Chinese patients, the long-term outcomes of patients that underwent routine pre- and post-operative chemotherapy combined, extensive resection, and metal prosthesis placements were examined, and complications were recorded.

Methods

Study design

A total of 47 knee joint tumour patients (M:F, 23:24; mean age 27±6 years; range 15 to 39 years) were enrolled in a retrospective study from March 1996 to March 1998. All patients were treated with routine pre- and post-operative chemotherapy for those tumours of chemosensitive, with extensive tumour resection plus metal prosthesis replacement and then followed from March 1998 to March 2008, until death or limb salvage failure. All subjects have written informed consent. The study protocol was approved by the Ethics Committee of the Changhai Hospital affiliated to The Second Military Medical University (China).

Patients

All included patients (1) were diagnosed with aggressive or malignant tumours subtypes with conventional regional X-ray imaging, computed tomography (CT) and magnetic resonance imaging (MRI) examinations, skeletal emission computer tomography (ECT) scans, confirmed by preoperative biopsy; (2) stage IIB; (3) underwent routine pre- and post-operative chemotherapy for those tumours of chemosensitive; underwent treatment with extensive resection, and metal prosthesis placement; and (4) completed follow-up until death or limb salvage failure. Patients were excluded that (1) exhibited other significant conditions, such as metastasis of other cancer, history of other malignancy, or genetic abnormalities; (2) had distal metastases prior to surgery; or (3) were lost to follow-up prior to death or limb salvage failure.

Pre-surgical treatment

Prior to surgery, patients diagnosed with osteosarcoma who were chemosensitive received 2-4 cycles of routine pre-operative chemotherapy (e.g., including methotrexate, adriamycin, and cisplatin) to reduce symptoms, decrease neoplasm mass, and provide clear tumour boundaries. Arterial angiographic embolization was performed 1 day prior to surgical resection and reconstruction for all patients. Preoperative MRI was used to determine surgical margins and appropriate prosthetic device dimensions using sizes and damage characteristics of muscle and bones surrounding the knee. The location of the each tumour (proximal tibia or distal femur) and tumour classification as osteosarcoma, chondrosarcoma, aggressive or malignant giant cell tumour of bone (GCTB; defined as GCTB capable of metastasis), and fibrosarcoma were recorded.

Surgical resection

Patients were placed in the supine position, the incision region was cleaned with alcohol, and 18±6 cm incision was made based on the tumour position to allow for complete tumour resection. Soft tissues were excised 1 cm from the tumour reactive zone and neoplasms were excised 3 cm from the damaged bone. In each patient, appropriate prostheses (Waldemar LINK, Germany) were placed to replace damaged areas of the bones adjacent to the knee. Shape and size of prostheses were determined based on individual patient. For each patients, the tendon was fixed directly in the prosthesis and the knee joint kept extended for 6 weeks after the operation in order to ensure mechanical stability of the knee joint stiff and prevent early damage due to overuse after prosthesis replacement.

Tumour resection method for the upper tibia

An incision was made from the upper edge of the patellar down to the inside of the patella and patellar tendon, reaching a point 5 cm below the bone to be resected. Incisions were made through the skin and subcutaneous tissues, at the top of the patella joint tendon and patellar tendon portion of the medial expansion aponeurosis. Free resection was conducted from the inside of the tumor of the medial collateral ligament and gracilis, semitendinosus, semimembranosus, and pes anserinus. The tendon-tibia was cut from the superficial layer of the tibial tubercle, and the patella and pretibial muscle group were everted. The lateral region of the tumor was dissected, or bone stripped patellar tendon were pasted over the tibial tubercle check points in order to maintain continuity with the osteofascial compartment. Then the anterior and posterior meniscus cruciate ligament and upper tibiofibular ligaments were resected, and nerves, blood vessels, and fat at the fossa of the trunk were pushed to the rear and cut off the soleus in a downwards manner. Then the tibia was cut off at 5 cm below the lower border of tumor, and the tumor was resected from the optimal boundary.

During surgery, distilled water was used to soak the surgical wound. Bone cement was imbedded from the residual myelin surface of tibia and inserted into the tibial side of the prosthesis. The cartilage surfaces of both femoral condyles were removed, and a hole was drilled from the center of the condyle. Sclerotin was resected in size of a square connector to reach the cavum medullare, and the tibial side of the prosthesis was inserted. A bolt was installed when the chain joints of the simple hinged prostheses were restored, with locking after adjusting the joint tension. Rotatable polymer polyethylene liners were placed, and the joint axis of rotation was installed. Closed reduction of the prosthesis was then conducted. Stop points of the patellar ligament were reconstructed with non-absorbable sutures, and the apocoptic ligamentum patellar was fixed on the accessory device of tibial prosthesis. The extensor device was then rebuilt and a silicone drainage tube was installed and sutured by layer.

Lower femur surgery methods

Incisions were made starting at the inner thigh along the trailing edge of the vastus medialis downstream and ending at the upper tibia in the inner side of the patellar ligament, cutting through skin, subcutaneous tissue, deep fascia, free femoral artery and vein, and adductor longus tendon. The normal muscle was disassociated outside the tumor response area, resecting the accessory ligament, cruciate ligament, and joint capsule on both sides and cutting off the tibia 5 cm above the tumor boundaries on the inner and external sides of the gastrocnemius head. The tumor was then removed from the optimal border and the surgical wound was soaked using cisplatin during surgery. The medulla was expanded, and a specially made intramedullary femoral prosthesis was inserted in the neutral position following bone cement implantation. The tibial plateau cartilage surface was resected in the upper end of the tibial connector, resulting in removal of the tibial bone in a triangle shape. The connector was then inserted into the tibia, a rotatable high molecular polyethylene liner was placed, and joint rotation axis and silicone drainage tubes were installed. Each was sutured by layer, and postoperative drainage tubes were then placed.

Post-surgical treatment and follow-up

All osteosarcoma patients received 4-6 additional cycles of routine chemotherapy after surgical resection and other patients were followed closely. Flexion and extension of the knee were tested 3 days after surgery. Patients

Table 1. Demographic and clinical condition of knee tumour patients (*n* = 47) by disease classification

Parameter	Osteosarcoma (*n* = 19)	Chondrosarcoma (*n* = 8)	Malignant GCTB (*n* = 15)	Fibrosarcoma (*n* = 5)	Total (*n* = 47)
Age (yr)	22±5 (15-33)	34±6 (22-39)	28±7 (18-34)	32±9 (19-38)	27±6 (15-39)
Male:Female	9:10	5:3	7:8	2:3	23:24
Proximal tibia tumour	10	3	6	1	20 (42.6%)
Distal femur tumour	9	5	9	4	27 (57.4%)
Local pain	18 (94.7%)	6 (75.0%)	12 (80.0%)	3 (60.0%)	39/47 (83.0%)
limping	7 (36.8%)	4 (50.0%)	6 (40.0%)	1 (20.0%)	18 (38.2%)
Incidental diagnosis	1 (5.3%)	2 (25.0%)	3 (20.0%)	2 (40.0%)	8 (17.0%)
Bleeding > 1000 mL	2 (10.5%)	0 (0%)	1 (6.7%)	0 (0%)	3 (6.4%)
Marginal resection	1 (5.3%)	2 (25.0%)	0 (0%)	1 (20.0%)	4 (8.5%)

Abbreviations: GCTB, giant cell tumour of bone.

began walking with the aid of crutches when intact scar tissues were observed to be fully formed at approximately 6 weeks postoperatively, and thereafter gradually began to walk independently during the following 3 months.

All patients were followed for a minimum of 41 months. The final follow-up time was March 2008. At each exam, chest CT scans, skeletal ECT scans, and/or plain film X-rays of the knee joint were conducted to assess healing and prosthesis situation. Diseased limb function was evaluated by the Musculoskeletal Tumour Society (MSTS) scoring system [8]. Patient graded pain scores, function, activity, emotional acceptance of disease, weight-bearing, and walking. The functional scores were converted into percentages.

Statistical analysis

All data were recorded as means ± standard deviations (SD) or percentile values, and statistical analysis was conducted using SPSS v.10.0 (IBM, USA). Kaplan-Meier analysis was used to evaluate survival rate of prostheses. *P*-values of less than 0.05 were considered statistically significant ($P < 0.5$).

Results

Clinical and demographic information for included patients

A total of 54 patients were assessed, and 7 patients were excluded because of distal metastases prior to surgery, all were pulmonary metastasis. Of the 47 included patients, 27 (57.4%) patients had tumours of the distal femur and 20 (42.6%) patients had tumours of the proximal tibia. Tumours were classified as osteosarcoma (19/47, 40.4%), chondrosarcoma (8/47, 17.0%), aggressive or malignant giant cell tumour of bone (15/47, 32.0%), and fibrosarcoma (5/47, 10.6%), and all tumours were classified as Stage IIB (**Table 1**). Follow-up was conducted for a median of 89±16 months (ranging 41 to 122 months). Preoperative symptoms included local pain from a fixed mass that most noticeable at rest (39/47, 83.0%), walking impairments or limping (18/47, 38.2%). In 8 (17.0%) patients, the tumours were discovered incidentally following other injury. Typical preoperative imaging is shown in **Figure 1**. Furthermore, postoperative pathological slides indicated positive surgical margins (**Figure 2**). All patients had complete follow-up data and received resection with prosthesis reconstruction.

Intraoperative outcomes

Mean surgical time was 2.8±0.6 (1.5-3.5) h, and mean bleeding volume was 600±154 (300-1500) mL. In 3 (6.4%) patients, the bleeding volume was > 1000 mL, including two osteosarcoma patients and one fibrosarcoma patient. Of the total 47 patients, 43 (91.5%) patients underwent large resections, and 4 (8.5%) patients that exhibited inadequate popliteal fossa vasculature underwent marginal resection. A total of 2 (4.3%) patients with tumours in the proximal tibia required common peroneal nerve resection during the surgery, with both undergoing arthrodesis of the ankle 6

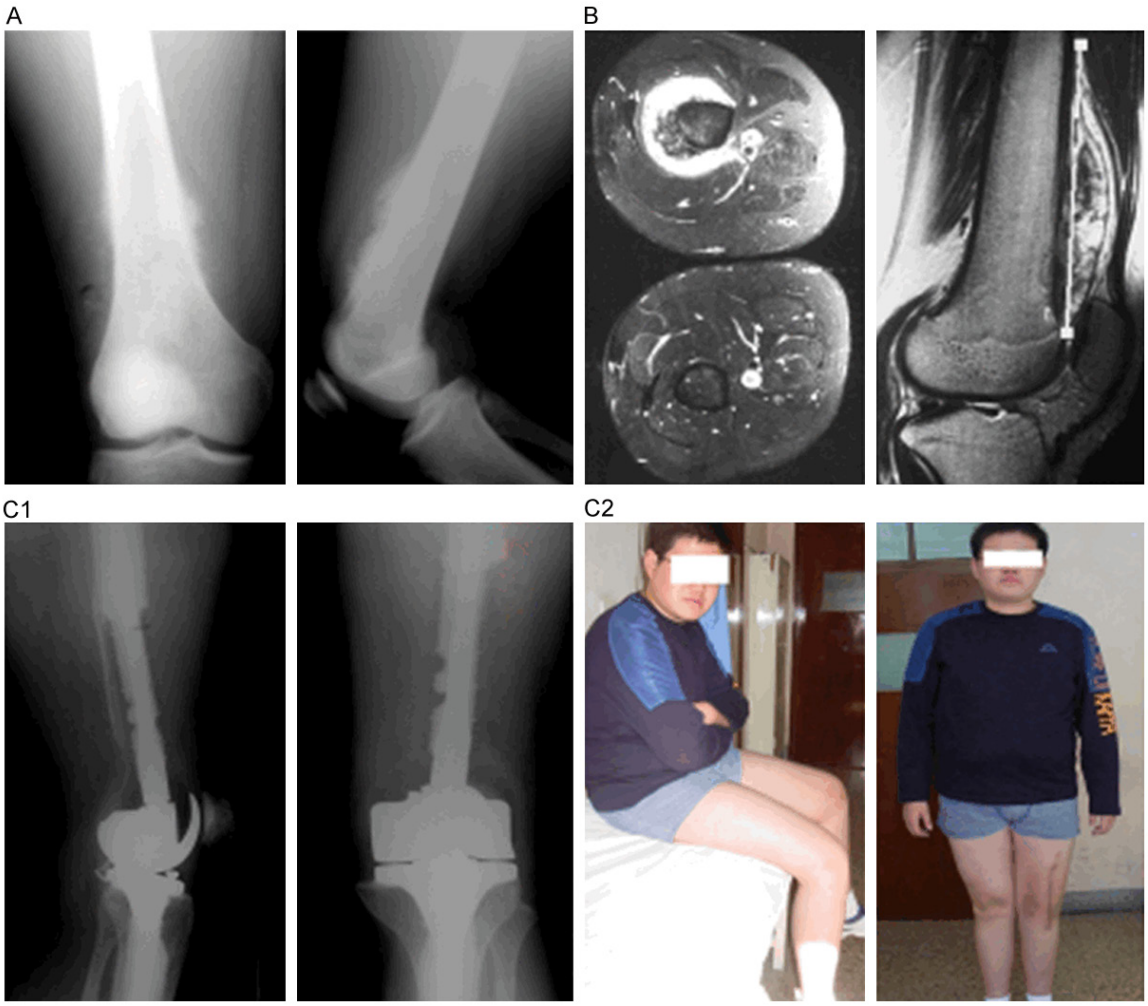

Figure 1. Preoperative imaging and functional outcomes in a 16-year-old male patient with sarcoma at the distal femur Shown are (A) preoperative X-ray images, (B) preoperative MRI images, (C) X-ray (C1) and functional (C2) image at 9-years postoperative.

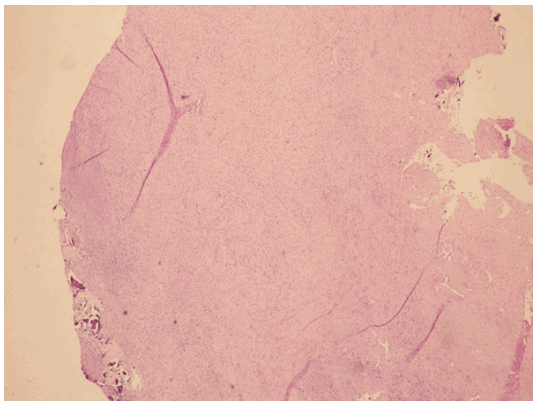

Figure 2. Postoperative pathological slides indicating positive surgical margins.

months later. Detailed data is shown in **Table 1**.

Surgical complications

One (2.2%) patient exhibited femoral shaft fracture during prosthesis placement following neoplasm resection of the distal femur, potentially attributable to over-amputationamputation of bone prior to prosthesis insertion. The fracture was repaired with metal wire binding and lower-limb fixation with a plaster cast, exhibiting normal healing at 6 weeks. Superficial infections were observed during the early postoperative period in 8 (17.0%) patients, leading to poor healing and requiring secondary debridement and local rotational flap due to a skin defect after debridement in one patient. Debridement with rinsing and drainage was required in 4 (8.5%) patients due to repeated effusion accompanied by disunion of the wound and purulent secretion, and in 3 (6.3%) patients

Table 2. Surgical complications

Complications	Osteosarcoma (*n* = 19)		Chondrosarcoma (*n* = 8)		Malignant GCTB (*n* = 15)		Fibrosarcoma (*n* = 5)		Total (*n* = 47)
	PF	DT	PF	DT	PF	DT	PF	DT	
Femoral shaft fracture	-	1 (2.2%)	-	-	-	-	-	-	1 (2.2%)
Superficial infections	3	1	-	2	1	-	1	-	8 (17.0%)
Debridement	1	1	-	1	-	-	1	-	4 (8.5%)
Deep tissue infection	1	-	-	1	-	-	1	-	3 (6.3%)
DVT (swelling)	2	1	1	-	3	1	1	-	9 (19.1%)
Prosthetic loosening	2	1	1	-	2	-	1	-	7 (14.9%)
Prosthetic breaking	-	1	1	-	-	-	-	-	2 (4.3%)
Prosthesis removal	-	1	1	1	-	-	-	-	3 (6.3%)
Amputation	-	-	-	1	-	-	-	-	1 (2.1%)

Abbreviations: PT, proximal tibia; DF, distal femur; GCTB, giant cell tumour of bone; DVT, deep venous thrombosis.

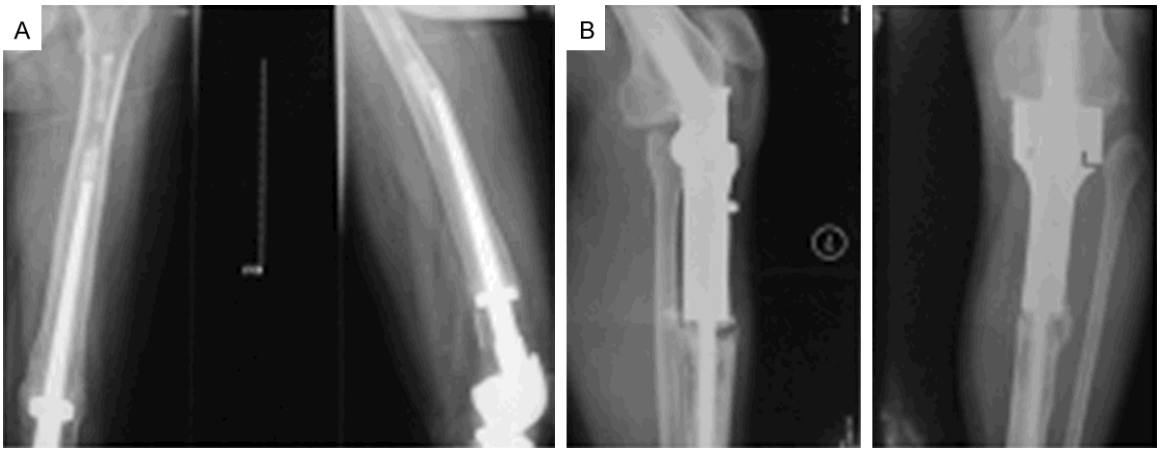

Figure 3. A. Loosening of the prosthesis at the distal femur 3 years postoperative. B. Breakage of the prosthesis at the proximal tibia 4 years postoperative.

infection progressed into deeper tissues. Infection was controlled by prosthesis removal followed by Stage I fusion 16 weeks later in 3 (6.3%) patients, with successful outcomes in 2 (4.3%) patients and subsequent required amputation in 1 (2.1%) patients. A total of 9 (19.1%) patients developed post-operative lower-limb swelling, with imaging indicating deep venous thrombosis successfully treated with anticoagulant and thrombolysis therapy with low molecular heparin and warfarin in all cases (**Table 2**).

Prosthesis loosening and breakage

A total of 6 (12.8%) of patients with distal femur tumours and 1 (2.2%) a proximal tibia tumour experienced prosthesis loosening by postoperative year 1 (1/47, 2.2%), year 5 (4/47, 8.5%), and year 7 (*n* = 2/47, 4.3%). Prosthesis loosening initially manifested as progressive walking pain without infection. Two patients experienced prosthesis loosening and breakage in the fourth and fifth year of the follow-up period (**Figure 3**), including 1 case caused by injury and 1 case that appeared spontaneous (**Table 3**). Notably, metal fragments were identified in the soft tissue regions surrounding broken prostheses, potentially contributing to failure. All fragments were surgically removed and defects were repaired using smaller fitted prostheses due to soft tissue contracture and scarring. Local rotational flaps were applied as necessary, and all incisions were drained to ensure healing.

Outcomes

The 3- and 5-year survival rates for prostheses were 91% (43/47) and 78% (37/47), respective-

Table 3. Number of cases of prosthesis loosening by year

Year	Osteosarcoma (*n* = 19)		Chondrosarcoma (*n* = 8)		Malignant GCTB (*n* = 15)		Fibrosarcoma (*n* = 5)		Total (*n* = 47)
	PF	DT	PF	DT	PF	DT	PF	DT	
3	1	-	-	-	-	-	-	-	1 (2.2%)
5	1	1	-	-	1	-	1	-	4 (8.5%)
7	-	-	1	-	1	-	-	-	2 (4.3%)
Total	2	1	1	-	2	-	1	-	7 (14.9%)

Abbreviations: PT, proximal tibia; DF, distal femur; GCTB, giant cell tumour of bone.

ly. Local recurrence was observed in 12 (25.5%) patients, including 8 osteosarcoma, 3 chondrosarcoma, and 1 fibrosarcoma patients. A total of 23 (48.9%) patients developed distal pulmonary metastases, and 11 (23.4%) patients developed primary tumour recurrence simultaneously, and 21 (44.7%) patients died from pulmonary metastasis in less than 5 years postoperatively , respectively in year 2 (8/47, 17.0%), 3 (6/47, 12.8%), 4 (4/47, 8.5%) and 5 (3/47, 6.4%). Another two pulmonary metastasis patients died in 7 year postoperatively. The 5-year survival rate was 55.3% (**Table 4**).

Functional outcomes

Approximately 6 weeks after surgery, patients gradually were able to resume normal loadbearing and walking without the aid of crutches. Once patients self-reported normal walking ability and resumption of daily activities, mean MSTS scores were determined to be 78±12% (ranging 73-92%). All surviving patients were able to complete normal activities of daily living, normal occupational activities, and live independently.

Discussion

The current study found that complications, particularly deep infection, were common in LSS patients treated with routine pre- and postoperative chemotherapy, extensive resection, and metal prostheses for tumours of the knee joint. Notably, pulmonary metastasis was the leading cause of death among these patients in the decade following surgery, with only about 55.3% of patients surviving to 5 years; however, surviving patients demonstrated overall positive functional results and normal ability to go about daily activities and occupational activities. Thus, LSS with metal prosthetic devices is a promising strategy for maximizing functional outcomes; however, further study and more advanced engineering and surgical techniques will be required to reduce complication rates and improve survival in these procedures.

Metal endoprostheses, or implantable metal replacement prostheses, have revolutionized the field of limb salvage; furthermore, the availability of these devices, which required extensive custom manufacturing time in previous decades, has greatly improved in recent years [9]. Compared to allografts, tissue regeneration, and fusion, the functional restoration of metal prosthetic devices is superior [9]. Using metal prosthesis reconstruction for limb salvage, 5-year prosthesis survival rates between 72% to 93% have been reported, with infection rates as low and 3.0% to 5.4% in specialized treatment centres [10, 11]. Other studies, however have reported 5-year prosthetic survival rates of 72.8% in the distal femur and 74.6% in the proximal lower leg, with mean functional MSTS scores of 81% in surviving patients with distal femur tumours and 82% in patients with proximal lower leg tumours [3]. Notably, in this same study, nearly half (~43%) of patients reported complications [3]. Furthermore, devitalized reconstruction procedures have been reported to raise risks on complications for metal prostheses of the knees compared to non-devitalized procedure (55.5% vs. 30.4%) [7]. In our study, the incidence of post-operative complications was 41.8% in the LSS group, which was much higher than that in the amputation group (6.7%), though highly consistent with previous reports. This suggests that complications, particularly infection, remain a central risk factor to patient survival following prosthesis placement in Chinese facilities. Notably, discrepancies have been reported in postoperative function based on the location of the tumour and prosthetic device in the proximal tibia or distal femur, with postoperative MSTS scores of 76% and 84%, respectively [12]. These discrepancies have been largely attributed to the involvement of the end point of the patellar ligament in reconstruction following neoplasm resection in the proximal tibia. Notably, the current study findings reflected this well-documented trend,

Table 4. Treatment outcomes

Parameter	Osteosarcoma (*n* = 19)		Chondrosarcoma (*n* = 8)		Malignant GCTB (*n* = 15)		Fibrosarcoma (*n* = 5)		Total (*n* = 47)
	PF	DT	PF	DT	PF	DT	PF	DT	
distal pulmonary metastases	7	5	2	1	4	2	1	1	23 (48.9%)
primary tumour recurrence	4	3	2	1	-	-	1	-	11 (23.4%)
Pulmonary metastasis leading to death	6	5	2	-	3	2	-	1	19 (40.4%)
Year 2 deaths	3	2	2	-	1	-	-	-	8 (17.0%)
Year 3 deaths	3	2	-	-	1	-	-	-	6 (12.8%)
Year 4 deaths	1	1	-	-	-	1	1	-	4 (8.5%)
Year 5 deaths	-	-	-	1	1	1	-	-	3 (6.4%)
Year 7 deaths	-	-	-	-	1	-	-	1	2 (4.3%)
Total	7	5	2	1	4	2	1	1	23 (48.9%)

Abbreviations: PT, proximal tibia; DF, distal femur; GCTB, giant cell tumour of bone.

though the infection rates in the current study were notably higher than those reported for previous operations.

In the current study, good healing was generally observed in cases that did not develop either acute or deep infection, consistent with previous research on wound healing that suggested that infection was a leading cause of early failure of metal prosthetic devices of the knee [13]. Notably, metal prosthetic devices have been demonstrated to exhibit substantial healing between the tendon and metal (tantalum) used in the prosthesis in the absence of infection, leading to good overall biomechanical stability indicated y radiographic evidence of the joint structure and functional measurements [14]. In patients with malignant tumours, intensive cytotoxic chemotherapy has been reported to increase and prolong neutropenia, often resulting in increased risk for infection and potentially resulting in death due to deep or severe infection [15]. As a result, patients eligible for prosthesis implants of the knee may be at greater risk for infection due to chemotherapy, offering a potential explanation for the relatively higher rates of infection reported in the current study. As a result, long acting antibiotics are generally prescribed for patients undergoing chemotherapy or being treated with immunosuppressant [15]. Based on our experience, however, we suggest that good soft tissue coverage, adequate postoperative drainage, and reduced surgical times can aid in the risk of reducing early infection, supported by the recently reported successful use of muscle flap transfer covering prostheses to decrease infection rates, especially in the case of smaller prosthetic devices [16]. Furthermore, we, in part, attribute the short surgical times achieved by our centre to our rich experience, including the use of tourniquet, reduced ligation hemostasis time during surgery, loosening of the tourniquet before reconstruction following tumor resection (thus stopping bleeding uniformly), strict control of preoperative limb-salvage indicators, formulation of strict preoperative regimens according to MRI results to guide soft tissue resection, and the careful resection of tumors according to anatomic and preoperative determinations of normal tissue boundaries. Notably, muscle flap techniques were applied in just under half of the studied patient population in the current study. Further research, however, will be required to weigh the benefits of these parameters and chemotherapy regimens with the risk of infection following prosthesis placement.

Long-term prosthetic loosening is a concern that is paramount in prostheses of the knee, as biomechanical stability and differential stress distribution over time may lead to fatigue and failure of the prosthetic device or, more commonly, the union between the prosthetic device and soft tissues [17]. In contemporary research, engineering device design, including proper fit and tapering, have been reported to play a significant role in decreasing the likelihood of prosthetic loosening [17], suggesting that optimal device design and fit should be paramount preoperative considerations. In the current study, all 9 cases of prosthesis loosening were determined to be related to decentralized

stress distribution, further confirming that contemporary preoperative evaluations, in many cases, fail to determine optimal fit and stress distribution for long-term stability. Recent research, however, has suggested that extracortical bone bridge fixation and specialized cementation techniques can prolong the survival of prostheses of the knee *in vivo*, thereby allowing the bone ridge to bear a greater part of the load [18, 19]. While this research does not offer potential solutions to the growing issue of prosthesis failure, this study does highlight the importance of care in prosthetic device selection and placement, particularly in Chinese facilities that may be less experience and thus present greater risk to patients as these techniques become more widely available. Thus, greater attention to proper prosthetic device selection and stress distribution should be taken to prevent early device failure in the years following surgery.

The current results, however, may be limited by the relatively small sample size and specialized nature of the treatment centre. In less experienced facilities in China and worldwide, it is likely that poor prostheses fit and longer surgery times may contribute to higher infection rates at these centres; however, this will require further investigation through multi-centre cooperation. Also, it is notable that, compared with other studies [3, 10, 11, 20], the current operative procedures were generally performed more rapidly, in part due to preoperative planning and the high experience level of the surgeons. While the overall oncologic prognosis in the current study was comparable to that achieved with limb salvage [20], prosthesis-related complications and local recurrence remained primary concerns, indicating that further research will be required to develop and assess potential solutions for these issues and their relationship with variant pre- and post-operative chemotherapy regimens.

Combined pre- and post-operative chemotherapy with resection and metal prosthetic reconstructive surgery can provide optimal functional outcomes in knee malignant tumour patients requiring reconstruction of the distal femur or proximal tibia; however, success and complications rates vary by location and tumour type. Currently, however, the long-term success of prosthesis and patient survival remains relatively low, with relatively high risks of potentially life-threatening infection or pulmonary recurrence. Thus, further research in materials, surgical procedures, prosthesis engineering and stress-testing, and patient eligibility criteria will be required before metal prosthesis reconstruction of the knee can be considered as a mature and widely applicable alternative to amputation.

Disclosure of conflict of interest

None.

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