Primary malignant bone and soft-tissue tumours of the spine and appendicular sacrum

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Cite this article: *Bone Jt Open* 2025;6(2): 109–118.

DOI: 10.1302/2633-1462.62.BJO-2024-0169.R1

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Aims

The aim of the present study was to analyze the oncological and neurological outcome of patients undergoing interdisciplinary treatment for primary malignant bone and soft-tissue tumours of the spine within the last seven decades, and changes over time.

Methods

We retrospectively analyzed our single-centre experience of prospectively collected data by querying our tumour registry (Medical University of Vienna). Therapeutic, pathological, and demographic variables were examined. Descriptive data are reported for the entire cohort. Kaplan-Meier analysis and multivariate Cox regression analysis were applied to evaluate survival rates and the influence of potential risk factors.

Results

A total of 119 consecutive patients (mean age 38 years (SD 37; 1 to 83), mean follow-up 66 months (SD 26; 0 to 505) were investigated. Histological entities included Ewing's sarcoma (EWS; 33), chondrosarcoma (CSA; 20), osteosarcoma (OSA; 22), and soft-tissue sarcoma (STS; 44). Surgery was performed in 88 patients (74%). Neurological parameters improved in 18 patients (20%) after surgery. Overall, 32 patients (36%) suffered from surgical complications requiring revision. The median survival was 42 months (IQR 10 to 204). The one-, five-, and ten-year survival rates were 73%, 47%, and 39%, respectively. Corresponding five-year survival rates for EWS, CSA, OSA, and STS were 63%, 61%, 40%, and 32%, respectively. The decade of diagnosis, histological entity, surgical intervention, resection margin, and the presence of metastases had significant influence on survival. (Neo-)adjuvant therapies alone had no significant influence on overall survival.

Conclusion

Our study clearly demonstrates the positive impact of improved surgical techniques, as well as refined imaging methods and evolved adjuvant therapy options, on survival rate in all tumour entities. However, despite a multimodal treatment plan, the long-term mortality of these tumours remains high.

Take home message

- A multidisciplinary team approach, as well as individualized treatment plans, seem to be indispensible in order to achieve the best possible outcome.
- The positive impact of improved surgical techniques, the availability of new chemotherapeutics, and conformal radiotherapy on survival could be clearly demonstrated.

Bone & Joint Open

Introduction

Malignant bone and soft-tissue tumours are rare and therefore listed in the rare cancer list with an incidence of <6/100 000/year and account for only 0.4% to 1% of all tumours.[1–3] While metastatic disease is common in the spine, the occurrence of primary malignant tumours in the spine is even scarcer.[4,5] They account for less than 5% of all malignant bone lesions[5] and therefore for 0.2% of all neoplasms.[4] In children and adolescents, malignant spine tumours amount to less than 30% of all spinal tumours. This changes in the elderly, in whom approximately 75% of all spine tumours are malignant due to a clear preponderance of metastatic disease.[1] The most common primary malignant lesions of the spine and paravertebral compartment are chordoma, solitary plasmocytoma, and multiple myeloma, which were not under investigation in the present study, as the focus lies on primary bone and soft-tissue sarcomas (STSs) as chondrosarcoma (CSA; 6.5 to 15% prevalence in the spine,[6,7] Ewing's sarcoma (EWS; 3.5% occurrence in the spine,[8] and osteosarcoma (OSA; 3 to 5% of all OSAs).[9] The outcome of these tumours is still modest due to significant treatment challenges, such as long asymptomatic intervals resulting in large tumour sizes, delicate adjacent anatomical structures, and limited conservative treatment options.[10] If the tumour does not affect neural structures there can be a long asymptomatic interval; therefore, spinal tumours are mostly large in size and can affect multiple osseous segments when being diagnosed. When, by contrast, the tumour affects neural structures and acute decompression is indicated due to neurological symptoms without adequate diagnostic evaluation beforehand, the tumour may be spread during surgery. A larger tumour also poses a dilemma for the surgeon: to ponder about the principles of spine surgery considering biomechanics versus the need to respect the principles of musculoskeletal oncological resections. Delicate structures such as nerves, vessels, and the costotransverse joint may be infiltrated and therefore limit the resection margins and aggravate surgery in advanced stages. Furthermore, conservative treatment by radiation therapy (RTX) can only be applied with limited intensity owing to the vulnerability of neural structures.

In summary, there is no existing classified treatment regimen, as these tumours are rare, difficult to treat, and often operated on intralesional in an acute setting and thereafter impeding adequate treatment.[11] Yet, we hypothesized that survival improved over time due to advancements in surgical and anaesthetic approaches, as well as refinements in chemo- (CX) and radiotherapeutic strategies.

Thus, the aim of the present study was to systematically investigate data prospectively collected in our Bone and Soft-tissue Tumour Registry (Medical University of Vienna), analyzing patients undergoing interdisciplinary treatment for primary bone and soft-tissue sarcomas of the spine within the last seven decades.

Methods

General

The study was performed as a retrospective cohort study using prospectively collected data from our Bone and Soft-tissue Tumour Registry. The corresponding institutional review board approved the study design and protocol. By July 2023, we identified 119 consecutive patients who underwent treatment at our department (Department of Orthopedics and Trauma Surgery, Division of Orthopedics, Medical University of Vienna) due to a primary malignant spine tumour from May 1952 onwards. Included were all patients who underwent treatment for a primary malignant bone or soft-tissue tumour invading the bony structures of the spine. Excluded were all patients with chordoma, malignant giant cell tumour (GCT), plasmocytoma, multiple myeloma/lymphoma, and spinal metastases at initial presentation to avoid further potential bias in an already heterogenous patient cohort. Chordoma does not respond to adjuvant therapy except for proton therapy,[12] which was quite recently established, malignant GCT can be treated with specific antibody therapy (denosumab) in contrast to the other tumours, and multiple myeloma/lymphomas require systematic therapy rather than wide tumour resection, thus differing significantly from the other entities mentioned. Patient assessment for adequate tumour staging and planning followed our standardized protocol, including current conventional radiographs of the affected spinal region in two plains, MRI and CT.[13] If necessary, angiography was also performed. In patients undergoing neoadjuvant therapy, radiological imaging was repeated directly before surgery in order to adequately assess the resection margins. CT scans of the abdomen and chest, and from 2010 onwards, positron emission tomography (PET) and scintigraphy were performed to detect secondary lesions. All cases were reviewed and discussed in our multidisciplinary tumour board, consisting of orthopaedic, oncological, radiotherapeutic, radiologial, pathological, and anaesthesiological specialists, on a weekly basis, also involving specialists from other departments (e.g. thoracic or plastic surgeons, but not exclusively), as required for individual cases. All histological specimens have been analyzed at the same corresponding pathological department over the whole study period. Histological specimens, as well as previous radiological data from patients undergoing biopsy or previous treatment at an outside institution, were re-evaluated at our pathological and radiological departments.

Patients

Table I gives a detailed overview of main patient demographic and pathological characteristics. The predominant number of patients presented in their second decade of life (29 patients; 24%). At the time of diagnosis, 62 patients (52%) were aged younger than 40 years. The mean age of patients with bone sarcoma was 30 years (SD 18.497) compared to patients with STS who presented at a mean age of 50 years (SD 17.32). In 23 patients (19%), a follow-up longer than ten years was observed. At first contact, 63 patients (53%) presented with pain, 49 (41%) with swelling as the main symptom, six (5%) with pathological fractures, and one (1%) with incidental finding. The mean duration of symptoms was seven months (SD 6; 0 to 39).

Surgery

All surgeries were performed either by the head of our department (RW) or by trained members of our tumour and spine team. The indication of the respective surgical procedure was based on the anatomical extension of the tumour, general health condition of the patient, and the presence of metastases. From 1990 onwards, the technique of en bloc

Table I. Main patient demographic and pathological characteristics.

Variable	EWS (n = 33 (28%))	CSA (n = 20 (17%))	OSA (n = 22 (18%))	STS (n = 44 (37%))	Total (n = 119)	p-value
Mean age, yrs (SD, range)	17 (18; 1 to 33)	46 (44; 16 to 77)	35 (30; 9 to 73)	50 (51; 7 to 83)	38 (37; 1 to 83)	
Sex, n (%)						0.456*
Female	10 (30)	9 (45)	11 (50)	17 (39)	47 (39)	
Male	23 (70)	11 (55)	11 (50)	27 (61)	72 (61)	
Decade of diagnosis, n (%)						< 0.001†
< 1980	4 (12)	3 (15)	1 (5)	4 (9%)	12 (10)	
1980 to 2000	12 (36)	7 (35)	8 (36)	15 (34)	42 (35)	
> 2000	17 (52)	10 (50)	13 (59)	25 (57)	65 (55)	
Mean follow-up, mnths (SD; range)	98 (38; 0 to 505)	76 (47; 2 to 296)	52 (25; 0 to 276)	44 (15; 0 to 304)	66 (26; 0 to 505)	
Location, n (%)						0.505†
Cervical	2 (6)	3 (15)	1 (5)	6 (14)	12 (10)	
Thoracic	9 (27)	5 (25)	7 (32)	15 (34)	36 (30)	
Lumbar	10 (30)	4 (20)	3 (14)	15 (34)	32 (27)	
Sacrum	12 (36)	8 (40)	11 (50)	8 (18)	39 (33)	
Grade, n (%)						0.103†
Low	N/A	3 (15)	N/A	3 (7)	6 (5)	
High	33 (100)	17 (85)	22 (100)	41 (93)	119 (95)	
Primary metastases	5 (15)	2 (10)	5 (23)	12 (38)	24 (20)	0.202†

*Chi-squared test.
†Fisher's exact test.
CSA, chondrosarcoma; EWS, Ewing's sarcoma; N/A, not applicable; OSA, osteosarcoma; STS, soft-tissue sarcoma.

total vertebrectomy was established at our department and further refined, as double-approach en bloc total vertebrectomies were performed in selected cases from 2010 onwards. According to Enneking's classification, resection margins were defined as intralesional, marginal, or wide.[14]

Functional assessment

Frankel score[15] was used to grade the severity of neurological loss pre- and postoperatively.

Follow-up

At our department, the standard follow-up protocol for sarcoma patients formerly consisted of clinical and radiological examination of the tumour site and chest radiographs every four months for three years, every six months for a further three years, and yearly thereafter.[13] With increasing availability, thoracic/abdominal CT scans in the mentioned intervals, and yearly bone scans were embedded into this algorithm, which now represents the standard of care at our institution. On reasonable suspicion of a recurrent tumour in radiographs, we also applied advanced local imaging. Local tumour control was presumed if the patient showed no signs of tumour within four months after surgery. Local recurrence was defined as recurrence of a tumour at least four months after surgery. Primary metastases were defined as metastases detected within the first three months of diagnosis.

Statistical analysis

Statistical analysis focused on the surgical, functional, and oncological treatment outcome of primary malignant tumours of the spine. Demographic variables (sex, age, and follow-up), pathological variables (site, grade, extension, resection margins, local recurrence, metastatic disease, and death of disease), and therapeutic variables (surgery, neoadjuvant and adjuvant therapy, and function) were examined. Descriptive data (mean, SD, median, IQR, and proportions) are reported for the entire patient cohort. Differences between categorical variables were tested with the chi-squared test or Fisher's exact test in case of less than five observations. An independent-samples *t*-test or Wilcoxon signed-rank test was used for continuous variables depending on the respective distribution. Kaplan-Meier analysis was used to evaluate survival rates and median survival times. Log rank test was used to compare survival curves. Cox regression was used to model survival times for the entire cohort, as well as for different subgroups. Additionally, a multivariate Cox regression analysis was performed. All statistical tests were used in their two-sided version. A p-value < 0.05 was considered statistically significant. Information was stratified by diagnosis, whether or not the patient had (neo-)adjuvant therapy (chemotherapy, radiotherapy), subsequent surgery, spinal stabilization, overall survival and complications. Data were analyzed using SPSS v. 29.0 (SPSS, USA) and R v. 4.3.1 (R Foundation for Statistical Computing, Austria).

Table II. Main therapeutic characteristics and oncological results.

Variable	EWS (n = 33 (28%))	CSA (n = 20 (17%))	OSA (n = 22 (18%))	STS (n = 44 (37%))	Total (n = 119)	p-value
Surgery, n (%)*	21 (64)	19 (95)	13 (59)	35 (80)	88 (74)	0.059†
En bloc (wide/marginal), n (%)§	10 (48)	9 (47)	5 (38)	9 (26)	33 (38)	
Piecemeal (intralesional), n (%)§	11 (52)	10 (53)	8 (62)	26 (74)	55 (63)	
Spondylodesis, n (%)§	10 (48)	7 (37)	9 (69)	23 (66)	49 (56)	
Complication n (%)§	8 (38)	10 (53)	3 (23)	11 (31)	32 (36)	
Adjuvant therapy, n (%)						
Chemotherapy*	31 (94)	6 (30)	20 (91)	22 (50)	79 (66)	0.519‡
Radiation*	30 (91)	7 (40)	14 (59)	35 (80)	86 (72)	0.999‡
Recurrence, n (%)						
Local	3 of 21 (14)	7 of 19 (37)	2 of 13 (15)	7 of 23 (30)	19 of 88 (22)	0.091†
Distant	11 (33)	3 (15)	4 (18)	9 (20)	27 (23)	0.521†
Death from disease, n (%)	11 (33)	11 (55)	12 (55)	28 (64)	62 (52)	
Overall five-year survival, % (range)	63 (47 to 85)	61 (42 to 89)	40 (23 to 71)	32 (19 to 52)	43 (38 to 58)	

*% of all 119 patients.
†Fisher's exact test.
‡Chi-squared test.
§% of all 88 operated patients.
CSA, chondrosarcoma; EWS, Ewing's sarcoma; OSA, osteosarcoma; STS, soft-tissue sarcoma.

Results

Tumours

The occurrence of histological entities is depicted in Table I. The STS group included not-other-specified (nos) sarcoma (nine patients), angiosarcoma (five), leiomyosarcoma and spindle cell sarcoma (four patients each), fibrosarcoma, rhabdomyosarcoma, and haemangioendothelioma (three patients each), liposarcoma, malignant fibrous histiocytoma (MFH), malignant peripheral nerve sheet tumour (MPNST), synovial sarcoma, and epitheloid sarcoma (two patients each), and myopericytoma, haemangiopericytoma, and dermatofibrosarcoma (one patient each).

Apart from the 24 patients (20%) who presented with primary metastases(16 patients (67%) generalized), another 30 patients (25%; 11 generalized (37%)) developed metastatic disease after a mean time of 28 months (SD 18; 2 to 116). According to the pathological grading for CSA[16] (Grade 1 to 3; grade 1 referring to low grade), G2 was found in the predominant number of patients (n = 7; 37%), followed by showed G1 in two cases (11%), G3 in one case (5%), as well as mesenchymal (two), myxoid (one), and other (six) sub-differentiation, respectively. OSA could be subdivided into G2 = one (5%), G3 = 14 (64%), and others (anablastic, osteoblastic, chondoblastic) in seven cases (32%).

Surgery

Table II refers to the main therapeutic characteristics. A total of 92 patients (77%) underwent biopsy of their lesions either at our institution (55 patients; 60%), an outside institution (37 patients; 40%), or both (12 patients; 13%). Most patients who underwent biopsy at our institution received an open procedure (34; 62%) followed by 14 CT-guided (25%), and seven ultrasound-guided (13%) ones. In 11 patients (20%), the result of the biopsy at our institution was inconclusive and needed to be redone (all of them open): four patients after a previously performed CT-guided biopsy (29% of all CT-directed ones), five patients after precedent open biopsy (15% of all open ones), and two patients (29%) after ultrasound-guided needle biopsy.

Overall, 31 patients (26%) were regarded as inoperable due to advanced stage of metastatic disease (16 patients; 52%), primary tumour extension (seven patients; 23%), previous intralesional operation (five patients; 16%), or reduced general health condition (two patients; 6%); in one young patient (3%) with an OSA of the sacrum, we refrained from surgery after CX and RTX and under continuous denosumab therapy. In most of the inoperable patients the tumour was localized in the sacrum (16 patients; 52%), the lumbar spine (seven patients each; 23% each), followed by the thoracic (six; 19%), and the cervical spine (two patients; 6%). The mean age of nonoperated patients was 20 years (SD 30; 7 to 70 years); for patients undergoing surgery, it was 40 years (SD 43; 2 to 83 years).

There were 32 complications (36% of all patients undergoing surgery) within the follow-up period which required consecutive intervention. The majority of patients (17; 53%) suffered from a singular complication: seven wound healing disturbances (22%), four neurological (13%), three inflammatory (9%), and mechanical, bleeding, and intraoperative injury of the urinary tract (3% each) in one patient each. In 15 patients (47%), a combination of complications could be observed, demanding more than one successive surgical intervention: eight mechanical complications followed by revision surgery and subsequent healing disturbances. Three

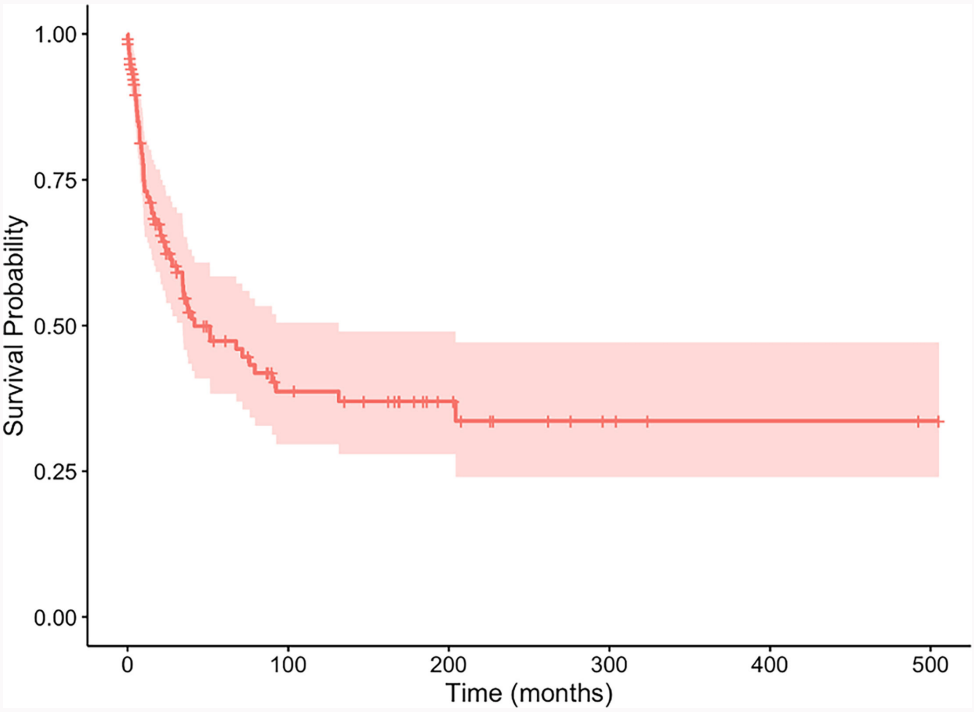

Fig. 1
Overall survival of the cohort. The Kaplan-Meier curve (dark red) illustrates the survival of the overall cohort, with the 95% CI represented by the light red shaded area.

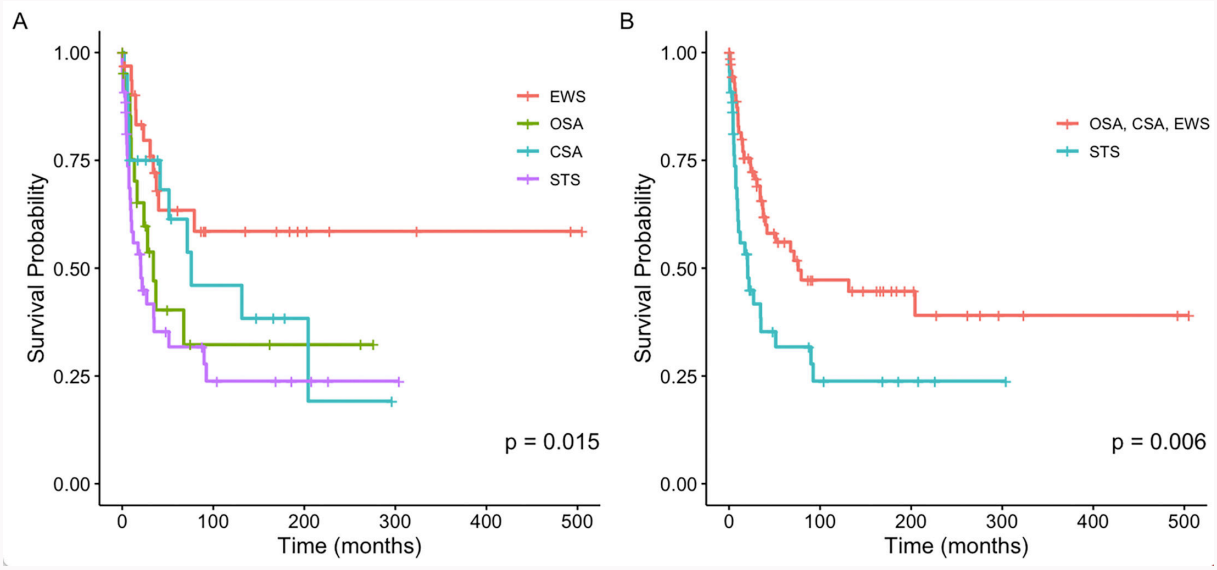

Fig. 2
Survival according to the four different histological entities of a) Ewing's sarcoma (EWS), osteosarcoma (OSA), chondrosarcoma (CSA), and soft-tissue sarcoma (STS), and b) bone versus STS.

patients suffered from postoperative abscess as a consequence of mechanical, neurological, or wound healing revision surgery, two patients suffered from repetitive mechanical complications, and one patient each experienced major bleeding followed by wound healing deficit and mechanical revision surgery after a previous neurological complication. In the subpopulation of patients undergoing a stabilization procedure additionally to resection surgery, the complication rate increased to 40% with 55% multiple complications.

Adjuvant therapies

Overall, 79 patients (66%) received chemotherapy according to the following protocols: CESS (Cooperative Ewing's Sarcoma Studies) = 12 patients; 15%; EuroEwing chemotherapy protocol = 11 patients (14%); COSS (Cooperative Osteosarcoma Study = ten patients (13%); CWSS (Cooperative Weichteilsarcoma Study = seven patients (9%); VIDE (Vincristine-Ifosfamide-Doxorubicin-Etoposide = six patients (8%); EURAMOS (European and American Osteosarcoma

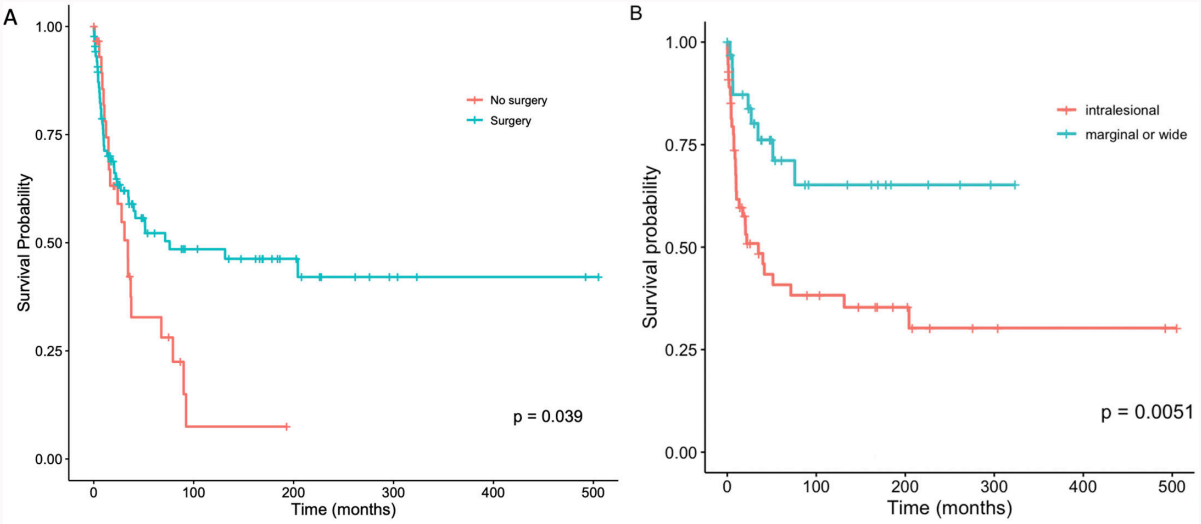

Fig. 3
Survival according to a) surgical intervention, and b) the resection margin.

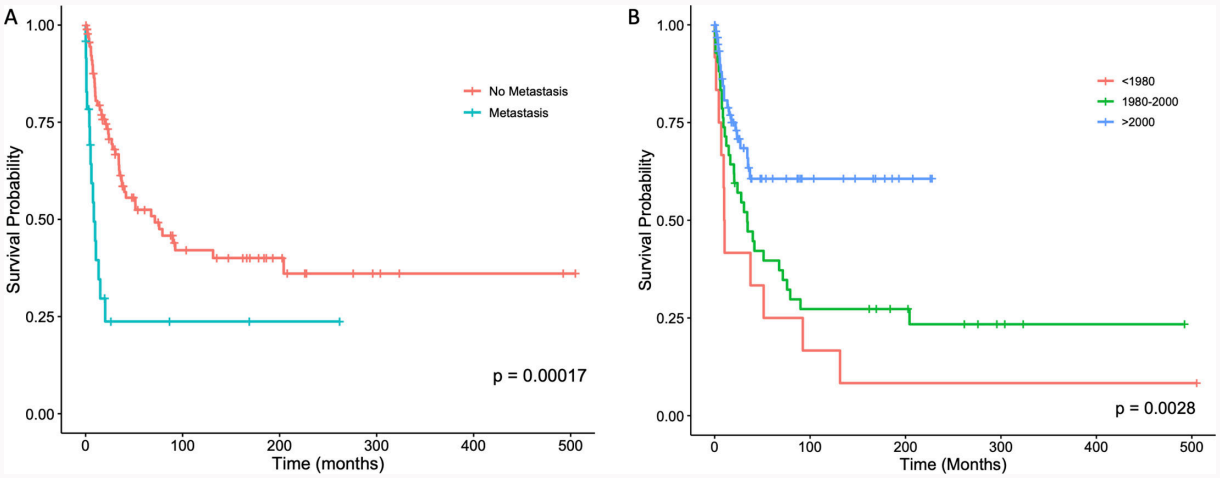

Fig. 4
Survival according to the a) presence of metastases, and b) decade of treatment.

Study protocol = five patients (6%), Rosen protocol = (two patients (3%); EUROBOSS (EUROpean Bone over 40 Sarcoma Study protocol = one patient (1%); and others = 25 patients (32%)). In addition, 86 patients (72%) underwent radiotherapy. The protocols and the indications changed over time and were adapted individually for each patient according to the interdisciplinary tumour board statements. If a wide surgical resection margin could not be achieved without sacrificing important bony segments or indispensable neurovascular structures, preoperative radiotherapy was applied. This indication, for instance, was subject to change as surgical skills evolved over time. If patients had positive margins after surgical excision, interdisciplinary re-evaluation was performed deciding on further treatment strategies as additional surgery, postoperative RTX or additional CX. Concerning the combination of therapies, the majority of patients (44; 37%) received the triple combination of surgery combined with RTX and CX, 30 patients (25%) received conservative treatment only (23 patients (77%) RTX and CX, four (13%) CX only, three (10%) RTX only), 24 patients (20%) received a double combination (16 patients (67%) surgery and RTX, eight patients (33%) surgery combined with CX), 20 patients (17%) underwent surgery only without any additional treatment, and one patient (0.8%) did not undergo any treatment at our institution.

Functional assessment

The Frankel score[15] was evaluated in 80 of 88 patients (90%) who underwent surgery. Patients reached the following scores preoperatively: one = A, five = B, seven = C, 21 = D, and 46 = E compared to the postoperative scores of three = A, 1 = B, four = C, 21 = D, and 51 = E. It therefore remained unchanged in 52 patients (59%), improved in 18 (20%), and decreased in ten (11%).

Oncological outcome

Table II also depicts the main oncological outcomes. The one-, five-, and ten-year survival rates for all tumour types were 73%,

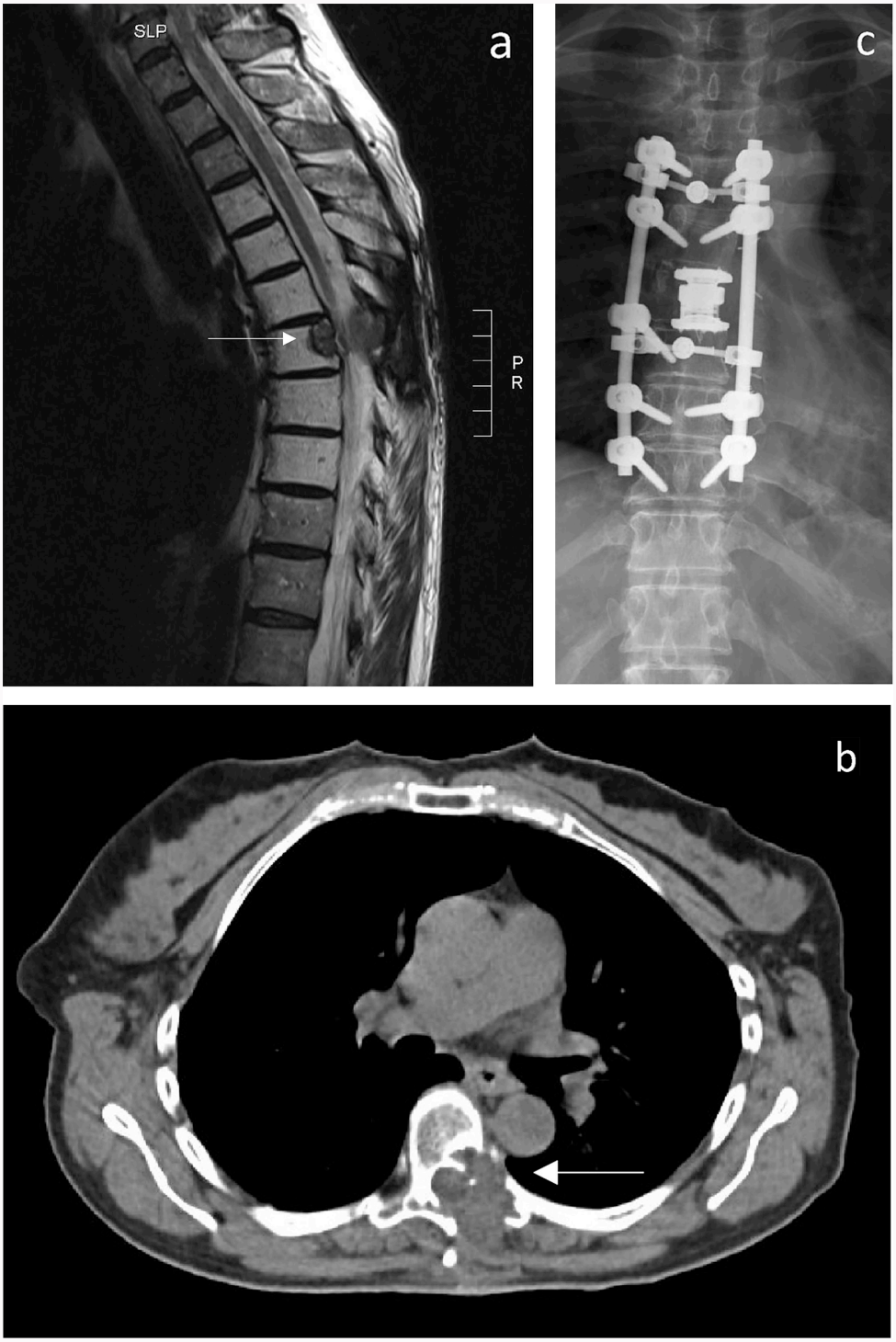

Fig. 5

A 63-year old female patient experiencing pain for one month, with inconclusive biopsy of the lesion in the seventh thoracic vertebral body, as shown by a) sagittal and b) axial MRI at time of diagnosis. Intralesional tumour resection and hemilaminectomy Th7 using a single-staged posterior approach and postoperative radiotherapy were performed; histology revealed leiomyosarcoma G1. Local recurrence in Th7 infiltrating the adjacent rib occurred four years later. Costotransversectomy Th6 and Th7 and hemivertebrectomy Th7 followed by dorsal stabilization Th5 to 10 was performed (postoperative plain radiographs in c) anteroposterior view). Eight years later, a single metastatic lesion in the sacrum was detected and addressed by curettage. At latest follow-up, no evidence of disease could be found.

47%, and 39%, respectively (Figure 1). The median survival was found to be 42 months (95% CI 34 to 131; 0.13 to 505). The median survival of the different histological entities was as follows: CSA 76 months (IQR 25 to 204), OSA 34 months (IQR is 13 to N/A; the Kaplan-Meier curve never dropped below 25%), and STS 21 months (IQR 6 to 92) (Figure 2). For EWS, no reliable estimate of the median survival can be calculated, as the survival rate in our cohort never drops below 50% (Figure 2a). The median overall disease-free survival was found to be 63 months (IQR 3 to 296).

A total of 19 patients (22%) developed a local recurrence after a mean time of 29 months (SD 10; 4 to 133). In patients with an intralesional index surgery (i.e. positive resection margin; 13 (68%)) the local recurrence occurred after 29 months (SD 12; 5 to 133) compared to those with a negative resection margin (6; 32%) when the local recurrence occurred after 28 months (SD 10; 4 to 116; Figure 3). Five patients developed a second recurrence 15 months later (SD 12; 4 to 32). Affected were four CSA patients (80%; three intralesional index surgery, one prior negative resection margin) and one patient (20%) with a STS and a wide resection margin at primary surgery.

As the histological entity seemed to have a high impact on survival, a univariate analysis for bone sarcoma only was performed. In the subgroup of tumours restricted to bone, the one-, five-, and ten-year survival rates were 81%, 56%, and 47%, respectively. The corresponding rates for STS were 58%, 32%, and 24%. The median overall survival for bone tumours was 76 months (IQR 23 to N/A; survival was > 75% at the end of the observation period, so no 75% percentile could be calculated)) compared to 21 months (IQR 6 to 92) in the STS group (Figure 2b). In the univariate analysis between the two groups the histological entity proved to be significant for overall survival ($p = 0.006$). However, no significance was detected in the multivariate Cox-regression analysis ($p = 0.269$). The the one-, five-, and ten-year survival rates for patients without primary metastases at diagnosis were 81%, 53%, and 42%. The corresponding survival rates for patients with primary metastases were 39%, 24%, and 24%, respectively. According to these results primary metastases were found to be a highly significant factor influencing overall survival in the multivariate Cox regression analysis ($p < 0.007$). The number of patients treated by multimodal therapy increased over the years and correlated well with the increase of overall survival over the decades, but neither chemo- ($p = 0.519$) nor radiotherapy ($p = 0.999$) had a significant impact on survival rates (Figure 4).

Surgical outcome

In the univariate analysis, the survival rate did significantly differ as a function of surgery, and a trend was found for an increased overall survival of patients undergoing surgery ($p = 0.039$) compared to patients without surgery. Patients with wide or marginal resection margins had a significant better overall survival compared to patients with intralesional resections ($p = 0.005$). Neither complications after surgery ($p = 0.095$) nor local recurrences ($p = 0.798$) had a significant impact on survival rates. Concerning the influence of the tumour localization on survival, no significance could be found when comparing the mobile spine (cervical, thoracal, and lumbar) with the sacrum ($p = 0.928$). Analysis of a subgroup of patients with tumours restricted to the bone revealed a significant effect of surgical treatment on overall survival in the univariate analysis ($p = 0.006$). Multivariate Cox regression analysis allowed detection of significance in favour of the decade of treatment (< 1980, 1980 to 2000, > 2000; $p < 0.001$), age ($p < 0.001$), and the presence of metastases at the time of diagnosis ($p = 0.007$), as well as a trend towards surgery ($p = 0.087$). When analyzing the subgroup of bone tumours only in the multivariate Cox regression model, a significant effect of surgery ($p = 0.005$), decade of treatment (< 1980, 1980 to 2000, > 2000); $p < 0.001$), and age ($p < 0.001$) on the overall survival could be revealed. A representative case is depicted in Figure 5.

Discussion

We are presenting the results of our survival estimation for four (OSA, CSA, EWS, and STS) of the five most common primary spine tumours over a period of 71 years. These results provide an overview on a very rare tumour entity. Over the past seven decades, survival has risen steadily for all entities. The number of patients receiving multimodal therapy methods increased over the years. Improvements concerning specific radiation, chemotherapy, and surgical techniques were achieved, especially in the light of Tomita et al[17] introducing total en bloc vertebrectomy as a new surgical technique in managing primary spinal tumours in 1997, correlating with an increase in patient's survival. Still, the most influential negative prognostic factors for survival were the presence of primary metastases at the time of diagnosis, as well as the decades of treatment. Surgery seems to be a positive influential factor for spinal sarcoma.

Limitations

There are considerable limitations to this study, which primarily concern the retrospective, single-centre design, and low patient number, which limits the prognostic value of our data and implies critical interpretation of the results as compared to large multicentre studies. However, as primary malignant spine tumours are rare, most published data in this field are based on retrospective series.[4,18–21] The second limitation is that the time interval of our study period may influence the results, as methods of preoperative imaging and treatment strategies have evolved over time. Chemotherapy protocols were adapted and stratified accoridng to the tumour response and the definition of radiation fields, and surgical methods and perioperative treatment were refined over time. En bloc vertebrectomies are now established as standard procedures where applicable, and have broadened the possibilities for wide resection margins from 2010 onwards at our department. Finally, we had no specific data on the tumour size. This reflects the need for multicentre cooperations between centralized databases and registries.

In general, our results are well in line with published data concerning major oncological endpoints: overall survival rates are lower as for other sites, but have improved over time. Schoenfeld et al[21] state that adequate short-term survival can be reached by patients suffering from OSA of the spine, but the five-year mortality rate still remains high. Several variables such as the presence of metastases, tumour histology, and age serve as strong predictors.[10,22] In their analysis of 1,892 patients, Mukherjee et al[4] described the presence of distant metastases as the most influential factor on survival. Overall, 414 patients suffering from chordoma, an entity excluded in the presented study, formed the largest subgroup of their study. Concerning the surgical approach, there is strong agreement in trying to achieve wide resection margins whenever possible.[18,20,23] By achieving negative resection margins (wide/marginal resection), the survival was shown to improve significantly compared to intralesional resection margins. Surgical resection seems beneficial, especially for bone sarcoma, whereas radiation therapy and no surgery

seem to be adequate treatment options for STS.[18] Even though en bloc resection is associated with a higher rate of complications, Amendola et al[20] were able to show that the risk of local recurrences and tumour-related mortality decreased.

In summary, patient treatment plans need to be individualized by a multidisciplinary team approach to achieve the best possible outcome.[24] The existing data underline the importance of further advancements concerning the multimodal treatment for bone and STS in order to continue the improvement of overall survival of patients suffering from primary malignant spine tumours.[25] Our study clearly demonstrates the positive impact of improved surgical techniques, the availability of new chemotherapeutics, and conformal radiotherapy on survival rate in all types of tumours described above. The wide application of 3D-guided resections will most likely further improve the results, as well as increasing knowledge in the evolving broad field of targeted drug therapies.[26] Nonetheless, owing to the rarity of primary malignant tumours of the spine, multicentre studies should be performed for a better understanding and optimized treatment options.

References

1. **Papagelopoulos PJ**, **Mavrogenis AF**, **Currier BL**, **et al**. Primary malignant tumors of the cervical spine. *Orthopedics*. 2004;27(10):1066–1075.
2. **Jemal A**, **Siegel R**, **Ward E**, **Hao Y**, **Xu J**, **Thun MJ**. Cancer statistics. *CA Cancer J Clin*. 2009;59(4):225–249.
3. **Casali PG**, **Trama A**. Rationale of the rare cancer list: a consensus paper from the Joint Action on Rare Cancers (JARC) of the European Union (EU). *ESMO Open*. 2020;PMCID(2):e000666.
4. **Mukherjee D**, **Chaichana KL**, **Gokaslan ZL**, **Aaronson O**, **Cheng JS**, **McGirt MJ**. Survival of patients with malignant primary osseous spinal neoplasms: results from the Surveillance, Epidemiology, and End Results (SEER) database from 1973 to 2003. *J Neurosurg Spine*. 2011;14(2):143–150.
5. **Kelley SP**, **Ashford RU**, **Rao AS**, **Dickson RA**. Primary bone tumours of the spine: a 42-year survey from the Leeds Regional Bone Tumour Registry. *Eur Spine J*. 2007;16(3):405–409.
6. **Boriani S**, **Iure F**, **Bandiera S**, **et al**. Chondrosarcoma of the mobile spine: report on 22 cases. *Spine*. 1976;25(7):804–812.
7. **Shives TC**, **McLeod RA**, **Unni KK**, **Schray MF**. Chondrosarcoma of the spine. *J Bone Joint Surg Am*. 1989;71-A(8):1158–1165.
8. **Whitehouse GH**, **Griffiths GJ**. Roentgenologic aspects of spinal involvement by primary and metastatic Ewing's tumor. *J Can Assoc Radiol*. 1976;27(4):290–297.
9. **Katonis P**, **Datsis G**, **Karantanas A**, **et al**. Spinal osteosarcoma. *Clin Med Insights Oncol*. 2013;7:199–208.
10. **Rao G**, **Suki D**, **Chakrabarti I**, **et al**. Surgical management of primary and metastatic sarcoma of the mobile spine. *J Neurosurg Spine*. 2008;9(2):120–128.
11. **Rustagi T**, **Schwab JH**, **Iwenofu H**, **Mendel E**. Overview of the management of primary tumors of the spine. *Int J Neurosci*. 2022;132(6):543–557.
12. **Jae-Min Park A**, **McDowell S**, **Mesfin A**. Management of chordoma of the sacrum and mobile spine. *JBJS Rev*. 2022;10(12).
13. **Schneider E**, **Lutschounig M-C**, **Straub J**, **et al**. En bloc total vertebrectomy of the thoracic and lumbar spine. *J Clin Med*. 2024;13(17).
14. **Enneking WF**, **Spanier SS**, **Goodman MA**. A system for the surgical staging of musculoskeletal sarcoma. *Clin Orthop Relat Res*. 1980;153:106–120.
15. **Frankel HL**, **Hancock DO**, **Hyslop G**, **et al**. The value of postural reduction in the initial management of closed injuries of the spine with paraplegia and tetraplegia. I. *Paraplegia*. 1969;7(3):179–192.
16. **Choi JH**, **Ro JY**. The 2020 WHO classification of tumors of bone: an updated review. *Adv Anat Pathol*. 2021;PMID(3):119–138.
17. **Tomita K**, **Kawahara N**, **Baba H**, **et al**. Total en bloc spondylectomy. a new surgical technique for primary malignant vertebral tumors. *Spine*. 1976;22(3):324–333.
18. **Ozaki T**, **Flege S**, **Liljenqvist U**, **et al**. Osteosarcoma of the spine: experience of the cooperative osteosarcoma study group. *Cancer*. 2002;94(4):1069–1077.
19. **Schwab J**, **Gasbarrini A**, **Bandiera S**, **et al**. Osteosarcoma of the mobile spine. *Spine*. 2012;37(6):E381–E386.
20. **Amendola L**, **Cappuccio M**, **De Iure F**, **Bandiera S**, **Gasbarrini A**, **Boriani S**. En bloc resections for primary spinal tumors in 20 years of experience: effectiveness and safety. *Spine J*. 2014;14(11):2608–2617.
21. **Schoenfeld AJ**, **Hornicek FJ**, **Pedlow FX**, **et al**. Osteosarcoma of the spine: experience in 26 patients treated at the massachusetts general hospital. *Spine J*. 2010;10(8):708–714.
22. **Zils K**, **Bielack S**, **Wilhelm M**, **et al**. Osteosarcoma of the mobile spine. *Ann Oncol*. 2013;24(8):2190–2195.
23. **Bergh P**, **Gunterberg B**, **Meis-Kindblom JM**, **Kindblom LG**. Prognostic factors and outcome of pelvic, sacral, and spinal chondrosarcomas: a center-based study of 69 cases. *Cancer*. 2001;91(7):1201–1212.
24. **Missenard G**, **Bouthors C**, **Fadel E**, **Court C**. Surgical strategies for primary malignant tumors of the thoracic and lumbar spine. *Orthop Traumatol Surg Res*. 2020;106(1S):S53–S62.
25. **Yeung CM**, **Bilsky M**, **Boland PJ**, **Vaynrub M**. The role of en bloc resection in the modern era for primary spine tumors. *Spine*. 2024;49(1):46–57.
26. **Costăchescu B**, **Niculescu A-G**, **Iliescu BF**, **Dabija MG**, **Grumezescu AM**, **Rotariu D**. Current and emerging approaches for spine tumor treatment. *Int J Mol Sci*. 2022;23(24).

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Funding statement
The author(s) received no financial or material support for the research, authorship, and/or publication of this article.

ICMJE COI statement
P. Krepler reports payment for educational events from Globus and Medacta, which are unrelated to this work. R. Windhager declares consulting fees from Johnson & Johnson and Stryker Europe, both of which are also unrelated.

Data sharing
The data that support the findings for this study are available to other researchers from the corresponding author upon reasonable request.

Acknowledgements
The authors wish to thank Dr Jennifer Straub, MD, for her valuable contribution to the presented study.

Ethical review statement
The corresponding institutional review board approved the study design and protocol (EK642/2011).

Open access funding
The authors received open access funding for this manuscript from the Department of Orthopedics and Traumatology, Division of Orthopedics, Medical University of Vienna, Austria.