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Research Paper

Outcomes and prognostic factors after surgery for bone metastases in the extremities and pelvis: A retrospective analysis of 140 patients

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ABSTRACT

Background: Surgical therapy of bone metastases is becoming increasingly important due to prolonged life expectancy and improved oncological treatment options. In a mostly palliative approach, it is necessary to identify those patients who might benefit from surgery. The shorter the remaining lifetime, the more restricted the indication and the less radical the intervention should be. The aim of this study was to evaluate the postoperative outcomes and prognostic factors for survival of patients with surgically treated bone metastases.

Methods: We retrospectively included 140 patients who underwent surgery for 151 bone metastases in the extremities and pelvis at our hospital between 2010 and 2020. We examined patient demographics, surgical procedures, 30-day complications, local tumour progression, and reoperations. Survival was calculated using Kaplan-Meier analysis. Prognostic factors were investigated by univariate analysis using the log-rank test and multivariate analysis using the Cox regression hazard model.

Results: In 138 patients, the median survival time was 12.3 months. The overall survival rates at one, two, three and five years were 52.3%, 37.6%, 28.0%, and 18.0%, respectively. In univariate analysis, lung cancer, renal cell carcinoma, pathological fracture, visceral metastasis and multiple bone metastases were significantly associated with prognosis. No significant influence was determined for gender, age, location of bone metastasis, type of surgical procedure and time between diagnosis of primary tumour and surgery for bone metastasis. Multivariate analysis confirmed that pathological fracture, visceral metastasis and lung cancer were negative prognostic variables in terms of survival. Within 30 days, the incidence of complications was 25.0% and mortality was 9.3%. The most common complications were urinary tract infections (5.0%), pneumonia (4.3%), and delirium (2.9%). Local tumour progression occurred in 12 patients (8.7%) and five reoperations (3.6%) were performed. There were no significant differences between patients treated with endoprosthetic replacement (n = 47) and those treated with internal fixation (n = 91) in terms of 30-day complications and mortality as well as local tumour progression.

Conclusions: Survival of patients after surgery for bone metastases in the extremities or pelvis is very limited. The presence of a pathological fracture, visceral metastasis and lung cancer were independent prognostic factors for poor survival. Both internal fixation and endoprosthetic replacement achieved similar outcomes.

1. Introduction

Bone metastases are the most common malignant bone tumours [1,2]. Their exact incidence is unknown as they are often neither clinically nor radiologically conspicuous [3]. Although the frequency of bone metastases is often underestimated, their occurrence has been reported in up to 85% of cases depending on the primary tumour [4]. It can be assumed that the statistical probability of an individual patient developing bone metastases has been increasing over the last decades: On the one hand, the number of cancer cases is steadily growing, mainly due to rising life expectancy and higher prevalence of risk factors [5,6]. On the other hand, medical progress and specialised therapy of primary tumours allow for a prolonged survival of those affected, so that metastases form more frequently in advanced stages of the disease [7–10].

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Although cure is rarely possible, patients with bone metastases can survive for several years [11–16]. During this time, patients' quality of life can be significantly affected by skeletal complications. The main indications for surgery on the extremities are impending or complete fractures and pain management [17,18]. The most commonly used surgical procedures are internal fixation (IF) and endoprosthetic replacement (EPR).Fig. 1..

In the evaluation of surgical treatment options, chances of increased life expectancy, fracture prevention and symptom relief must be weighed against the risks of surgery. However, technically simple and short interventions with low risk should be preferred to minimise the complication rate [19]. In order to identify patients who might benefit from surgery and to choose the best surgical procedure in each case, the expected survival time is one of the most important decision parameters [17]. Although individual postoperative outcomes are known in many cases, systematic assessments of how long patients have benefited from the intervention are often missing, as follow-up treatment and examinations are frequently carried out by oncologists.

The aims of this study were to determine the postoperative outcomes of patients with bone metastases in the appendicular skeleton and pelvis and to evaluate prognostic factors for overall survival. We hypothesised that (a) EPR is associated with more short-term complications after surgery but leads to longer survival and less tumour progression and reoperations than IF, and that (b) primary tumour entities, metastatic load and location are prognostic factors for overall survival.

2. Methods

This study was approved by the local ethics committee of the regional medical association (2021–300060-WF).

Patients with surgical treatment of bone metastases between August 2010 and August 2020 at the department for trauma and orthopaedic surgery of a university medical centre were included. In total, this study includes data from 140 patients with 151 surgically treated bone metastases in the extremities and pelvis. All metastases were confirmed by biopsy. We retrospectively collected and anonymously analysed the following data from the patients' electronic medical records: gender, age, primary tumour entity, location of bone metastasis, presence of single or multiple metastases in other bones, presence of visceral metastasis, indication for surgery, surgical procedure, and postoperative complications. Visceral metastasis was defined as the presence of metastasis in the lung, brain, liver or other abdominal organs. As previously suggested by Bindels et al. [20] in regards to patients undergoing surgery for long bone metastasis, we considered all complications within 30 days after surgery that corresponded to grade II-V of the Clavien-Dindo classification and divided them into minor (grade II) and major (grade III-V) complications [21]. Grade II complications included adverse events requiring pharmacological intervention. Grade III complications were defined as complications leading to surgical, endoscopic, or radiological intervention. Grade IV denoted a life-threatening complication requiring intensive care unit management and grade V indicated the death of a patient. Grade I complications were defined as adverse events that did not require therapy (except for electrolyte adjustments, analgetic, antipyretic, antiemetic or diuretic drugs, physiotherapy or wound infections opened at bedside). Grade I complications were not included due to their low clinical relevance to this study and the difficulty of retrospective ascertainment [20]. Regarding long-term patient outcomes, we collected data on local tumour progression or recurrence and reoperations at the surgical site over the entire follow-up period. For this purpose, we defined a follow-up period of at least six months for all surviving patients. For patients who underwent multiple surgeries, we considered the first surgery for determining survival and 30-day complications. The median follow-up period was 12.3 months (interquartile range [IQR] 2.7–43.9) for all patients and 27.2 months (IQR 12.3–53.0) for surviving patients. Two patients (1.4%) were lost to follow-up after 30 days. Therefore, they were included in the analysis of 30-day complications but excluded from the analysis of overall survival, local tumour progression and reoperations.

Statistical analyses were performed using IBM® SSPS® Statistics for Windows, V.27 (IBM, Armonk, NY, USA). Complication rates were compared between patients undergoing EPR or IF using the chi-square test. The Kaplan-Meier method was used to calculate survival probabilities of the entire cohort. Preoperative data were dichotomised and the groups were compared using the log-rank test. The variables that showed a significant effect on survival in univariate analysis were included in multivariate analysis. A Cox regression model was deployed to identify independent prognostic factors and to evaluate their influence on overall survival. A result was considered statistically significant at a p-value of < 0.05.

3. Results

The median age at the time of surgery was 67.6 years (IQR 58.0–76.3). 67 patients were male (67.8 years [IQR 60.2–75.3], 47.9%) and 73 were female (66.5 years [IQR 56.8–76.7], 52.1%). The most common primary tumour was breast cancer, followed by lung cancer and multiple myeloma (Table 1). The median time from diagnosis of the primary tumour to surgery for bone metastasis was 9.0 months (IQR 0–43.0). Multiple bone metastases were detected in 110 patients (78.6%). 67 patients (47.9%) had at least one visceral metastasis.

Two different locations of metastases were treated in nine patients, seven of which were addressed during the same operation. One patient underwent surgery twice due to three different lesions. Most metastases were located in the proximal femur, followed by the humerus, pelvis, and tibia (Table 2). A pathological fracture was the first clinical symptom of malignant disease and led to the initial diagnosis in 19 patients (13.6%). Surgery for solitary metastasis without impending or pathological fracture was performed in 5 cases (3.3%); all these patients suffered from renal cell carcinoma and a curative treatment approach was followed. Table 3.

All EPR procedures were performed with the use of bone cement. Within the femur group, a total of 34 endoprostheses were implanted. These can be divided into 18 tumour prostheses, ten hemiprostheses, and six total hip replacements. Within the humerus group, three tumour prostheses were used after resection of proximal metastases, the diaphysis and distal humerus were replaced once each. In six cases, a total hip replacement in combination with a support ring (Burch-Schneider ring) was utilised due to pelvic lesions with metastatic infiltration of the acetabulum. Two tumour prostheses were implanted, one of them after internal hemipelvectomy. Within the tibia group, two proximal metastases were treated with a tumour prosthesis.

All complications occurred in patients treated with IF or EPR (Table 4). Within the first 30 days after surgery, the proportion of patients with minor complications (Clavien-Dindo grade II) was lower in the IF group than in the EPR group (p = 0.032), whereas the opposite was found for the proportion of those with major complications (Clavien-Dindo grade III-IV) or death (p = 0.520; p = 0.380). In the long-term course, one periprosthetic and two *peri*-implant fractures, two deep infections and one non-union were recorded in one patient each. Local tumour progression was observed in twelve patients (8.7%) with a progression-free survival rate of 89.7% after one year. Eight of these were in the IF group

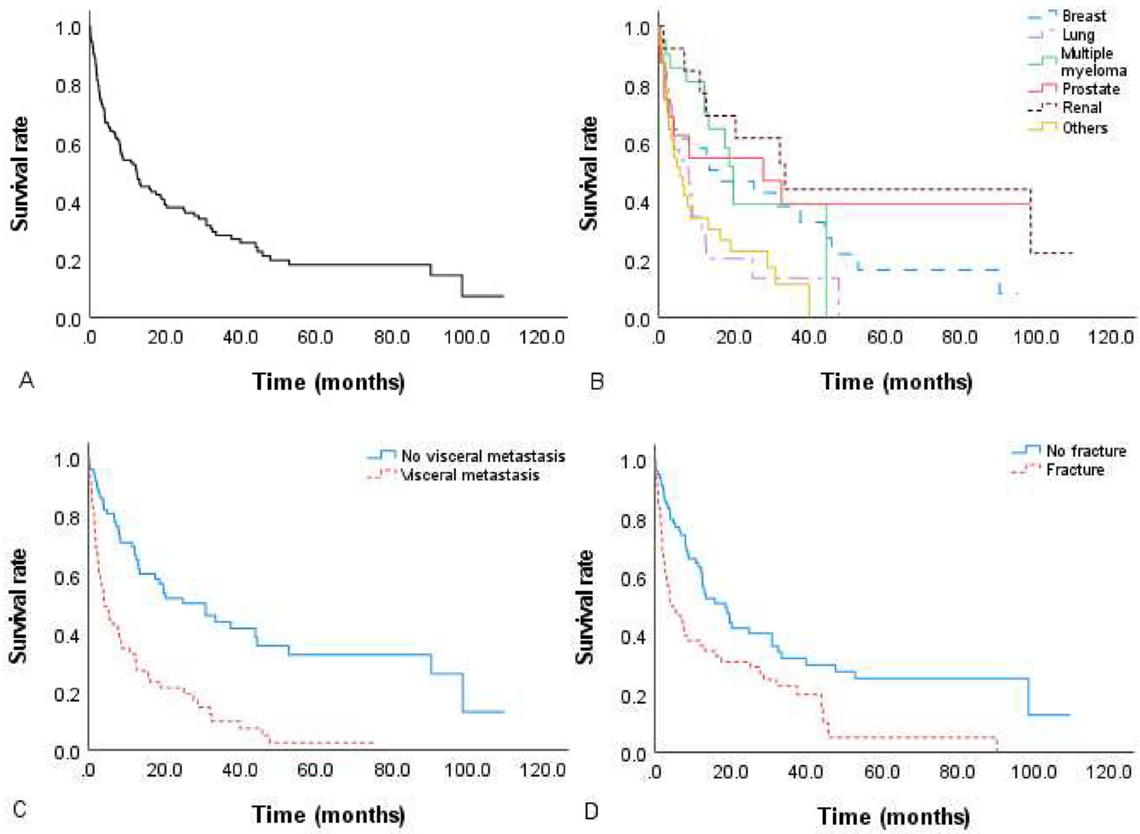

Fig. 1. Survival rates after surgery for bone metastases. (A) Overall survival of 138 patients using the Kaplan–Meier method, (B) survival depending on primary tumour entity, (C) survival depending on presence of visceral metastases (p < 0.001) and (D) fractures (p = 0.001).

Table 1
Primary tumour entities (n = 140): distribution, metastatic load and median time from diagnosis of primary tumour to surgery for bone metastasis.

Primary tumour	Total	Multiple metastases	Visceral metastasis	Median time to surgery in months (IQR)
Breast	32 (22.9%)	26 (81.3%)	16 (50.0%)	49.0 (9.0–148.0)
Lung	26 (18.6%)	23 (88.5%)	15 (57.7%)	0.5 (0–6.3)
Multiple myeloma	21 (15.0%)	20 (95.2%)	0	24.0 (0–76.5)
Prostate	16 (11.4%)	14 (87.5%)	9 (56.3%)	9.5 (0–50.5)
Renal cell	14 (10.0%)	5 (35.7%)	5 (35.7%)	6.0 (0–48.8)
Digestive system[1]	12 (8.6%)	6 (50.0%)	11 (91.7%)	10.0 (0–32.8)
Urinary bladder	4 (2.9%)	4 (100%)	2 (50.0%)	1.0 (0–19.3)
Uterus	3 (2,1%)	2 (66.7%)	1 (33.3%)	n.a.
CUP	3 (2.1%)	2 (66.7%)	2 (66.7%)	n.a.
Others[2]	9 (6.4%)	8 (88.9%)	6 (66.7%)	30.0 (7.0–72.0)

n.a., not available: number of cases was too low for median calculation.
[1] , colon (n = 5; 3.8%), pancreas (n = 2; 1.4%), rectum (n = 1; 0.7%), bile duct (n = 1; 0.7%), liver (n = 1; 0.7%), oesophagus (n = 1; 0.7%), salivary gland (n = 1; 0.7%).
[2] , thyroid (n = 2; 1.4%), lymphoma (n = 2; 1.4%), sarcoma (n = 2; 1.4%), melanoma (n = 1; 0.7%), paraganglioma (n = 1; 0.7%), adrenal gland (n = 1; 0.7%).

(8.9%) and four in the EPR group (8.7%) (p = 0.970). Five patients

(3.6%) required reoperation, with a median time to surgery of

Table 2
Bone metastases (n = 151): location and indication for surgery.

Location	Total	Proximal/diaphyseal/distal	Pathological fracture	Impending fracture	Solitary metastasis
Femur	100 (66.2%)	47/44/9	33 (33.0%)	67 (67.0%)	0
Humerus	26 (17.2%)	7/15/4	21 (80.8%)	5 (19.2%)	0
Pelvis	13 (8.6%)		7 (53.8%)	4 (30.8%)	2 (15.4%)
Tibia	10 (6.6%)	4/6/0	4 (40.0%)	5 (50.0%)	1 (10.0%)
Radius	1 (0.7%)	0/0/1	0	0	1 (100%)
Clavicle	1 (0.7%)		0	0	1 (100%)

Multiple metastatic locations in patients undergoing stabilisation during the same procedure were femur (one patient with bilateral pathological fractures and six patients with bilateral impending fractures) and tibia (one patient with bilateral impending fractures).
Multiple metastatic locations in patients undergoing stabilisation in two procedures were humerus and femur (one patient with pathological fractures), radius and femur (one patient with solitary metastasis and impending fracture) as well as bilateral femur and humerus (one patient with bilateral impending fractures and pathological fracture).

Table 3
Surgical procedures (n = 151) according to location of bone metastasis.

Location	Endoprosthetic replacement	Intramedullary nailing	Compound osteosynthesis	Plate osteosynthesis	Screw osteosynthesis	Resection only
Femur	34 (34.0%) 18[1]	61 (61.0%)	3 (3.0%)	2 (2.0%)	0	0
Humerus	5 (19.2%) 5[1]	15 (57.7%)	4 (15.4%)	2 (7.7%)	0	0
Pelvis	8 (61.5%) 2[1]	0	1 (7.7%)	2 (15.4%)	1 (7.7%)	1 (7.7%)
Tibia	2 (20.0%) 2[1]	5 (50.0%)	3 (30.0%)	0	0	0
Radius	0	0	0	1 (100%)	0	0
Clavicle	0	0	0	0	0	1 (100%)
Total	49 (32.5%)	81 (53.6%)	11 (7.3%)	7 (4.6%)	1 (0.7%)	2 (1.3%)

[1] , number of tumour prostheses.

Table 4
Complications within 30 days after surgery (n = 140) according to internal fixation and endoprosthetic replacement.

Complication	Total (n = 140)	Internal fixation (n = 91)	Endoprosthetic replacement (n = 47)
Systemic complications	**35 (25.0%)**	**22 (24.2%)**	**13 (27.6%)**
Pneumonia	6 (4.3%)	5 (5.5%)	1 (2.1%)
Sepsis	3 (2.1%)	3 (3.3%)	0
Cardiovascular failure	3 (2.1%)	2 (2.2%)	1 (2.1%)
Delirium	4 (2.9%)	1 (1.1%)	3 (6.4%)
Urinary tract infection	7 (5.0%)	4 (4.4%)	3 (6.4%)
Multiple organ failure	2 (1.4%)	2 (2.2%)	0
Pancreatitis	1 (0.7%)	0	1 (2.1%)
Respiratory decompensation	3 (2.1%)	2 (2.2%)	1 (2.1%)
Pulmonary embolism	1 (0.7%)	0	1 (2.1%)
Air embolism	1 (0.7%)	0	1 (2.1%)
Fever of unclear source	1 (0.7%)	1 (1.1%)	0
Death due to unclear infection	1 (0.7%)	1 (1.1%)	0
Acute renal failure	2 (1.4%)	1 (1.1%)	1 (2.1%)
Local complications	**5 (3.6%)**	**3 (3.3%)**	**2 (4.3%)**
Delayed wound healing	3 (2.1%)	3 (2.1%)	0
Dislocation of the femoral head	2 (1.4%)	0	2 (4.3%)
Death	**13 (9.3%)**	**10 (11%)**	**3 (6.4%)**
At least one complication	**35 (25%)**	**24 (26.4%)**	**11 (23.4%)**
Minor complication	20 (14.3%)	13 (14.3%)	7 (14.9%)
Major complication	15 (10.7%)	11 (12.1%)	4 (8.5%)

13.1 months (Table 5**).** Reoperation rates were significantly higher in the EPR group (p = 0.026).

A total of 38 patients (27.5%) were alive at the last follow-up evaluation. The median survival time (MST) for 138 patients was 12.3 months (IQR 2.7–43.9). One, two, three, and five years after surgery, 52.3%, 37.6%, 28.0%, and 18.0% of patients were alive, respectively. Table 6 shows the influence of different parameters on overall survival in the univariate analysis. As they significantly influenced overall survival in the univariate analysis, multiple bone metastases, visceral metastasis, pathological fracture, lung cancer, and renal cell carcinoma were included in the multivariate analysis. Thus, visceral metastasis, pathological fracture, and lung cancer were identified as independent prognostic factors for poor survival ($p < 0.001$, $p = 0.001$, $p = 0.021$) (Table 7). Patients with all three prognostic factors had a severely reduced overall survival (MST 3.1 months) compared to patients with none of them (MST 33.4 months).

4. Discussion

In the present study, we investigated the outcomes of patients after surgery for appendicular or pelvic bone metastases. We identified prognostic factors and found similar short- and long-term outcomes comparing IF and EPR.

4.1. Short-term outcome

The incidence of 30-day postoperative complications (25%) was similar to a study by Bindels et al. [20], which evaluated short-term outcomes. In both studies, the Clavien-Dindo classification was used to assess complications [21]. A direct comparison with further studies is difficult as there is no uniform definition of postoperative complications, resulting in a variety of inclusion criteria and reported complication rates ranging from 5.8% to 25% in a systematic review [22]. Minor events such as urinary tract infections or delirium are often neglected, so our complication rate seems comparatively high. We also found few studies that focused on short-term outcome [20,23–25]. Although there was no intraoperative death, a substantial number of our patients (9.4%) died within the first 30 days. The mortality rate and the incidence of major complications were higher in the IF group compared to the EPR group, but without reaching statistical significance. On the one hand, IF is less invasive than EPR. On the other hand, a patient's poor health status that leads to a preference for IF over EPR could well be an influencing factor for a higher complication rate with the less invasive surgical procedure. Tsuda et al. [23] reported significantly higher rates of mortality and respiratory complications after IF. However, in the study by Bindels et al. [20], the surgical procedure was not an independent risk factor for 30-day postoperative complications.

4.2. Long-term outcome

Local tumour progression occurred in 8.7% of our patients. Reported rates after surgery for long bone metastasis ranged from 0% [26] to 48% [27]; in a review by Errani et al. [28], the overall incidence was 11.5%. We found no significant advantages for patients treated with EPR over those treated with IF in either recurrence rate or progression-free survival. This is remarkable because only the first group underwent wide tumour resection. Sarahrudi et al. [29], who focused on the treatment of pathological femur fractures, also reported similar progression rates for EPR and IF. Hara et al. [30] found the lowest progression rate in the EPR group compared to IF without curettage or resection and to IF with bone cement filling after curettage, while progression-free survival rates were similar. Although local tumour progression carries the risk of implant failure, only one of our patients (0.7%) required reoperation due to implant failure. Surgical treatment of bone metastases

Table 5
Reoperations (n = 5): patient characteristics, surgical procedure, reason for reoperation and subsequent follow-up.

Patient/ age, gender	Metastatic presentation	Surgical procedure	Complication	Time to reoperation	Surgical treatment	Follow-up after reoperation
1/67.8, F	Breast, humerus, impending fracture, solitary	Intramedullary nailing	Peri-implant fracture	23.8 months	Plating	28.9 months, dead
2/29.5, M	Osteosarcoma, femur, fracture, multiple, visceral	Prosthesis	Dislocation	2 days	Change of dual-head	16.2 months, dead
3/69.4, M	Renal cell, femur, fracture, multiple	Tumour prosthesis	Local progression	13.1 months	Change of prosthesis	25.9 months,alive
4/63.4, M	Renal cell, femur, impending fracture, solitary	Tumour prosthesis	Prosthetic fracture	12.9 months	Change of prosthesis	56.6 months,alive
5/72.5, F	Breast, tibia, fracture, multiple	Tumour prosthesis	Deep infection	35.5 months	Arthroscopic washout	1.9 months, dead

Table 6
Univariate analysis of clinical prognostic factors.

Variable	Number	Median survival time (months)	P-value
Gender			
Male/female	72/66	13.2/12.2	0.165
Age (years)			
< 65/≥ 65	56/82	12.4/12.2	0.818
Time from diagnosis to surgery (months)			
< 3/≥ 3	56/82	12.2/12.5	0.497
< 36/≥ 36	98/40	12.2/12.7	0.883
Location of metastasis			
Pelvis and lower/upper extremity	111/27	12.7/8.6	0.570
Metastatic load			
Multiple/solitary	108/30	10.8/30.8	**0.033**
Visceral/bone only	65/73	4.1/30.8	**< 0.001**
Pathological fracture			
Yes/no	60/78	4.1/18.6	**0.001**
Primary tumour			
Breast/r	31/107	15.8/12.1	0.783
Lung/r	26/112	7.8/15.8	**0.012**
Multiple myeloma/r	21/117	19.6/8.6	0.169
Prostate/r	16/122	27.6/12.3	0.192
Renal cell/ r	13/125	33.4/11.4	**0.025**
Surgical procedure			
Intramedullary nailing/r	71/67	8.0/20.3	0.115
Endoprosthetic replacement/r	46/92	20.3/10.8	0.629
Compound osteosynthesis/r	11/127	12.3/12.4	0.401
Intramedullary nailing/ endoprosthetic replacement	71/46	8.0/20.3	0.308
Internal fixation/endoprosthetic replacement	90/46	8.8/20.3	0.469

r, remaining cases.

Table 7
Multivariate analysis of clinical prognostic factors.

Variable	Hazard ratio	95%-CI[1]	P-value
Negative influence			
Multiple metastases	1.193	0.688 – 2.069	0.530
Visceral metastasis	2.596	1.714 – 3.931	**< 0.001**
Pathological fracture	2.077	1.356 – 3.180	**0.001**
Lung cancer	1.863	1.097 – 3.163	**0.021**
Positive influence			
Renal cell carcinoma	0.651	0.281 – 1.511	0.318

[1] , 95%-confidence interval for hazard ratio.

should be definitive and durable to avoid reoperations that could substantially worsen the patient's general condition [17,22,31]. Endoprostheses have been described to be associated with fewer reoperations than osteosynthetic approaches, with local complications after IF occurring more frequently over time [22,28,32–34]. Our results cannot confirm these observations and we even found a significantly higher rate of reoperations in the EPR group. It should be noted that some patients were not reoperated due to their poor general condition and only five reoperations (3.6%) were performed in total. The estimated 1-year survival rate after surgery for bone metastasis varies in the literature between 17% and 69.5% [22]. The survival rate in our study was within this range at 52.3% after one year.

4.3. Prognostic factors

By demonstrating that pathological fracture is independently associated with reduced survival, we agree with several studies [35–39] and emphasise the benefit of prophylactic stabilisation of a fracture-prone lesion. In 14% of our patients, the primary tumour was not previously known and only detected due to the fracture. Therefore, no further systemic therapy had taken place up to this point, which likely worsened the prognosis. However, some authors found no significant difference in overall survival between complete and impending fracture [40–42]. Regardless of its prognostic role, the presence of a pathological fracture in a long weight-bearing bone is an absolute indication for surgery [17]: On the one hand, fracture healing is impaired due to the underlying malignant disease and (neo-)adjuvant treatment [43]. On the other hand, the patient may suffer from pain as well as tremendous psychological and physical impairments. Prophylactic stabilisation is both easier to perform and reported to be less complicated [44]. If metastatic cancer is present, imaging of the extremities and pelvis should be considered, particularly of the proximal femur as it is the most commonly affected location [41,45,46]. However, identifying those lesions that would lead to a fracture without surgery can be difficult. Patients may die before this complication occurs or the recovery period after surgery may exceed the remaining lifetime. In these cases, good prediction of survival is even more important. The presence of visceral metastasis was also found to be an independent prognostic factor, in accordance with other studies [30,37–41,47–49]. The distribution of primary tumours in our collective underlines the established literature that breast cancer, lung cancer, multiple myeloma, prostate cancer and renal cell carcinoma are the most common malignancies requiring surgery for bone metastases [29,37,41]. The primary tumour not only determines the incidence of bone metastases, but also decisively affects the patient's prognosis. While breast cancer, renal cell carcinoma and multiple myeloma are considered to have a favourable prognosis [41,48], we were only able to confirm this for renal cell carcinoma in the univariate analysis. Among the primary tumours included, it had the highest proportion of patients with solitary bone metastasis without concomitant visceral metastasis (47.6%). This condition is described as improving prognosis [12,14,15] and solitary metastasis was the sole indication for surgery in 29% of our patients with renal cell carcinoma. The evidence for the influence of lung cancer seems to be more profound. In our study, it was independently associated with reduced survival which is also supported by other publications [37,41,48,49]. In addition to disease stage at diagnosis, response to systemic therapy is also considered important for a more accurate classification of the primary tumour [49,50]. For example, the prognosis score of Katagiri et al. [49] subdivides prostate and breast cancer according to their sensitivity to hormonal therapy and lung cancer according to its sensitivity to molecularly targeted drugs. Over the years, several models have been developed to predict survival in patients undergoing surgery for appendicular bone metastases [39,40]. Establishment of a reliable scoring system could support individual surgical decision-making and should therefore be attempted in future studies.

4.4. Limitations

This study has some limitations. First, retrospectively collected data may be associated with selection and performance bias. Treatment decisions were not based on predefined criteria but were evaluated individually for each patient. The initial choice of surgical procedure depended on the location and size of the lesion, the patient's general condition and expected survival time, and was always discussed in a multidisciplinary setting involving radiotherapists, oncologists, pathologists and radiologists. After this multidisciplinary discussion, the final treatment strategy was only determined after discussing the options and preferences with the patients to reach a common agreement on the best individual path of treatment. EPR was preferred to IF if long-term survival was assumed. All patients underwent surgery at the same musculoskeletal tumour centre. The surgeons acted according to current medical and internal standards and used the same surgical techniques. Most of the operations were performed by the senior author. Second, the patient population is very heterogeneous and some factors that may have influenced survival were not analysed in this study. These include comorbidities, performance status, (neo-)adjuvant treatment and diversity of implants used by the surgeons. As (neo-)adjuvant therapy is carried out depending on several factors such as primary tumour entity, disease status, medical developments and patient wishes, forming comparison groups with a sufficient number of patients is difficult. Furthermore, it was not possible to record exactly how many patients received postoperative chemotherapy, radiation and/or therapy with bone modifying agents, as these treatments were often performed on an ambulatory setting outside our institution. These additional treatments might have influenced patient outcome, but their impact could not be analysed in this study. We routinely recommended postoperative radiation therapy, yet application and absence of postoperative radiation therapy have shown similar surgical revision rates for lower extremity bone metastases [51]. If patients were not already under treatment with bone modifying agents prior to surgery, we routinely referred patients to specialised osteologists to evaluate the addition of bone modifying agents to their medication, as it is generally recommended [52]. Third, complication rates may be higher. Although all patients were treated at the same institution, they may have consulted a hospital or doctor closer to home after discharge. Fourth, it is questionable whether all complications are related to surgery.

5. Conclusions

Postoperative prognosis of most patients with bone metastasis in the extremities or pelvis was very limited. Pathological fracture, visceral metastasis and lung cancer were independent negative prognostic factors for overall survival. The surgical approach should be evaluated individually for each case as the comparison of IF and EPR showed trends but no significant differences in the rates of 30-day complications, local tumour progression and overall survival.

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Ethical approval

This study was approved by the local ethics committee of the regional medical association (2021–300060-WF).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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