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Original Article

Functional Results after Reconstruction with Modular Tumor Endoprostheses in Patients with Malignant Bone Tumors

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Abstract

Introduction: The functional outcome in patients after limb salvage surgery, and in particular reconstructions with modular tumor endoprostheses, has been the subject of many international series, but only a few publications mention the functionality in a Bulgarian patient group.

Aim: The aim of the present study was to analyze the functional outcome in a Bulgarian group of patients with malignant bone tumors that underwent resection and reconstruction with modular tumor endoprostheses.

Materials and methods: Our series consists of 14 patients with malignant bone tumors who underwent limb salvage surgery and reconstruction with modular tumor endoprostheses between February 2012 and January 2021. Staging was done using the AJCC staging system for bone sarcoma. The MSTS score system was used to evaluate the functional results.

Results: The mean follow-up time was 38.5 months (range, 8 to 96). The mean MSTS score for our series was 70%. Distant metastases were found in 4 (28%) patients. Local recurrence occurred in 3 (21%) patients. The most severe late complication was a mechanical failure of the expanding mechanism in 1 patient.

Conclusions: Reconstruction with modular tumor endoprostheses offer superb functionality and improved life quality in patients with primary malignant bone tumors.

Keywords

endoprostheses, limb salvage, reconstructive surgical procedures, sarcoma

INTRODUCTION

Primary malignant bone tumors (PMBT) account for 0.2% of all malignancies in adults and 3-6% in pediatric patients.[1-6] Osteosarcoma and Ewing's sarcoma are the most common entities in children and teenagers, while chondrosarcoma is the most common bone tumor in adult patients.[6] The treatment of PMBT is challenging and requires a multidisciplinary approach. Surgery is the method of choice for local control of the disease and is usually done after neoadjuvant chemo- and radiotherapy. The main goal of the surgeon is to achieve a wide resection of the tumor, which is done by ablative procedures or limb sparing surgery.

In the present day, more than 85% of patients with PMBT can undergo some form of limb salvage surgery.[7] Bone defects after resection are large and range from 15

to 20 cm.[7] In pediatric patients, the resection specimen usually contains a growth plate, which leads to limb length discrepancy at skeletal maturity. Modular tumor endoprostheses have become one of the most used methods of reconstruction in limb salvage surgery because of the excellent intraoperative flexibility and the ability for early rehabilitation and weight bearing. The problem with the developing limb length discrepancy after limb sparing surgeries in pediatric patients can be solved with the implementation of expandable tumor endoprostheses, which offer a non-invasive regular elongation of the affected limb. In Bulgaria, very little research has been conducted on the functional outcomes of patients who have undergone this type of reconstruction.

AIM

The aim of our study was to analyze the functional outcome in a Bulgarian group of patients with PMBT who underwent limb salvage surgery and reconstruction with modular tumor endoprostheses.

MATERIALS AND METHODS

This study was conducted at Prof. Boycho Boychev University Orthopedic Hospital, in the Department of Orthopedics and Traumatology of the Medical University of Sofia. Our series consists of 14 patients with PMBT who underwent limb salvage surgery and reconstruction with modular tumor endoprostheses in the mentioned institution between February 2012 and January 2021. The diagnosis was Ewing's sarcoma in 7 patients, osteosarcoma in 4 patients, malignant giant cell tumor of the bone in 1 patient, mesenchymal chondrosarcoma in 1 patient, and malignant chondroblastoma in 1 patient. Our series consists of 10 males and 4 females, with a mean age of 20.5 years (range 13 to 71 years). Localizations of the primary tumor include the humerus, tibia, and femur, the most common being the distal femur.[1] MRT, CT, and/or PET/CT were conducted in all cases for the diagnosis, staging, preoperative planning, and follow up.

For staging, we used the AJCC staging system for bone sarcoma, which is based on 4 key aspects of the tumor: T – size of the tumor, N – lymph node involvement, M – distant metastases, and G – histological grade of the tumor.[8] There are 4 different stages with additional substages. All 14 patients underwent neoadjuvant chemotherapy after which they were restaged and evaluated for surgical treatment. The patients diagnosed with Ewing's sarcoma were treated with the EURO EWING 2012 protocol.[9] As for the patients with osteosarcoma, depending on the stage of the tumor, a combination of methotrexate, cisplatin, doxorubicin, and ifosfamide were used.[6] For the reconstruction, we used modular tumor endoprostheses type MUTARS and MUTARS Xpand (WITTENSTEIN intens GmbH, Igersheim, Germany). A total of 8 distal femur reconstructions were conducted, making it the most common localization. One of our patients received a total humeral mega-endoprosthesis, after resection **(Fig. 1)**. In 2 of our cases, the reconstruction was done with a femoral mega-endoprosthesis after a total femur resection **(Fig. 2C)**. Expandable tumor endoprostheses were implemented in 5 of our patients. Adjuvant chemotherapy was done in all patients after surgery.

For functional assessment of the patients after surgery we used the MSTS score system for upper and lower extremity.[10] MSTS score is composed of 6 criteria, the first three being pain, emotional acceptance, and functionality. Walking ability, the need for walking aid, and gait are the 3 additional criteria for lower extremity. For the upper

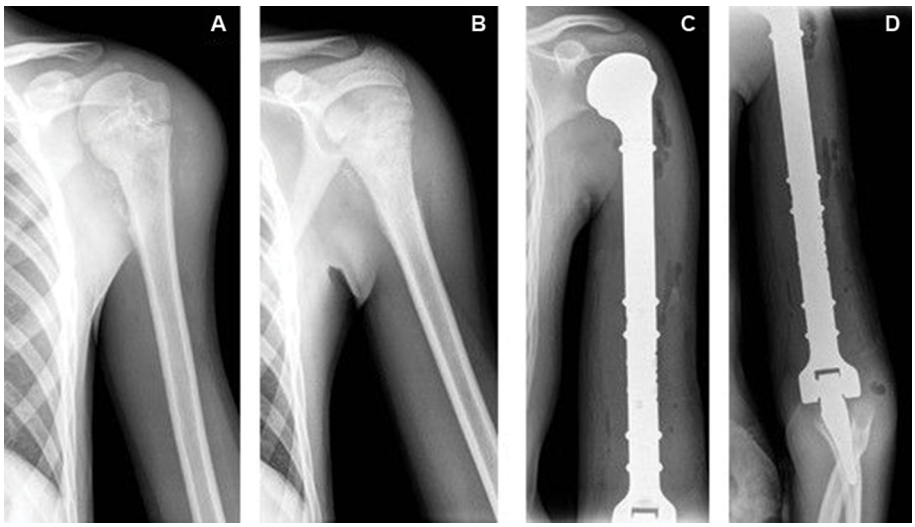

Figure 1. A 13-year-old male patient with osteosarcoma in the proximal humerus stage IIB (**A**,**B**). Reconstruction was done with a total humerus modular mega-endoprosthesis (**C**,**D**). MSTS score – 63%.

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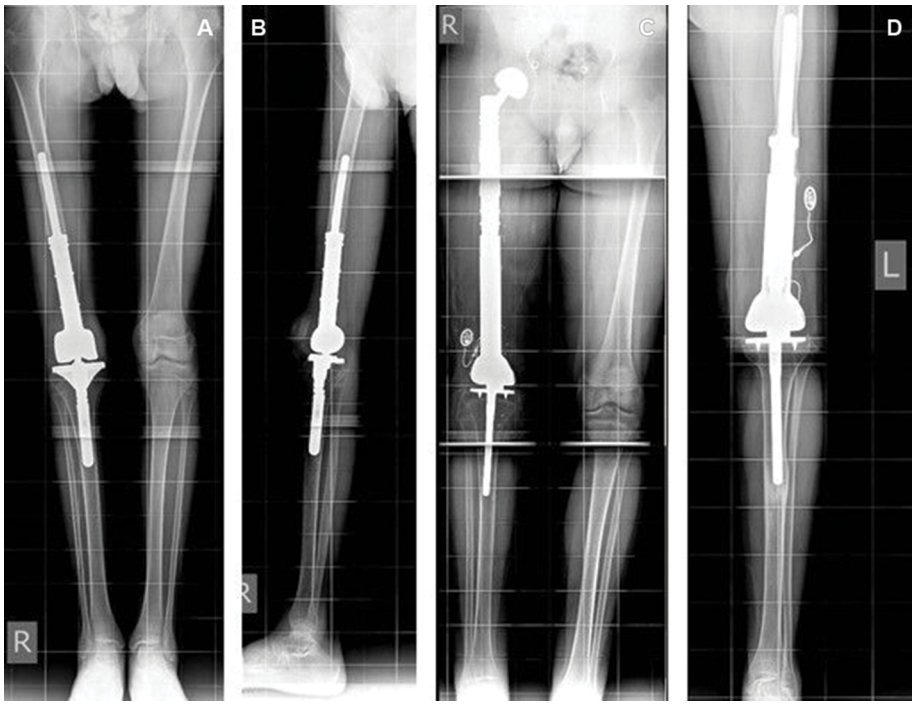

Figure 2. A, **B**. A 14-year-old male after reconstruction with a conventional modular tumor endoprosthesis. MSTS score – 60%. **C**. A 13-year-old male patient with mesenchymal chondrosarcoma of the proximal femur stage III, reconstruction with a total femur expandable endoprosthesis, MSTS score – 73%. **D**. A 14-year-old female patient with malignant chondroblastoma of the distal femur stage IIA. Reconstruction was done with an expandable tumor endoprosthesis. MSTS score – 73%.

extremity hand positioning, manual dexterity, and lifting capability are assessed. Each of these criteria is rated on a scale of 0 to 5 with a maximum score of 30 points. The higher score indicates a better functional outcome. A follow-up was done every 6 months for 2 years, after which yearly for at least 5 years.

RESULTS

The mean follow-up time was 38.5 months (range 8 to 96). A total of 17 operative procedures were conducted, 3 of which were secondary revisional surgeries.

Oncologic results

Eleven (78%) of our 14 patients were evaluated as stage II on the AJCC staging system, 6 of them being stage IIA and 5 – stage IIB. Two of the patients (15%) were stage IV, one of them stage IVA, and one stage IVB. Only one patient was evaluated as being stage III. Distant metastases were found in 4 (28%) patients, as the most common localization were the lungs. Local recurrence occurred in a total of 3 (21%) patients and one of those cases required a secondary ablative surgery for its management. Two patients died from complications associated with the disease during the follow-up period.

Functional results

The mean MSTS score for our series was 70%. Patients with distal femur reconstruction had an MSTS score between 63 and 83%. Two of the patients with a proximal humerus endoprosthesis had an MSTS score of 63 and 76%, respectively. Our only patient with a proximal femur reconstruction had an MSTS score of 53%. All five of the patients with an expandable endoprosthesis had very good functionality with a mean MSTS score of 73%.

Complications

The most common early complication in our series was surgical wound necrosis and dehiscence, which was reported in three of the patients. Peripheral nerve palsy was encountered in one patient and was successfully treated with conservative methods. The most severe late complication was a mechanical failure of the expanding mechanism in 1 patient, and although not life threatening, it caused the development of a limb length discrepancy. This complication occurred two consecutive times in a single year and required two revisional surgeries for its management. The other late complication that we encountered was an aseptic loosening of the femoral stem of the modular endoprosthesis in 1 patient, which was diagnosed 1 year after reconstruction. A revisional surgery was done and the femoral stem was replaced with a longer one.

DISCUSSION

The main advantage of modular tumor endoprostheses comes from their modular design, which allows the surgical team to adjust the length of bone resection intraoperatively and gives them the freedom to achieve a wide resection of the tumor especially in cases in which tumor infiltration is more severe than that seen on the preoperative imaging studies. Unlike biological reconstruction methods, modular tumor endoprostheses offer lower risk of deep infections and completely avoid any risk of non-union, disease transmission, and immune response. Patients with this type of reconstruction can start rehabilitation and weight bearing as early as the next day after the procedure. Expandable tumor endoprostheses are also modular and were designed to prevent limb length discrepancy in pediatric patients who underwent limb salvage surgery for malignant bone tumors. The expandable endoprosthesis that we used in our series is MUTARS® Xpand, the lengthening of which is based on a "growing" intramedullary nail or "FITBONE®".[11] The lengthening itself is non-invasive, daily and could be done by the parents after proper training. A downside of these expanding endoprostheses is the need for a conversion to a conventional modular endoprosthesis after skeletal maturity.

Early complications after reconstruction with a modular tumor endoprosthesis include wound necrosis, peripheral nerve damage, infection, and thromboembolic incidents.[7,11-14] The late complications associated with this method are severe and usually require surgical management. Aseptic loosening is the most common late complication with an incidence of 5-27%. It is the most common reason for failure of the reconstruction.[1,11,14-19] The aseptic loosening of endoprosthesis usually occurs in reconstructions of the distal femur and proximal tibia. Unwin et al. reported that 32.8% of all revision surgeries done in their series were due to aseptic loosening.[19] Fracture of the endoprosthesis is another late complication with an incidence ranging from 1% to 22%, which depends on the site of reconstruction and the length of the stem.[7,17,18,20] Joint instability and dislocation of the modular endoprosthesis usually occur in reconstruction of the hip and shoulder joint. The incidence of dislocation after shoulder joint reconstruction is 56%, and between 10% and 15% after hip reconstruction.[7,15,21,22] The infection rate after reconstruction with a modular tumor endoprosthesis is 1%–13%.[17,18,20,23,24] This is a serious complication that could potentially lead to amputation after limb sparing surgery. Gosheger at al. reports a 13% infection rate from their series of 250 patients treated with resection and endoprosthetic reconstruction for malignant bone tumors.[20] Mechanical failure of the expanding mechanism is a specific complication for the expandable modular endoprosthesis, which requires a revision surgery for its management. Gilg et al. reported a failure in the lengthening mechanism in 5 prostheses (9.8%).[25]

Endoprosthesis survival rates and overall reconstruction longevity vary by anatomic site. Pala et al. reported an overall prosthesis survival rate of 70% at 4 years and 58% at 10 years.[26] Grimer et al. reported a 18% endoprosthesis survival rate after a mean follow-up of 29.4 years.[27] In the Horowitz et al. series of 93 reconstructions, prosthesis survival at 5 years was 88% for the proximal femur. Distal femur and proximal tibia reconstructions had 59% and 54%, respectively. Overall endoprosthesis survival for the same series was 63% at 5 years and 36% at 10 years.[28]

The functional results after reconstruction with modular tumor endoprostheses are generally positive. According to most literature sources, the mean MSTS score value is between 60 and 90.[12,15,16,20,24,25,27-30] Gosheger at al. report a MSTS score of 70% in their series of 250 patients.[20] Rougraff et al. also report an MSTS score of 77% after reconstruction of the distal femur.[17] Upper extremity functional results are also positive as Wang et al. report a mean MSTS score of 66.7% after reconstruction of the proximal humerus.[22] Tang et al. achieved even better results with the usage of a synthetic mesh for soft tissue reinsertion, as that patient group had an MSTS score of 79% in comparison to 66% for the patient group with no synthetic mesh.[21] Balke et al. report excellent functional results and an MSTS score of 80% and 83% after reconstruction of the distal femur and proximal tibia, respectively.[31] An expandable modular endoprosthesis also offers good functional results as the mean MSTS score for reconstructions around the knee is between 75-90%, between 50-75% in patients with a hip endoprosthesis, and 50% in those with a shoulder expandable endoprosthesis.[7,16,18,25] Torner et al. report a mean MSTS score of 86% in their series of 7 pediatric patients with expandable endoprostheses.[30] Gilg et al. also reported a MSTS score of 86% in their patient group.[25]

Atalay et al. compare the functional levels of patients with a conventional total hip endoprosthesis and those with a tumor hip endoprosthesis.[32] Interestingly, patients with conventional total hip endoprostheses have no significant difference in functionality from the patients with a tumor endoprosthesis.

The mean MSTS score and overall functional results in our patient group were very good and comparable to those of other authors **(Table 1)**.

As for the complications until now, we have encountered only 2 severe ones that required surgical management. The misuse of the impulse transmitter for the expanding endoprosthesis was probably the reason for the mechanical failure of the expanding mechanism, which required replacement in one of our patients. The aseptic loosening of the femoral component that we encountered was caused by a shorter femoral stem that was used in the initial reconstruction. To lower the risk of these complications, a proper diameter and length of the femoral stem should always be used.

The limitations of the study are the short follow-up period and the small patient group, which did not allow for a more in-depth analysis of the late complications, the secondary surgeries needed for their management and for the conversion from an expandable to a conventional modular endoprosthesis at skeletal maturity in some patients. All

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Table 1. Comparison between our functional results and those of other large series with these types of reconstruction

	Number of patients	Mean follow-up	Mean MSTS score
Ivanov et al.(present study)	14	38.5 months	70%
Gosheger et al.[20]	250	45 months	70%
Rougraf et al.[17]	73	144 months	77%
Gilg et al.[25]	50	64 months	86%
Pala et al.[26]	223	24 months	81%
Torner et al.[30]	7	65.3 months	86%

the mentioned conditions cause a significant impact on the end functional results. The strict follow-up of the patients will continue, as some of them will soon need conversion surgery.

CONCLUSION

Reconstruction with modular tumor endoprostheses offers superb functionality and improved life quality in patients with primary malignant bone tumors.

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Competing interests

The authors have declared that no competing interests exist.

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Функциональные результаты после реконструкции модульными опухолевыми эндопротезами у больных со злокачественными опухолями костей

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Резюме

Введение: Функциональные результаты у пациентов после операций по спасению конечностей и, в частности, реконструкции модульными опухолевыми эндопротезами, были предметом многих международных серий, но лишь в нескольких публикациях упоминается функциональность в болгарской группе пациентов.

Цель: Целью настоящего исследования был анализ функционального исхода в болгарской группе пациентов со злокачественными опухолями костей, которым была проведена резекция и реконструкция модульными опухолевыми эндопротезами.

Материалы и методы: Наша серия включает 14 пациентов со злокачественными опухолями костей, которым в период с февраля 2012 г. по январь 2021 г. была проведена операция по спасению конечностей и реконструкция модульными опухолевыми эндопротезами. Стадирование было проведено с использованием системы стадирования AJCC для саркомы кости. Для оценки функциональных результатов использовали шкалу оценки MSTS.

Результаты: Среднее время наблюдения составило 38.5 месяцев (от 8 до 96). Средний показатель по шкале MSTS для нашей серии составил 70%. Отдалённые метастазы выявлены у 4 (28%) пациентов. Местный рецидив возник у 3 (21%) больных. Наиболее тяжёлым поздним осложнением явилась механическая поломка расширительного механизма у одного больного.

Заключение: Реконструкция модульными опухолевыми эндопротезами обеспечивает превосходную функциональность и улучшение качества жизни у пациентов с первичными злокачественными опухолями костей.

Ключевые слова

эндопротезы, спасение конечностей, реконструктивные хирургические вмешательства, саркома