European Spine Journal (2025) 34:3592–3600
https://doi.org/10.1007/s00586-025-08893-y

RESEARCH

Oxford spinal sarcoma service: excellent oncological outcomes with a centralised multidisciplinary approach to primary spinal tumour care

Jonathan Jiong Hao Tan[1] · Euan Stirling[2] · Radek Kaiser[2] · Gerard Mawhinney[2,3] · Dominique Rothenfluh[4] · Yiong Huak Chan[5] · Shilin Wang[1] · Ruxandra Mihai[6] · Stana Bojanic[7] · Jeremy Reynolds[2]

Received: 5 February 2025 / Revised: 19 April 2025 / Accepted: 25 April 2025 / Published online: 31 May 2025

Abstract

Purpose The Oxford Spinal Sarcoma Service is a designated primary spinal tumour referral centre in the United Kingdom serving over ten million residents. We report the outcomes of this centralised approach to primary spinal tumour care.

Methods This is a retrospective review of surgically treated primary spinal tumour patients during 2008-2022. Patients were classified based on tumour resection margins - Enneking Appropriate (EA) or Enneking Inappropriate (EI). Outcomes studied include local recurrence and overall survival.

Results 119 patients were included. 86/119(72%) cases involved the mobile spine; 33/119(28%), the sacrum. 96/119(81%) patients were virgin cases. EA margins were achieved in 68%(81/119) of cases. There were 38/119(32%) EI patients; 23/38(61%) were non-virgin cases which precluded EA resection. EA resection was achieved 90%(81/90) of the time when attempted. In EA patients with mobile spine tumours, local recurrence rate was 2%(1/51), vs. 18%(5/28) in EA patients with sacral tumours, 20%(7/35) in EI patients with mobile spine tumours, and 80%(4/5) in EI patients with sacral tumours. Mean local recurrence-free survival was 5.2(range 1-13.5) years; local recurrence rate, 18.5%(22/119). Mortality rate was 21.0%(25/119); mean overall survival was 5.63(range 1-13.5) years post-surgery. On multivariate analysis, EI margins and post-operative systemic treatment were significant predictors for local recurrence; presence of metastases and pre-operative systemic therapy, significant predictors for mortality.

Conclusion Centralisation of primary spinal tumour care has led to excellent oncological results comparable to most large spinal tumour centres. In mobile spine primary tumours where EA margins were achieved, our local recurrence rate (2.0%) is one of the lowest reported in literature.

Keywords Primary spinal tumours · Spinal sarcomas · Oncology · Spinal surgery · Outcomes · Recurrence · Survival · Multidisciplinary care · Quarternary referral centre

Introduction

Primary spinal sarcomas are a heterogeneous group of tumours that constitute 5% of all skeletal sarcomas diagnosed in the United Kingdom annually [1]. Surgery remains the cornerstone of the management of primary spinal sarcomas, and adequate resection is a significant predictor of long-term outcomes. As such, in 2009, the Spine Oncology Study Group recommended that en-bloc resection with marginal or wide margins should be performed for malignant primary spinal tumours [2].

The Enneking classification system [3] is commonly used to stage spinal sarcomas and describe the appropriateness of surgical margins. Tumours are staged based on histological grade, local extent and presence of metastases, with each stage having a specific recommended margin of resection.

Enneking appropriate (EA) resection of primary spinal tumours is significantly associated with decreased local recurrence [4, 5, 6, 7] and improved survival [7]. However, the complex anatomy of the spine and its surrounding critical structures renders surgical treatment challenging and increases the risk of potential complications. Even in high-volume tertiary centres, planned resection margins

Extended author information available on the last page of the article

may only be achieved 75% of the time [8]. Primary spinal tumours should be managed in quaternary centres [2] as inappropriate diagnostic procedures [9] and treatment in non-high volume centres are associated with poorer patient outcomes and survival [10].

The Oxford Spinal Sarcoma Service serves approximately ten million residents and is part of a network of four designated primary spinal tumour referral centres in the United Kingdom. Prior to its inception in 2008, there was a wide variation in regional practice, with EA resection being performed only for tumours of the sacrum and pelvis, but not for tumours of the mobile spine. An outreach programme was established to educate spinal surgeons of the need to avoid unnecessary diagnostic or surgical procedures in patients with suspected primary spinal tumours. Treating specialists were allowed to directly refer suspected cases to the Sarcoma Multidisciplinary Team Meeting. This centralisation of primary spinal tumour care with formalised referral of all primary spinal tumours to a designated quaternary referral centre remains uncommon internationally.

This study aims to review the outcomes of centralised treatment of patients with primary spinal tumours at a quaternary referral centre. Primary outcomes studied were the incidence of local recurrence and patient survival.

Methods

This is a retrospective study of consecutive patients who underwent surgical treatment for primary spinal sarcomas during the period of 2008–2022 at Oxford University Hospitals (OUH). This study was conducted in accordance with the principles of the Helsinki Declaration; ethics approval was granted by the OUH National Health Service (NHS) Foundation Trust.

Patients were identified via histopathological records of the Oxford Bone and Soft Tissue Tumour Service. Patients were excluded if they underwent treatment for spinal metastases, were diagnosed with a primary spinal cord tumour, or had distant metastases at the time of treatment. A minimum of one year of postoperative follow-up was a prerequisite for inclusion. All patients were followed up on a regular basis until demise.

Diagnosis and treatment were based on the consensus opinion of the regional multidisciplinary sarcoma team meeting. Histological diagnosis was obtained via computed tomography (CT)-guided trocar biopsies, performed by an interventional radiologist under the direction of the attending surgeon. No excision of skin and biopsy tract was done. Surgery was performed by the senior author with the assistance of allied surgical subspecialists on an as-needed basis.

Clinical data that were collected include - patient demographics, preoperative symptoms, presence of pathologic vertebral fractures, premorbid Eastern Cooperative Oncology Group (ECOG) status, American Spinal Injury Association (ASIA) score, pre-operative treatment details, and tumour characteristics (e.g. histology, Enneking stage, spinal levels of involvement and dimensions).

Pre- and postoperative treatment characteristics were recorded. Patients who had undergone prior open biopsy or intra-lesional surgical procedures at other institutions were classified as non-virgin cases; patients who had not were classified as virgin cases. Surgical data, including surgical approach, nerve root sacrifice, type of resection, amount of blood loss, need for allogenic/autogenic transfusion, preoperative surgical plan, intraoperative impression of surgical margins and final pathologist's impression were collected.

Margins were defined as Enneking appropriate when the final pathological margins matched the Enneking-recommended surgical margins. Margins were considered Enneking inappropriate (EI) if the recommended surgical margins were not achieved intraoperatively [7, 11, 12], or if previous intralesional procedures had been performed (i.e. in non-virgin cases). The use of adjuvant therapy and patient outcomes, such as local recurrence, metastases, overall survival and the presence of postoperative complications, were recorded. A complication was an event that adversely affected patient recovery, requiring medical/surgical treatment.

Statistical analysis

Kaplan-Meier analysis was performed to determine overall and local recurrence-free survivals; Cox regression, to determine risk predictors for survival time. Death was classified as a competing event for time to local tumour recurrence. Significant univariate variables were identified for further multivariate analysis; multicollinear variables were excluded from multivariate analysis. Hazard ratios (HR) with 95% confidence intervals (CI) were presented.

Stata (Version 17.0, StataCorp, USA) was used for analysis. Significance was set at $p < 0.05$.

Results

There were 119 patients included in this study. 63% (75/119) of patients were male. Three patients who died in the perioperative period are discussed separately below. Mean age at the time of surgery was 46(range 8–86) years. Most patients were ECOG 0 (66/119, 55%) and ASIA E (94/119, 79%) preoperatively. Patient demographics and clinical characteristics are shown in Table 1.

Table 1 Patient demographics and clinical characteristics ($n=119$)

Characteristic	n(%)
Mean age at surgery (years) (range)	46 (8–86)
Sex	
Male	75 (63.0)
Female	44 (37.0)
Duration of symptoms	
0-3mo	20 (16.8)
3-6mo	19 (16.0)
>6mo	72 (60.5)
Asymptomatic	8 (6.7)
Clinical presentation	
Myelopathy	20 (16.8)
Radiculopathy	44 (37.0)
Bladder dysfunction	5 (4.2)
Bowel dysfunction	7 (5.9)
Sexual dysfunction	10 (8.4)
Pathological fracture	14 (11.8)
Premorbid ECOG status	
0	66 (55.5)
1	34 (28.6)
2	12 (10.1)
3	5 (4.2)
4	2 (1.7)
ASIA score	
A	0 (0)
B	0 (0)
C	6 (5.0)
D	19 (16.0)
E	94 (79.0)

Table 2 Tumour characteristics ($n=119$)

Characteristic	n (%)
Tumour histology	
Chordoma	30 (25.2)
Chondrosarcoma	13 (10.9)
Schwannoma	11 (9.2)
Giant cell tumour	10 (8.4)
Osteosarcoma	9 (7.6)
Malignant peripheral nerve sheath tumour	8 (6.7)
Osteoblastoma	7 (5.9)
Other sarcomas	6 (5.0)
Aneurysmal bone cyst	5 (4.2)
Others	20 (16.8)
Enneking classification	
Benign (Stage 2 or 3)	48 (40.3)
Malignant (IA, IB, IIA, IIB)	71 (59.7)
Spinal levels of involvement	
Mobile spine	86 (72.3)
Cervical	25 (21.0)
Thoracic	34 (28.6)
Lumbar	27 (22.7)
Sacral	33 (27.7)
Tumour dimensions (cm) (mean (range))	
Anteroposterior	4.91 (0.80–16.20)
Mediolateral	5.25 (1.50–15.00)
Craniocaudal	5.27 (1.07–18.50)

The most common histological types were chordomas (30/119, 25%), chondrosarcomas (13/119, 11%), schwannomas (11/119, 9%), giant cell tumours (10/119, 8%) and osteosarcomas (9/119, 8%). Most tumours involved the mobile spine (86/119, 72%); 28%(33/119) of cases were sacral tumours. Based on the Enneking classification, 40%(48/119) of cases were benign and 60%(71/119), malignant (Table 2).

81% (96/119) of patients were virgin cases. EA margins were achieved in 68%(81/119) of patients. Margins were EI in 32%(38/119) of cases, of which 61%(23/38) were non-virgin cases which precluded EA resection; 18%(7/38)were noted to have a breach intraoperatively; EA resection was deemed not possible or desirable in 11%(4/38) of cases; EI margins were detected by a pathologist in the remaining 11%(4/38) of cases. EA margins were attempted for 90 patients (virgin cases with tumours deemed surgically treatable with EA margins), and were achieved in 90%(81/90) of these patients. Thirty-five (29%) patients received postoperative radiotherapy and 20(17%) received postoperative systemic therapy. Surgical site infections (25%, 30/119), implant-related complications (15%, 18/119), neurological complications (16%, 19/119) and dural tears (11%, 13/119) were the most common postoperative complications.

Mean local recurrence-free survival was 5.2(range 1-13.5) years. Local recurrence rate was 18.5%(22/119). Mortality rate was 21.0%(25/119) with a mean overall survival of 5.63(range 1-13.5) years post-surgery. There were 25/119(21.0%) cases with distant metastases; mean duration of metastases-free survival was 5.32(range 1-13.5) years (Table 3).

On multivariate analysis, EI margins (sHR=5.51,95%CI=1.32–22.96,$p=0.019$) and postoperative systemic treatment (sHR=4.54,95%CI=1.62–12.73,$p=0.004$) were significant predictive factors for tumour recurrence (Table 4). Notably, in EA patients with mobile spine tumours, local recurrence rate was 2.0%(1/51), versus 17.9%(5/28) in EA patients with sacral tumours, 20%(7/35) in EI patients with mobile spine tumours, and 80%(4/5) in EI patients with sacral tumours (Fig. 1). On multivariate analysis, only presence of metastases (HR=3.17,95%CI=1.28–7.84,$p=0.012$) and use of preoperative systemic therapy (HR=4.07,95%CI=1.19–13.93,$p=0.025$) were significantly associated with decreased survival (Table 5).

Table 3 Treatment characteristics and outcomes ($n=119$)

Characteristic	*n* (%)
Preoperative radiotherapy	
Yes	16 (13.4)
No	103 (86.6)
Preoperative systemic therapy	
Yes	24 (20.2)
No	95 (79.8)
Previous surgical treatment	
Non-virgin	23 (19.3)
Virgin	96 (80.7)
Surgical plan	
En bloc	94 (79.0)
Intralesional	25 (21.0)
Final surgical margins	
Enneking appropriate	81(68.1)
Enneking inappropriate	38 (31.9)
Nerve sacrifice	
Yes	64 (53.8)
No	55 (46.2)
Intraoperative blood loss (ml) (mean (range))	3073 (80-18000)
Blood transfusion	
Intraoperative cell salvage	65 (54.6)
Allogenic	37 (31.1)
Postoperative radiotherapy	
Yes	35 (29.4)
No	84 (70.6)
Postoperative systemic therapy	
Yes	20 (16.8)
No	99 (83.2)
Local recurrence	
Duration of recurrence-free survival (years) (mean (range))	5.2 (1-13.5)
Yes	22 (18.5)
No	97 (81.5)
Metastases	
Duration of metastases-free survival (years) (mean (range))	5.32 (1-13.5)
Yes	25 (21.0)
No	94 (79.0)
Survival	
Duration (years) (mean (range))	5.63 (1-13.5)
Dead	25 (21.0)
Alive	94 (79.0)
Complications	
Yes	70 (58.8)
Surgical site infection	30 (25.2)
Implant-related complications	18 (15.1)
Neurological complications	19 (16.0)
Dural tear	13 (10.9)
Wound complications	10 (8.4)
Non-surgical site infection	9 (7.6)
Deep venous thrombosis/pulmonary embolism	8 (6.7)
No	49 (41.2)

Table 4 Significant univariates and multivariate analysis of risk factors for local recurrence (death competing)

		Univariate		Multivariate	
Variable	No. of events	Hazard ratio (95%CI)	*p*	Hazard ratio (95%CI)	*p*
Age	-	1.04 (1.01–1.07)	0.036	-	0.102
Enneking margins					
EI	16/38 (42.1%)	10.37 (2.32–46.30)	0.002	5.51 (1.32–22.96)	0.019
EA	5/81 (6.2%)	Reference		Reference	
Postop. systemic treatment					
Yes	9/20 (45.0%)	6.45 (2.01–20.74)	0.002	4.54 (1.62–12.73)	0.004
No	12/99 (12.1%)	Reference			

Case examples

Selected examples, with illustrations, of cases treated at our centre are shown in Appendix 1.

Discussion

It is of paramount importance that patients with primary spinal sarcomas receive multidisciplinary treatment at a high-volume quaternary centre. Stroud et al. [11] found that patients treated at non-specialised centres were more likely to receive non-optimal treatment, increasing patient mortality. Lazarides et al. [10] also reported that patients treated at high-volume facilities had significantly higher five-year survival rates (71%, versus 58% at low-volume centres).

Boriani et al. [13] reported a series of patients who had undergone en-bloc resection of primary spinal tumours or isolated spinal metastases, of which 77.8%(168) were virgin cases and 22.2%(48) were non-virgin cases. In their cohort, overall local recurrence rate was 15.28%, with a local recurrence rate of 29.17% in non-virgin cases and 11.31% in virgin cases; mortality rate was 23.21% for virgin cases and 43.75% for non-virgin cases. Direct comparison with our results is difficult due to the admixture of spinal metastases cases in their patient cohort. Accounting for surgical technique, the local recurrence rate in our series was 13.8%(13/94) for patients who underwent en-bloc resection - with recurrence rates of 45.5%(5/11) and 9.6%(8/83) for non-virgin and virgin cases respectively. Mortality rates were 54.5%(6/11)for non-virgin cases and 16.9%(14/83) for virgin cases respectively. Our local recurrence and mortality rates thus compare favourably with the study above.

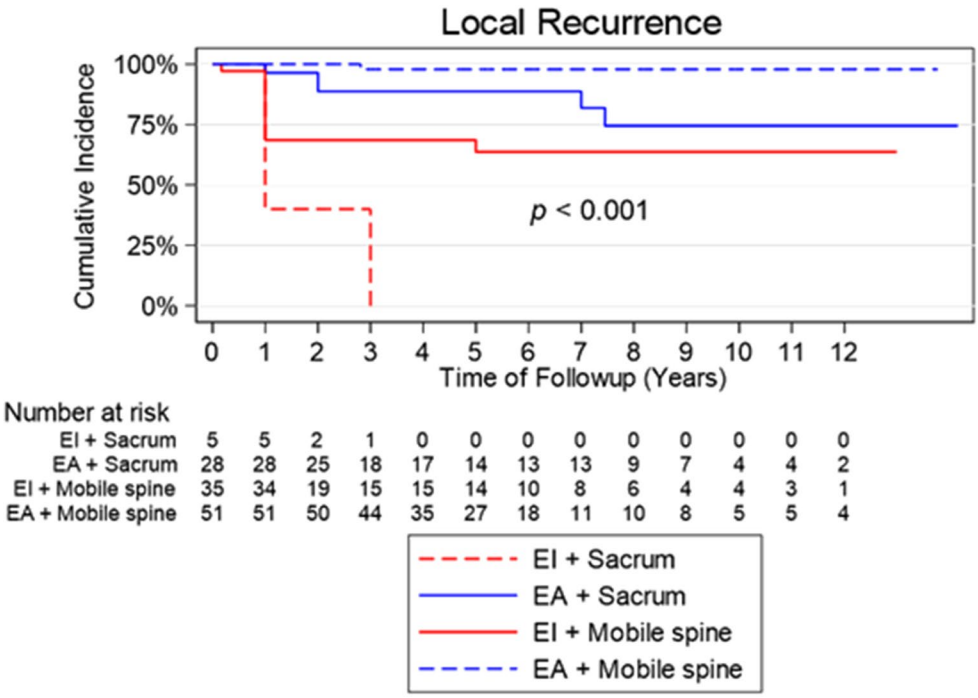

Fig. 1 Local recurrence rates of EI/EA patients with tumours of the sacrum and mobile spine

A multicentre study by Fisher et al. [14] reported a series of 147 patients −70 patients in the EA group and 77 patients in the EI group. An overall local recurrence rate of 48.2%(71/147) was reported −20%(14/70) for the EA group and 40%(57/77) for the EI group. We had a lower local recurrence rate of 7.4%(6/81) for the EA group and 42.1%(16/38) for EI patients. Achieving EA margins is the cornerstone of surgical treatment of primary spinal tumours. In chordomas of the mobile spine [4] and sacrum [5], osteosarcomas [7] and giant cell tumours [15], there was a significant association between EI margins and local recurrence. Local recurrence was associated with increased mortality in spinal chordomas [9], chondrosarcomas [6], giant cell tumours [15] and osteoblastomas [16].

Centralisation of primary spinal tumour care has also reduced inappropriate diagnostic and surgical procedures. Only 19.3% of our patients were non-virgin cases, whereas a multinational study of 300 patients by Dandurand et al. [8] found that 27.5% of patients were non-virgin cases. Previous open procedures preclude an EA procedure as they cause tumour seeding throughout the surgical field and wound. Luzzati et al. [17] found that even the presence of appropriate margins post salvage surgery did not reduce the rate of local recurrence or improve survival, which they attributed to the effect of previous inappropriate procedures. We were able to ensure that CT-guided percutaneous biopsies were performed. Barrientos-Ruiz I et al. [18] found that 32% of open biopsies had seeding of the biopsy tract as compared to 0.8% in percutaneous biopsies. We do not practice routine excision of the biopsy tract, as it is often distant from the planned incision, rendering excision of the biopsy tract non-viable. Despite this, we did not encounter any episodes of biopsy tract recurrence.

Achieving EA margins is challenging. Dandurand et al. [8] reported that preoperative planned surgical margins were only achieved 74.7% of the time. We managed to achieve EA margins in 90%(81/90) of the cases for which we planned EA resections. We had one local recurrence patient with primary tumours of the mobile spine who underwent EA surgery. To our knowledge, this is one of the best reported outcomes in the literature. In contrast, patients with sacral tumours had a local recurrence rate of 27.3%(9/33). Tumour resection with EA margins in the sacrum is challenging, due to the anatomic complexity of the region. Even when successful en-bloc surgery is performed, there may be microscopic satellite spread outside the field of resection [19]. We speculate that in cases of local recurrence in EA cases, there may have been unrecognised microscopic spread or breaches.

To achieve EA margins, we emphasise the importance of a team-based and multidisciplinary approach, utilising the expertise of different oncological surgeons. Examples where this would be necessary include tumours with extra-osseous extension, or situations in which surrounding critical structures need to be mobilised. A sample decision-making process is shown in Table 6. However, there is no one-size-fits-all approach - each patient should be evaluated and treated on a case-by-case basis with the emphasis on the development of extended perioperative teams.

Table 5 Significant univariates and multivariate analysis of risk factors for overall survival

		Univariate		Multivariate	
Variable	No. of events	Hazard ratio (95%CI)	*p*	Hazard ratio (95%CI)	*p*
Pre-op radiotherapy					
Yes	10/16 (62.5%)	4.99 (2.23–11.34)	<0.001		0.875
No	15/103 (14.6%)	Reference			
Pre-op systemic treatment					
Yes	9/24 (37.5%)	2.27 (1.01–5.14)	0.049	4.07 (1.19–13.93)	0.025
No	16/95 (16.8%)	Reference			
Previous surgical treatment					
Non-virgin	10/23 (43.5%)	3.79 (1.69–8.46)	0.001		0.449
Virgin	15/96 (15.6%)	Reference			
Enneking classification					
Malignant (IA/IB/IIA/IIB)	20/71 (28.2%)	19.03 (2.57-140.76)	0.004		0.119
Benign (Stage 2 or 3)	5/48 (10.4%)	Reference	-		
Metastases					
Yes	15/25 (60.0%)	8.29 (3.59–19.14)	<0.001	3.17 (1.28–7.84)	0.012
No	10/94 (10.6%)				
Enneking margins					
EI	16/38 (42.1%)	3.47 (1.56–7.73)	0.002		0.677
EA	5/91 (5.5%)	Reference			
Local recurrence					
Yes	11/21 (52.4%)	4.20 (1.90–9.29)	<0.001		0.309
No	14/98 (14.3%)	Reference			
Post-op radiotherapy					
Yes	13/35 (37.1%)	3.15 (1.42–6.98)	0.005		0.695
No	12/84 (14.3%)	Reference			
Post-op systemic treatment					
Yes	12/20 (60.0%)	5.61 (2.53–12.41)	<0.001		0.422
No	13/99 (13.1%)	Reference			

Table 6 Surgical planning based on tumour location and extent

Tumour location	Surgical approach	Involvement of allied oncological surgeon
Cervical spine		
Posterior arch only	Posterior	No
Vertebral body		
Confined to body	Posterior + anterior	No
Higher cervical or extra-osseous extension	Posterior + anterior	Yes (head and neck surgeon) + Plastic surgeon if flap coverage/ vascularised bone graft required
Thoracic spine		
Posterior arch only	Posterior	No
Vertebral body		
Confined to body	Posterior	No
Extra-osseous extension	Posterior + anterior	Yes (thoracic/cardiac surgeon) + Plastic surgeon if flap coverage/ vascularised bone graft required
Lumbar spine		
Posterior arch only	Posterior	No
Vertebral body		
Confined to body	Posterior + anterior	No
Extra-osseous extension	Posterior + anterior	Yes (vascular/general surgeon) + Plastic surgeon if flap coverage/ vascularised bone graft required
Sacrum		
Below S2/S3 junction		
Confined to body	Posterior	No
Extra-osseous extension	Posterior + anterior	Yes (vascular/colorectal surgeon)
Above S2/S3 Junction	Posterior + anterior	Yes (vascular/colorectal surgeon) + Plastic surgeon if flap coverage/ vascularised bone graft required

Postoperative systemic therapy was associated with a significantly increased risk of local recurrence in our cohort. In these patients, 8/9 patients had EI margins, and 5/9 patients were non-virgin cases undergoing revision surgery; all cases occurred in patients with malignant tumours. Systemic chemotherapy may have been given as salvage therapy and local recurrence may have occurred in spite of systemic treatment.

Other adjuncts to surgical treatment have been described [20, 21, 22, 23]. Proton therapy allows delivery of higher doses of radiation while limiting collateral damage to surrounding tissues. It has thus been recommended as a method of reducing the risk of tumour seeding in spinal chordomas

Table 7 Clinical details of perioperative mortalities

Patient profile	Surgical treatment	Cause of death	Cause analysis	Change in practice
62/Male Sacral chordoma	Complete sacrectomy via posterior approach	Intraop. haemorrhage	Inability to visualise and control bleeding from neuroforaminal tributaries of the internal iliac vein	High and total sacrectomies were performed via an anterior and posterior approach to ensure adequate visualisation [26] and haemostasis
24/Male Iliosacral chondrosarcoma	External hemipelvectomy + vascularised autograft	Postop. haemorrhage	Patient anticoagulated due to pulmonary embolism On-call team unable to identify and control source of bleeding	For patients undergoing complex reconstructions, member of surgical team present at initial operation should be present at any further returns to theatre
80/Male T8-T10 chondrosarcoma	Two stage en-bloc resection of T8-T10 tumour	Postop. sepsis	Contemporaneous surgery leading to major surgical site infection with similar microbiological profile performed in the same theatre	Investigation by infection control team and review of infection control practices Closure of operating theatre for deep cleaning

and sarcomas [20, 21, 22]. We reserve proton therapy for patients with high-risk tumour types, EI surgery and cases where we suspect that tumour seeding might have occurred despite clear pathological margins. Denosumab can also play a significant role in reducing the size of giant cell tumours prior to resection [24].

Overall mortality in our patients was 21.0%(25/119) and significantly associated with the presence of metastases and preoperative systemic treatment. Bandiera et al. [25], in a series of 298 patients, similarly found that local recurrence, metastases and preoperative treatment (with radiotherapy or chemotherapy) were significantly associated with increased mortality. The need for preoperative treatment and presence of metastases are suggestive of more aggressive disease and may thus explain the increased mortality rates.

There is a significant risk of mortality in attempting EA resection of primary spinal tumours. In our cohort there were three perioperative deaths - an overall perioperative mortality rate of 2.46%(3/122); two due to perioperative haemorrhage, another due to sepsis. All three patients had large malignant tumours requiring a total sacrectomy, external hemi-pelvectomy and multi-level vertebrectomy. Table 7 shows the patient profiles, causes of death and the changes in clinical practice that were adopted after these complications. In high-risk patients, it may be prudent to opt for non-surgical adjuvant treatment or less aggressive surgical treatment despite the possibility of less ideal oncological outcomes.

Study limitations

Limitations include the heterogeneous nature of the patient population with relatively small numbers of each tumour type, limiting the generalisability of our results. There is a limitation in the duration of follow-up as spinal sarcomas are known to recur even after 5–10 years.

Conclusion

Our practice of centralising the diagnosis and care of patients with primary spinal tumours has allowed us to achieve excellent oncological results, comparable to other large primary spinal tumour centres. In tumours of the mobile spine, we achieved a local recurrence rate of 2%, one of the lowest reported in the literature. Better education and increased ease of access have reduced inappropriate diagnostic and surgical procedures. We believe that our experience will be of benefit to other centres hoping to establish or improve their spinal sarcoma service.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s00586-025-08893-y.

Author contributions All authors contributed to the study conception and design, as well as material preparation, data collection and analysis. The first draft of the manuscript was written by JHJT and SW and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding No funding was received for conducting this study.

Data availability The data that support the findings of this study are not openly available due to confidentiality and ethical considerations and are available from the corresponding author upon reasonable request.

Declarations

Ethical approval This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The ethics committee of the OUH NHS Foundation Trust approved this study.

Competing interests The authors declare no competing interests.

References

1. Bone sarcoma incidence statistics (2022) Cancer Res UK
2. Yamazaki T, McLoughlin GS, Patel S, Rhines LD, Fourney DR (2009) Feasibility and safety of En bloc resection for primary spine tumors: a systematic review by the spine oncology study group. Spine 34(22 Suppl):S31–S38
3. Enneking WF (1986) A system of staging musculoskeletal neoplasms. Clin Orthop Relat Res. (204):9–24
4. Gokaslan ZL, Zadnik PL, Sciubba DM, Germscheid N, Goodwin CR, Wolinsky JP et al (2016) Mobile spine Chordoma: results of 166 patients from the aospine knowledge forum tumor database. J Neurosurg Spine 24(4):644–651
5. Varga PP, Szövérfi Z, Fisher CG, Boriani S, Gokaslan ZL, Dekutoski MB et al (2015) Surgical treatment of sacral Chordoma: prognostic variables for local recurrence and overall survival. European spine journal: official publication of the European spine society, the European spinal deformity society, and the European section of the cervical. Spine Res Soc 24(5):1092–1101
6. Fisher CG, Versteeg AL, Dea N, Boriani S, Varga PP, Dekutoski MB et al (2016) Surg Manage Spinal Chondrosarcomas Spine 41(8):678–685
7. Dekutoski MB, Clarke MJ, Rose P, Luzzati A, Rhines LD, Varga PP et al (2016) Osteosarcoma of the spine: prognostic variables for local recurrence and overall survival, a multicenter ambispective study. J Neurosurg Spine 25(1):59–68
8. Dandurand C, Fisher CG, Rhines LD, Boriani S, Charest-Morin R, Gasbarrini A et al (2021) Feasibility of achieving planned surgical margins in primary spine tumor: a PTRON study. Neurosurg Focus 50(5):E16
9. Bergh P, Kindblom LG, Gunterberg B, Remotti F, Ryd W, Meis-Kindblom JM (2000) Prognostic factors in Chordoma of the sacrum and mobile spine: a study of 39 patients. Cancer 88(9):2122–2134
10. Lazarides AL, Kerr DL, Dial BL, Steele JR, Lane WO, Blazer DG 3 et al (2020) Does facility volume influence survival in patients with primary malignant bone tumors of the vertebral column? A comparative cohort study. Spine Journal: Official J North Am Spine Soc 20(7):1106–1113
11. Stroud SG, Geiger EJ, Lichtensztajn DY, Goldsby RE, Cheng I, Wustrack R, Theologis AA (2022) Survival of patients with primary osseous malignancies of the mobile spine is associated with access to standard treatment protocols. J Am Acad Orthop Surg 30(17):841–850
12. Pombo B, Cristina Ferreira A, Cardoso P, Oliveira A (2020) Clinical effectiveness of Enneking appropriate versus Enneking inappropriate procedure in patients with primary osteosarcoma of the spine: a systematic review with meta-analysis. European spine journal: official publication of the European spine society, the European spinal deformity society, and the European section of the cervical. Spine Res Soc 29(2):238–247
13. Boriani S, Gasbarrini A, Bandiera S, Ghermandi R, Lador R (2017) En bloc resections in the spine: the experience of 220 patients during 25 years. World Neurosurg 98:217–229
14. Fisher CG, Saravanja DD, Dvorak MF, Rampersaud YR, Clarkson PW, Hurlbert J et al (2011) Surgical management of primary bone tumors of the spine: validation of an approach to enhance cure and reduce local recurrence. Spine 36(10):830–836
15. Charest-Morin R, Fisher CG, Varga PP, Gokaslan ZL, Rhines LD, Reynolds JJ et al (2017) En bloc resection versus intralesional surgery in the treatment of giant cell tumor of the spine. Spine 42(18):1383–1390
16. Versteeg AL, Dea N, Boriani S, Varga PP, Luzzati A, Fehlings MG et al (2017) Surgical management of spinal Osteoblastomas. J Neurosurg Spine 27(3):321–327
17. Luzzati A, Scotto G, Perrucchini G, Baaj AA, Zoccali C (2017) Salvage revision surgery after inappropriate approach for primary spine tumors: long term Follow-Up in 56 cases. World Neurosurg 98:329–333
18. Barrientos-Ruiz I, Ortiz-Cruz EJ, Serrano-Montilla J, Bernabeu-Taboada D, Pozo-Kreilinger JJ (2017) Are biopsy tracts a concern for seeding and local recurrence in sarcomas?? Clin Orthop Relat Res 475(2):511–518
19. Jin CJ, Berry-Candelario J, Reiner AS, Laufer I, Higginson DS, Schmitt AM et al (2020) Long-term outcomes of high-dose single-fraction radiosurgery for Chordomas of the spine and sacrum. J Neurosurg Spine 32(1):79–88
20. DeLaney TF, Liebsch NJ, Pedlow FX, Adams J, Weyman EA, Yeap BY et al (2014) Long-term results of phase II study of high dose photon/proton radiotherapy in the management of spine Chordomas, chondrosarcomas, and other sarcomas. J Surg Oncol 110(2):115–122
21. Indelicato DJ, Rotondo RL, Begosh-Mayne D, Scarborough MT, Gibbs CP, Morris CG, Mendenhall WM (2016) A prospective outcomes study of proton therapy for Chordomas and chondrosarcomas of the spine. Int J Radiat Oncol Biol Phys 95(1):297–303
22. Tobert DG, Kelly SP, Xiong GX, Chen YL, MacDonald SM, Bongers ME et al (2023) The impact of radiotherapy on survival after surgical resection of Chordoma with minimum five-year follow-up. Spine Journal: Official J North Am Spine Soc 23(1):34–41
23. Charest-Morin R, Boriani S, Fisher CG, Patel SR, Kawahara N, Mendel E et al (2016) Benign tumors of the spine: has new chemotherapy and interventional radiology changed the treatment paradigm?? Spine 41(Suppl 20):S178–s85
24. Beresford-Cleary N, Dandurand C, Mawhinney G, Kaiser R, Alageel M, Reynolds J (2025) The effect of denosumab on pain and radiological improvement in giant cell tumours of the spine in the acute setting. Global Spine J.:21925682251314378
25. Bandiera S, Noli LE, Griffoni C, Tosini G, Carretta E, Pasini S et al (2022) Complications and risk factors in En bloc resection of spinal tumors: A retrospective analysis on 298 patients treated in a single institution. Curr Oncol (Toronto Ont) 29(10):7842–7857
26. Kieser DC, Soltani S, Hammer N, Koutp A, Hughes E, Reynolds JJ (2021) Sacral insufficiency fractures are a risk of massive bleeding during sacrectomy: patient series. J Neurosurg Case Lessons 2(22):Case21493

Authors and Affiliations

Jonathan Jiong Hao Tan[1] · Euan Stirling[2] · Radek Kaiser[2] · Gerard Mawhinney[2,3] · Dominique Rothenfluh[4] · Yiong Huak Chan[5] · Shilin Wang[1] · Ruxandra Mihai[6] · Stana Bojanic[7] · Jeremy Reynolds[2]

✉ Jonathan Jiong Hao Tan
jonathan_jh_tan@nuhs.edu.sg

Euan Stirling
euan.stirling@ouh.nhs.uk

Radek Kaiser
radek.kaiser@ouh.nhs.uk

Gerard Mawhinney
gerard.mawhinney@ouh.nhs.uk

Dominique Rothenfluh
dominique.rothenfluh@mac.com

Yiong Huak Chan
medcyh@nus.edu.sg

Shilin Wang
wsl.wangshilin@gmail.com

Ruxandra Mihai
ruxandra.mihai@ouh.nhs.uk

Stana Bojanic
stana.bojanic@ouh.nhs.uk

Jeremy Reynolds
jeremy.reynolds@ouh.nhs.uk

[1] Department of Orthopaedic Surgery, National University Hospital, National University Health System, Singapore, Singapore

[2] Oxford Spinal Surgery Unit, Oxford University Hospitals National Health Service Foundation Trust, Oxford, UK

[3] Nuffield Department of Clinical Neurosciences, University of Oxford, Oxford, UK

[4] Department of Spinal Surgery, Lausanne University Hospital (CHUV), Lausanne, Switzerland

[5] Biostatistics Unit, Yong Loo Lin School of Medicine, National University of Singapore, Singapore, Singapore

[6] Department of Anaesthesia, Oxford University Hospitals National Health Service Foundation Trust, Oxford, UK

[7] Department of Neurosurgery, Oxford University Hospitals National Health Service Foundation Trust, Oxford, UK