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Prosthetic joint replacement for long bone metastases: analysis of 154 cases

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Abstract
Introduction Metastatic bone disease is the most common cause of malignancies to the skeleton in adults. The treatment of bone metastases is frequently palliative aiming to achieve a satisfactory control of pain and to prevent or to treat pathological fractures. In selected cases the resection of a single bone metastasis may improve the survival of the patients. Our experience with bone metastases located in the appendicular skeleton, between 1992 and 2004, is retrospectively reviewed here.
Materials and methods We report a series of 154 patients (95 females and 59 males) treated with prosthesis for metastatic bone disease. Lower limb localization was more frequent with 117 cases, while upper limb was affected in 37 cases. Metastatic breast and renal carcinoma predominated and accounted for 66% of the lesions. Indications to surgery were reported, oncologic outcome was evaluated and functional results were obtained by the Musculoskeletal Tumor Society scoring system.
Results Follow up ranged from 6 months to 12 years (median 26 months). One-year survival was 69.5%, 2-years survival was 44.8%, 5-years survival was 19.5%; and 5 (3.2%) died in the early post surgical period. Functional results were good or higher in 73.8% of patients for the proximal femur, in 50% of patients for the knee and 30.6% of patients for the proximal humerus.
Conclusion In this series, satisfactory results were achieved with few complications. We emphasized the importance of giving the patient a definitive treatment and preventing pathological fractures as they determine disability and a spreading of the tumor in the soft tissues, leading to an increased probability of local recurrence. Prosthetic replacement contributes to an improved quality of life and limb functionality and, in selected cases; this radical surgical approach is indicated as it may improve patient's life expectancy.

Keywords Bone metastases · Appendicular skeleton · Prostheses · Allograft-prosthesis reconstruction · Pathological fracture

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Introduction

Bone metastases are the most common malignant bone tumors and they exceed in number the primary malignancies of the skeleton [10]. Patients with metastatic bone disease have usually a poor survival and the occurrence of skeletal-related events tend to worsen the prognosis of these patients [33]. Patients with lung carcinoma or melanoma that has metastasized to the skeleton generally have less than a 6-month median survival, and patients with thyroid or prostate carcinoma have a 45-month median survival [11].

There are different therapeutic approaches for metastatic bone disease. Chemotherapy and radiation therapy are appropriate treatment options in case of sensitive tumors

[32]. Bisphosphonates have been shown to be useful in decreasing skeletal complications from breast and prostate carcinoma and multiple myeloma [27]. Surgery is indicated for intractable pain and for impending or established pathological fractures [29]. Intralesional tumor removal and cemented internal fixation has been the treatment of choice for most impending and actual pathological fractures: it is an unexpensive procedure that allows immediate weight bearing and function, with easier patient management. The introduction of modular joint prostheses in the late 1980s gave orthopaedic surgeon a new mean to treat bone metastases, after the previous experience with custom megaprostheses used for primary tumors. Indications for prosthetic joint replacement in patients with bone metastases are isolated lesions, extensive bone loss and failed conventional reconstruction with plates or rods [8, 14, 19, 31, 35]. The purpose of this approach is to prevent pathological fractures, allow immediate full weight bearing, control the pain in order to improve their quality of life [21, 22]. Wide resection and prosthetic replacement may also improve the survival of these patients, in case of isolated metastatic lesions [19]. In any case, the reconstruction with joint prostheses may improve the quality of life of these patients, restoring limb function, relieving pain and easing nursing care. Moreover, short-term improvement in pain and function status seems particularly important for patients with limited life expectancy [32]. Patients candidated for this procedure are those in classes 1, 2 and 3 according to Capanna's criteria [7–9] with metastases occurring in the epiphyseal/metaphyseal regions of long bones.

This study analyzes our experience with prosthetic joint replacement in the treatment of long bone metastases in the years from 1992 to 2004, reviewing the indications to surgery, the functional and the oncologic outcome.

Materials and methods

A retrospective analysis of patients treated by the same equipe with prostheses or allograft-prosthesis composite for epiphyseal/metaphyseal metastases located in the long bones from year 1992 to 2004 was done in our Department. During this period 284 patients referred to our Department for the surgical treatment of a bone metastasis: 154 patients (54.2%) with a metastasis located in the epiphysis/metaphysis of a long bone underwent resection and prosthetic reconstruction and were included in this study; 90 patients (31.7%) with a metastasis in these sites received intralesional curettage and cemented fixation; 40 patients (14%) with a metastasis located in the diaphysis of a long bone received fixation with intramedullary rod with curettage and filling with cement. Indication criteria were reported and both functional and oncologic outcomes were evaluated.

As far as the indications to surgery are concerned, they were retrospectively compared with the management protocol proposed by Capanna, summarized in Table 1 [7–9]. This protocol provides rational guidelines for indications for surgery, the type of operation to be undertaken and the methods of reconstruction available [3, 7–9]. The aim is to offer adequate individual treatment to the patient, avoiding undertreatment or overtreatment, to achieve control of pain and to manage impending and pathological fractures so that the longer survival is associated with a better quality of life [3, 7–9]. Based on these criteria, all patients in the classes 1, 2 and 3 underwent surgical treatment when it was possible and had adjuvant treatment, if indicated. Patients in class 4 were initially referred to conservative treatment. According to these criteria, 20 patients (13%) were in class 1, 89 patients (57.8%) were in class 2, 35 patients were in class 3 (22.7%) and 10 patients (6.5%) were in class 4. To evaluate the risk of pathological fractures we used the scoring system proposed by Mirels (Table 2) which is based on site (upper vs. lower limb or peritrochanteric), pain level (mild, moderate, severe), nature of the lesion (blastic, mixed, lytic), and size (<1/3, 1/3–2/3, >2/3 diameter of bone) [25]. The surgical treatment was considered mandatory for pathological fractures with a score of nine points (maximum, 12), while a score of eight points required further clinical judgment, as it was described by other authors [23].

When functional outcome could be evaluated, it was assessed by the Musculoskeletal Tumor Society scoring system for the evaluation of major skeletal resections and reconstructions [15].

Table 1 Summary of the management protocol proposed by Capanna

Class	Description
1	Solitary metastatic lesion Primary with good prognosis Interval over 3 years since detection of the primary
2	Pathologic fracture at any site
3	Impending fracture in a major long bone
4	Osteoblastic lesions at all sites Osteolytic or mixed lesions in non-structural bones (fibula, rib, sternum, clavicle) Osteolytic lesion with no impending fracture

Table 2 Assessment of the risk of pathologic fracture according to Mirels

Variable	One point	Two points	Three points
Site	Upper limb	Lower limb	Peritrochanter
Pain	Mild	Moderate	Weigh bearing
Lesion	Blastic	Mixed	Lytic
Size related to bone diameter	<1/3	1/3–2/3	>2/3

Oncologic outcome was evaluated by considering local recurrence, pathological fractures, need of revision surgery, and need of adjuvant therapies.

One hundred and fifty-four prostheses were implanted in our Department by the same equipe in patients with metastatic bone disease. We treated 95 females and 59 males ranging in age, at the time of surgery, from 32 to 83 years and having a median age of 59 years. The predominant primary tumor in our casuistry was breast carcinoma, occurring in 75 patients, followed by renal cell carcinoma in 27 patients, lung carcinoma in 25, prostatic carcinoma in 12 patients, 7 lesions of unknown primary tumor, plasmocytoma in 6 patients and melanoma in 2 patients. Lower limbs localization was more frequent with 117 lesions (76%), involving the proximal femur in 112 cases and the proximal tibia in 5 cases, while upper extremity was involved in 37 patients (24%), affecting the humerus in 36 patients and both humerus and scapula in one patient. Metastases were detected 6 months to 13 years after the diagnosis of the primary tumor in 139 patients (90.3%) while in 15 (9.7%) the metastasis was the first sign of the malignancy. In 123 patients (79.9%) prosthetic replacement was the primary treatment of the lesion while in 31 patients (20.1%) we performed revision surgery to replace failed conventional intralesional synthesis of pathological fractures (Fig. 1). Thirty-five patients (22.7%) were treated for an impending fracture; 58 patients (37.7%) were treated for pathological fractures (Fig. 2); 10 patients (6.5%) were treated for intractable pain; 20 patients (13%) were treated for solitary lesions. Forty-two patients (27.3%) were admitted to surgery after local radiation therapy had been previously performed. Following surgery, 45 patients (29.2%) were treated with local radiation therapy, 55 patients (35.7%) were treated with chemotherapy and 16 patients (10.4%) were treated with immunotherapy.

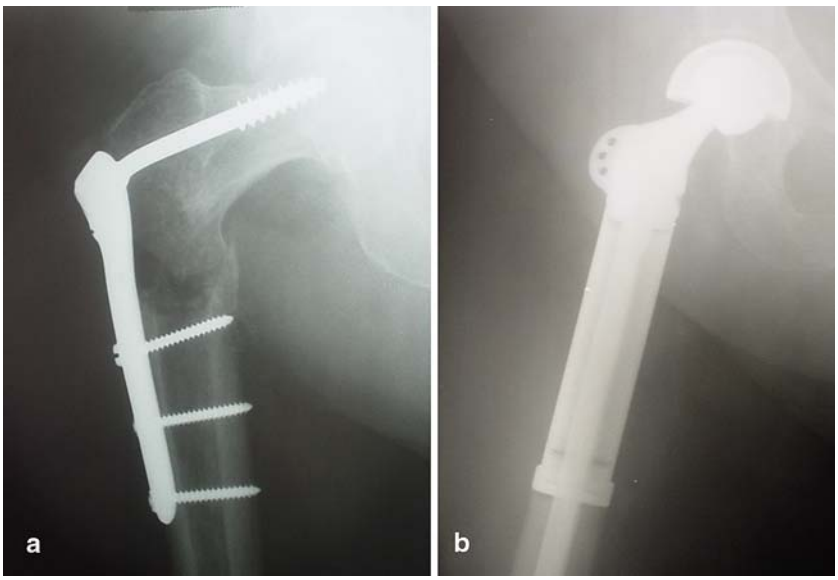

Fig. 1 **a** This patient, a female aged 59-year-old affected by an unknown primary tumor, was treated in another Institute with a plate for a pathological fracture. She came to our attention 6 months later with a painful nonunion and a supposed life expectancy <6 months. **b** We excised the proximal femur en bloc with the fixation device and implanted a cemented modular prosthesis. The patient was immediately allowed to a full weight bearing with a complete pain relief and died 18 months later for metastatic dissemination

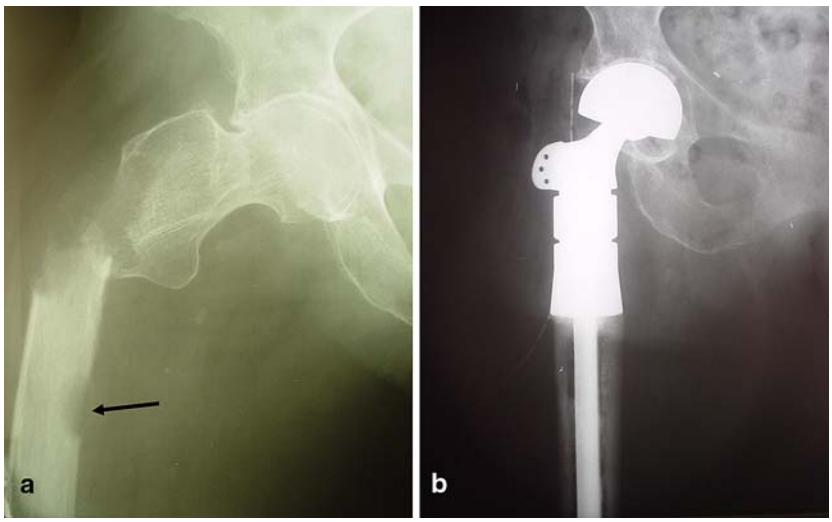

Fig. 2 **a** This patient, a female aged 72-year-old affected by breast carcinoma, came to our attention with a pathologic fracture of the proximal metaphysis of the femur. **b** There was also a skip metastasis distally (*arrow*). We implanted a cemented modular prosthesis. The patient died 15 months later for metastatic dissemination

The proximal femur was involved in 112 cases: 30 patients had a lesion located in the epiphysis and 82 in the metaphysis. Epiphyseal metastases were treated with 5 Thompson endoprostheses, 5 total hip arthroplasties and 20 bipolar endoprostheses (CL Trauma, Lima-Lto., San Daniele del Friuli, Italy; SPII, Waldemar Link GmbH & Co. KG, Germany). These prostheses had preferably a long stem and they were all cemented. Metaphyseal metastases were treated with 77 cemented modular endoprostheses (PGR and RPS, Lima-Lto.; MP Reconstruction Hip Stem, Waldemar Link), with a resection up to 16 cm, and with five allograft-prosthesis composites. Biological reconstruction is an exceptional procedure for metastatic disease [3]. Only younger patients with a good prognosis, scoring zero on ECOG performance status, with solitary bone lesions occurring years after resection of the primary tumour and no evidence of systemic involvement on recent restaging were, therefore, candidates for this treatment [26]. In cases of allograft-prosthesis composites, the prosthesis was cemented both into the allograft and into the host bone, and to avoid rotation of the bone allograft a plate was placed between the diaphysis and the allograft.

In the knee, when the lesion involves less than half of the epiphyseal or metaphyseal area, the treatment is open curettage, synthesis with a plate and filling the defect with cement; when the lesion involves more than half of the epiphyseal or metaphyseal area, the treatment is resection and reconstruction with a cemented modular prosthesis [7–9]. Of the five lesions located in the knee, four patients were treated with a modular prosthesis (Endo Modell, Waldemar Link) and one patient, having a single lesion from renal cell carcinoma, was treated with an allograft-prosthesis composite after selective arterial embolization (Fig. 3).

In all 37 patients with a metastasis located in the proximal humerus we implanted a modular prosthesis, as it permits a wide resection of the metaphyseal region. The patient with scapular involvement underwent modified Tikhoff–Linberg procedure: “en bloc” resection of the glenohumeral joint after an extra-capsular osteotomy of the neck of the scapula, followed by implantation of an I.O.R. modular prosthesis (I.O.R. Officine Ortopediche, Bologna, Italy) [6]. In 33 patients we used an endoprosthesis (RPS, Lima-Lto.) and in the last three patients treated we used a reverse modular prosthesis (SMR, Lima-Lto.) (Fig. 4). In the reverse prosthesis the humerus is converted to a socket and the glenoid to a ball providing a stable fulcrum for glenohumeral articulation. This is achieved through maximization of the length–tension relationship of the deltoid and of the remaining cuff musculature [4, 17].

Results

Regarding the indications to surgery, they matched the Capanna’s criteria in 115 cases (74.7%).

As far as the functional outcome is concerned, it could be evaluated in 142 patients out of 154 (92.2%): in 102 patients with a metastases located in the proximal femur out of

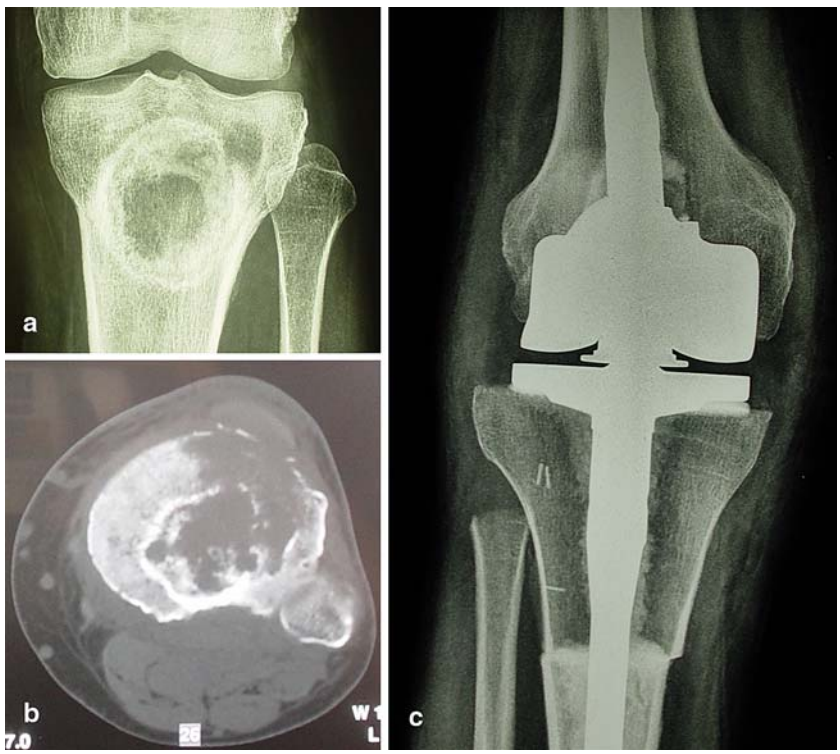

Fig. 3 **a** This patient, a male aged 57-year-old affected by renal cell carcinoma, presented to our attention with a single metastatic lesion occurred 2 years after the diagnosis of the primary tumor and located in the proximal tibia. **b** The lesion determined a wide destruction of the tibial metaphysic as demonstrated by the CT scan. **c** We performed a wide excision of the lesion and an allograft-prosthesis-composite reconstruction. During the latest follow-up control, performed 2 years after surgery, the patient was free from disease

Fig. 4 **a** This patient, a man aged 68-year-old affected by prostatic carcinoma, developed a metastasis located in the proximal humerus. **b** We performed resection of the proximal humerus "en bloc" with the rotator cuff but sparing the deltoid insertion and a reverse modular prosthesis was implanted. No local recurrence was presented. The patient is still alive with a follow up of 2 years

112 (85%), in 4 patients with a metastasis located around the knee out of 5 (80%) and in 36 patients with a metastasis located in the shoulder girdle out of 37 (97.3%). The overall functional outcome was excellent in 20 patients (14%), good in 78 patients (55%) and fair in 44 patients (31%). The Enneking score for the proximal femur was excellent in 20 patients (19.6%), good in 65 patients (54.2%) and fair in 17 patients (26.2%), demonstrating an improvement respect to our previous experience [5]. The Enneking score for the knee was good in two patients (50%) and fair in two patients (50%). The functional outcome for the shoulder was not evaluated in the case with an I.O.R. modular prosthesis, as it was used only with aesthetic reconstructive purpose. The Enneking score for the shoulder was good in 11 patients (30.6%) and fair in 25 patients (69.4%). Regarding patients with biological reconstruction, they had better or equal function compared to those with prosthetic reconstruction. In fact, four patients with biological reconstruction in the proximal femur had an excellent Enneking score and one had a good Enneking score while the patient with biological reconstruction in the proximal tibia had a good Enneking score.

As far as the oncologic outcome is concerned, analysis of the overall survival indicated that 69.5% of patients survived 1 year after surgery, 44.8% 2 years and 19.5% 5 years. Median survival was 26 months. Regarding patients with biological reconstruction, they had a longer survival (median 50 months) than those with prosthetic reconstruction. Five patients (3.2%) died in the early post surgical period. Nineteen patients (12.3%) presented a local recurrence between 6 and 12 months after surgery: the primary tumor was breast carcinoma in nine cases, renal cell carcinoma in eight cases and lung carcinoma in two cases. Interestingly, each of them experienced previously a pathological fracture. They were then treated with local radiation therapy.

We noticed a few complications. Three patients with a lesion located in the proximal femur, treated with a conventional short stem endoprosthesis, experienced a fracture at the inferior extremity of the stem, due to skip metastases. With the exception of these three cases, the prostheses always outlasted patients' life expectancy. Five patients operated in the proximal femur experienced a deep vein thrombosis in the early post-operative period. They were all treated successfully with medical therapy. Four patients experienced an early superficial wound infection, treated successfully with adequate antibiotic therapy. No deep infections were reported. Regarding patients with biological reconstruction, three of them experienced a fracture of the greater trochanter. None of the patients operated on the proximal femur experienced a dislocation of the prosthesis, while subluxation of the humeral head occurred in three cases, when sparing the rotator cuff was not possible and a RPS prosthesis was implanted. Pain relief was achieved in all patients after surgery.

Discussion

Conventional surgical treatment of metastatic bone lesions is internal fixation with plates or rods, with or without bone cement [34]. Prosthetic joint replacement is indicated in cases of isolated osteolytic metastases or when conventional treatment has failed [8, 14, 19, 31, 35]. Prosthetic replacement is a more invasive, more expensive procedure associated with more complications, longer hospital stay, and greater blood loss [1]. The aim of surgical treatment of

bone metastases is to prevent or stabilize pathological fractures, relieve pain and permit an acceptable quality of life with immediate full weight bearing [14].

In our opinion, the most important issue in treating bone metastasis located in the appendicular skeleton is the risk of pathological fracture. Pathological fractures of major long bones are common and have dramatic physical and psychological consequences for the patient [36]. Pathological fracture always requires an extended time to heal, and as many as 50% of cases will never heal at all [20]. Moreover, as already stated, it is easier to prevent a pathological fracture than it is to heal a fracture, especially one that requires radiation [2]. We found that all patients having a local recurrence experienced previously a pathological fracture, probably because they have determined a spreading of the tumor in the soft tissues. Consequently, avoiding a pathological fracture is one of the main goals of the surgical treatment of bone metastases, independently from life expectancy. Obviously, life expectancy should be longer than recovery from surgery [12, 28, 32]. Moreover, surgery in these patients should be definitive [35]; in fact, in our series the prostheses outlasted patients' life expectancy in 98% of patients. This is also a useful technique when radiochemotherapy cannot be performed.

Regarding the proximal femur, this is the most frequently involved site of metastases and it is a common site of pathological fractures because of the high weight bearing and rotational forces acting in this region [23]. When a metastasis is located in the epiphyseal region, it is important to evaluate the presence of skip metastases in the diaphysis, which can determine a pathological fracture at the inferior extremity of the stem when using a normal stem cemented endoprostheses. We had three cases of such complication; consequently, we now always implant long stem cemented endoprostheses. When a metastasis is located in the metaphyseal region, a wide resection is often mandatory: we performed resections up to 16 cm and the reconstruction was usually done with modular prostheses. These oncological megaprostheses replace the trochanteric region and the femoral head and neck. A major problem with these devices is that also the attachment for the gluteal muscles is resected, thus decreasing the abductor strength and, consequently, the function of the implant. In order to avoid this decrease in function, it is possible to perform an allograft-prosthesis reconstruction [13, 16, 30]. However, surgery of bone metastases should provide immediate stability with minimal complications while allograft-prosthetic composites presents many complications [13]. Modular prostheses reconstruction, on the other hand, permits immediate weight bearing with a few complications and an easier surgical technique. We believe that allograft-prosthesis composites should not be used routinely in metastatic patients, while the most suitable treatment of metastatic bone disease of the proximal femur should be the resection of the lesion and implant of modular prosthesis.

Regarding the knee, patients with highly destructive proximal tibial epiphyseal/metaphyseal lesions can be treated with a modular prosthesis [24], which is indicated when bone loss and invasion by the tumor is half of epiphyseal or metaphyseal area. In this region torsional forces are lower than in the proximal femur and loading forces are compressive. For the treatment of five cases of proximal tibia localization, we implanted four modular prostheses and performed one allograft-prosthesis reconstruction in a patient with a single metastasis from renal cell carcinoma preoperatively treated with selective arterial embolization. Pre-operative embolization and implant of modular prostheses permit to perform radical surgery even in those patients with soft tissues involvement.

Regarding the proximal humerus, biomechanical features of this site are slightly different from those of the lower limb, because of the absence of weight bearing. However, there are important rotational and bending forces, acting on a metaphysis which is largely cancellous with low cortical rigidity. The risk of fracture is therefore inferior than in the lower extremities, where a destruction of 50% has been considered a criterion for impending fracture. In the humerus, when cortical bone destruction reaches the 75%, the risk of spontaneous fracture is great [17]. Modular endoprostheses permit to maintain a normal activity in daily living, but shoulder motion if often limited. Results are dependent from rotator cuff preservation, patient's endurance and strength, and his participation to rehabilitation [18]. Better results can be achieved with reverse modular prosthesis.

In this series, satisfactory functional and oncologic results were achieved with few complications. Moreover, we want to emphasize the importance of preventing pathological fractures. In agreement with previous reports [5, 14, 19, 31, 35], we believe that prosthesis are a suitable mean for the treatment of bone metastases located in the appendicular skeleton and, when indicated following Capanna's criteria [3, 7–9], the excision of the lesion and the implant of a prosthesis has to be considered as the treatment of choice.

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