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Surgical Margins and Clinicopathological Determinants of Oncologic Outcomes in Pelvic Tumour Hemipelvectomy: A Single-Centre Retrospective Review

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Abstract

Introduction: Hemipelvectomy is a complex surgical procedure used to manage primary and metastatic pelvic tumours. Achieving safe surgical margins in pelvic tumour resections remains a major challenge due to anatomical complexity and late presentation. This study evaluated the accuracy of surgical margins, associated clinicopathological factors, and their implications on oncologic outcomes following hemipelvectomy. Materials and Methods: A retrospective review of 64 patients who underwent internal or external hemipelvectomy for pelvic tumours at a single referral centrewas conducted. Data on tumour type, volume, stage, resection type, and margin status were analysed. Oncologic outcomes assessed included local recurrence, distant metastasis, and disease-specific mortality. Tumours were staged using Enneking and American Joint Committee on Cancer(AJCC) systems, and margin status was classified histologically. Statistical analyses included Kaplan-Meier survival estimates and Cox regression. Results: The mean age was 39.8 years (range 8–79). Most tumours were primary (76.6%), with chondrosarcoma and osteosarcoma being the most common. Internal hemipelvectomy was performed in 64.1% of patients. Wide resection was attempted in 37 cases, of which 14 (37.8%) resulted in positive microscopic margins. Positive margins were significantly associated with tumour volume, stage, surgical type, and resection subtype. Contaminated wide margins had a higher positivity rate (56.3%). Positive margins correlated with higher recurrence rates but paradoxically showed lower disease-specific mortality, possibly due to adjuvant therapy or selection bias. Internal hemipelvectomy was associated with better disease-specific survival. Conclusion: Multiple clinicopathological factors influence surgical margin status and oncologic outcomes. While positive margins were linked to recurrence, they were not independently predictive of mortality. The probability of achieving a clear margin was low, highlighting the need for meticulous surgical planning. Internal hemipelvectomy offers favourable survival outcomes when performed with appropriate patient selection.

Keywords: Clinicopathological Factors, Musculoskeletal Oncology, Pelvic Surgery, Prognosis, Wide Resection

Introduction

Hemipelvectomy is among the most extensive surgical procedures in musculoskeletal oncology (1), primarily indicated for pelvic neoplasms such as chondrosarcoma, osteosarcoma, and soft tissue sarcomas (2,3). It may also be performed in selected cases of metastatic

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disease or locally advanced malignancies involving the pelvic bones. While once used for trauma and infection, its current role is predominantly oncologic (4,5). Advances in multimodal treatment have enabled a shift toward internal hemipelvectomy (limb-salvage surgery), reserving external hemipelvectomy (hindquarter amputation) for cases where limb preservation is not feasible (1,6,7,8,9).

Surgical resection aims to achieve local control through en bloc removal of the tumour with a wide margin of healthy tissue (6,10,11). However, this is particularly challenging in the pelvis due to its complex anatomy (1,3). The pelvic ring, comprising the ilium, ischium, and pubis fused to the sacrum, is surrounded by dense musculature and critical neurovascular and visceral structures. Although these anatomical boundaries can restrict tumour spread, they also limit resectability, increasing the risk of marginal or intralesional resections and associated recurrence (12,13,14,15,16).

Pelvic tumours are often diagnosed late, by which time they may have reached substantial size and extended into adjacent compartments (3,17). Involvement of structures such as the lumbosacral plexus, iliac vessels, or pelvic viscera complicates surgical clearance. Despite technological advances in imaging, navigation, and adjuvant therapies, pelvic resections remain associated with higher complication and recurrence rates compared to extremity sarcomas (15,16,17,18). Experimental studies show that achieving a 10-mm margin with acceptable tolerance is successful in only about 50% of pelvic resections, reflecting the technical difficulty (19).

Achieving negative surgical margins(no microscopic residual tumour at the resection edge) is a cornerstone of curative oncologic surgery. Negative surgical margins are a critical prognostic factor, strongly correlating with lower rates of local recurrence, metastasis, and disease-specific death (2,3,7). While wide margins are ideal, their feasibility in the pelvis is often compromised by tumour extent and anatomical limitations, necessitating a careful balance between oncologic control and functional preservation (1,7).

The objective of this study is to evaluate the accuracy and outcomes of surgical margins in pelvic tumour resections and identify clinicopathologic factors associated with margin positivity. Additionally, we aim to assess the impact of surgical margins on oncologic outcomes, including local recurrence, distant metastasis, and disease-specific mortality. It also compares the oncologic outcomes of internal versus external hemipelvectomy, intending to inform surgical planning and improve prognosis in pelvic tumour management.

Materials and Methods

This retrospective cohort study was conducted at a single tertiary tumour referral centre. A total of 64 patients who underwent internal or external hemipelvectomyfor primary or metastatic pelvic bone and soft tissue tumours between January 2001 and December 2010 were included. The study was approved by the institution's human research ethics committee (FWA Reg. No: 00007718; IRB Reg. No: 00004494).

Patient Selection and Data Collection

Inclusion criteria comprised patients diagnosed with primary, recurrent, or metastatic pelvic bone or soft tissue tumours who underwent internal or external hemipelvectomy and had complete clinical, surgical, and pathological records. Patients receiving non-surgical treatments as primary therapy or those with tumours not involving bone or soft tissue were excluded. Data were retrieved from institutional records, including the Medical Record Department and the Orthopaedic Oncology and Reconstructive Unit.

Variables and Definitions

Demographic data included age and sex. Tumour characteristics assessed were histological diagnosis and grade (benign, low-grade, or high-grade), anatomical site, size,

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volume, and staging. Tumour sites were classified as iliosacral, periacetabular, ischiopubic, sacral, hemipelvis (involving multiple subregions), or femur, based on a modified Enneking and Dunham system (18,20). Tumour size was defined as the largest single dimension on magnetic resonance imaging (MRI) or computed tomography (CT), while tumour volume was calculated using ellipsoid volume formulas as described in prior literature (3,21,22,23,24) and categorised as <1500 cm³, 1500–3000 cm³, or >3000 cm³.

Staging was performed using both the Musculoskeletal Tumor Society (MSTS/Enneking) system and the American Joint Committee on Cancer (AJCC) staging system. The Enneking system classifies tumours based on grade (G), anatomical compartment (T), and metastasis (M), with further correlation to anticipated surgical margins (25). It is most applicable to mesenchymal tumours and was used alongside AJCC staging, which is more widely applicable across tumour types and includes nodal status and tumour size criteria (26).

Presence of metastases at presentation (particularly pulmonary or distant organ involvement) was documented. Treatment variables included neoadjuvant therapy (chemotherapy, radiotherapy, or both), surgical intent (curative or palliative), type of surgical procedure, and classification of surgical margins.

Surgical Procedures

Surgical resections were classified as internal or external hemipelvectomy. Internal hemipelvectomy involved limb-sparing resections of the pelvic bone while preserving the ipsilateral lower limb and major neurovascular structures. The type of resection (Types I–IV) was defined anatomically according to Enneking and Dunham’s zones (18,20). Candidates for internal hemipelvectomy were selected based on the feasibility of achieving a negative margin and preservation of at least two of the following: the hip joint, lumbosacral plexus, or femoral neurovascular bundle.

External hemipelvectomy involved resection of the affected hemipelvis along with the ipsilateral lower limb. Variants included standard, modified (preserving part of the iliac crest), extended (involving adjacent musculoskeletal structures), or compound procedures (involving adjacent pelvic organs) as indicated by the extent of tumour involvement (27).

Margin Classification

Surgical margins were categorised using the Enneking classification into intralesional, marginal, wide, and wide-contaminated. Radical resections (removal of the entire involved compartment) were also considered. Intralesional resections traverse the tumour pseudocapsule; marginal resections pass through the reactive zone; and wide resections include a cuff of healthy tissue. Wide-contaminated resections referred to intended wide margins with intraoperative tumour violation. Microscopic margins were classified as positive or negative based on histopathological examination (25).

Outcome Measures

The primary outcomes were time to first local recurrence, distant metastasis, and disease-specific death. Local recurrence was defined as clinical, radiological, or histological evidence of tumour of the same histologic type occurring within or adjacent to the original tumour bed ≥3 months postoperatively. Distant metastasis refers to radiological or clinical evidence of disease beyond the primary site. Disease-specific death was defined as mortality directly attributable to the tumour or its progression.

Statistical Analysis

Data analysis was performed using Kaplan-Meier survival analysis to estimate disease-specific survival. Associations between surgical margin status and oncologic outcomes were evaluated using Cox proportional hazards models, adjusting for

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confounding variables such as tumour volume, stage, and type of surgery. Statistical significance was defined as $p < 0.05$.

Results

Patient Demographics

A total of 64 patients were included in this study, with a mean age at surgery of 39.84 years (SD = 16.19; range: 8–79 years). The most represented age group was 50–59 years. There was a slight male predominance, with 33 male (51.6%) and 31 female (48.4%) patients.

Tumour Characteristics and Histopathology

The majority of patients (76.6%) presented with primary tumours, while 14.1% had recurrent disease and 9.4% had metastatic tumours. Soft tissue sarcoma was the most frequent histological group (26.6%), with most cases (15 of 16) being high grade. Among bone sarcomas, chondrosarcoma (21.9%) and osteosarcoma (20.3%) were the most common, with 5 of 14 chondrosarcomas and all osteosarcomas being high grade. Other tumour types included sacral chordoma (n = 5), metastatic bone disease (n = 4), and squamous cell carcinoma (n = 2).Benign tumours included six cases of giant cell tumour and three cases of other benign bone or soft tissue lesions.

At presentation, 21 patients had radiologic or clinical evidence of metastasis. Pulmonary metastases were observed in 14.1% of cases, and four patients had other distant metastases,including lymph nodes, liver, or skeletal involvement. Several patients exhibited both pulmonary and other systemic metastases.

Treatment and Surgical Intervention

Most patients (75.0%) did not receive any form of neoadjuvant therapy before surgery. Chemotherapy alone was administered in selected cases of osteosarcoma, soft tissue sarcoma, and metastatic disease (12.5%), while a combination of chemotherapy and radiotherapy was used in only three cases (4.7%), primarily among chondrosarcoma and osteosarcoma patients. None of the metastatic cases received radiotherapy alone.

Surgery was performed with curative intent in 71.9% of cases, while 18.8% underwent surgery for palliative purposes, predominantly in the external hemipelvectomy group (Fig. 1(A)). Of the 64 cases, 41 (64.1%)

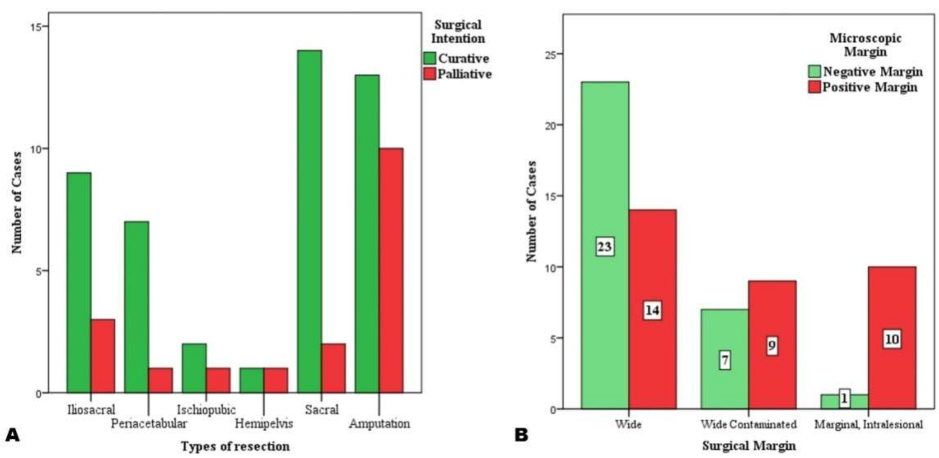

Fig. 1:(A) Distribution of pelvic tumour cases stratified by type of resection and surgical intent (curative vs palliative), and (B)comparison of the number of cases achieving negative versus positive microscopic margins across different categories of surgical margins, including wide, wide-contaminated, marginal, and intralesional resections.

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underwent internal hemipelvectomy and 23 (35.9%) underwent external hemipelvectomy.

Surgical Margin Analysis

Wide surgical margins were achieved in 37 cases, with 16 classified as wide but contaminated intra-operatively, and 11 as marginal or intralesional resections (Fig. 1(B). Among tumours <1500 cm³, most (25 cases) had wide margins, while larger tumours were more likely to be associated with contaminated or inadequate margins. Of the 37 intended wide resections, 14 (37.8%) were found to have positive microscopic margins. This rate was higher in cases where the wide margin was contaminated intra-operatively (56.3%).

Oncologic Outcomes: Recurrence and Survival

The mean follow-up for patients alive at the time of analysis was 20.3 months (range: 1–110 months). Local recurrence was identified in 12 patients (18.8%), with 75.0% of these cases having had positive microscopic margins. The 1-year and 5-year local recurrence-free survival rates were 80.8% and 68.2%, respectively (Fig. 2(A)). Distant recurrence occurred in 10 patients (15.6%), with 70.0% having positive margins. The corresponding 1-year and 5-year distant recurrence-free survival rates were 97.7% and 82.5% (Fig. 2(B)).

The 1-year and 5-year disease-specific survivalrates were 73.9% and 67.2%, respectively (Fig. 2(C)). At final follow-up, 27 patients (42.2%) were alive without disease, and 15 (23.4%) had died from their disease.

Prognostic Impact of Microscopic Margins

Of the 64 patients, 33 (51.6%) had positive and 31 (48.4%) had negative microscopic margins. The risk of local recurrence with positive margins was 14.1% versus 4.7% for those with negative margins (Table 1), although this difference did not reach statistical significance in univariate analysis (Table 2). The 1-year local recurrence-free survival rates were 94.0% for

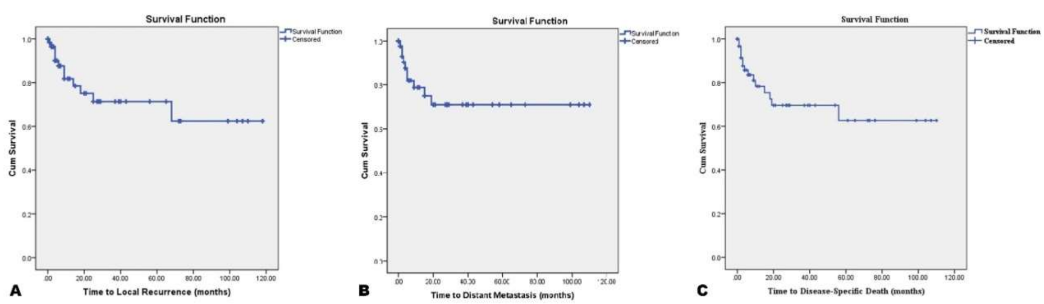

Fig. 2: Kaplan–Meier survival curves for the entire cohort depicting time to (A) local recurrence, (B) distant recurrence (metastasis), and (C) disease-specific death following pelvic tumour resection.

Table 1: Distribution of local and distant recurrence, and disease status at last follow-up according to the microscopic margin status.

Margin status	n (%)	Local recurrence	Distant recurrence (metastases)	Status at last follow-up				
				NED	AWD	DOD	DWD	DNE
Negative	31 (48.4)	3 (4.7)	3 (4.7)	12 (18.8)	5 (7.8)	10 (15.6)	3 (4.7)	1 (1.6)
Positive	33 (55.6)	9 (14.1)	7 (10.9)	15 (23.4)	11 (17.2)	5 (7.81)	2 (3.1)	0 (0)

NED: alive, no evidence of disease, AWD: alive with disease, DOD: died of disease, DWD: died with disease (but not the cause of death), DNE: died, no evidence of disease

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patients with negative margins and 73.0% for those with positive margins. Tumour volume, microscopic margin status, and AJCC staging demonstrated the strongest (albeit not statistically significant) influence on local recurrence-free survival (Table 2 and Fig. 3(A)).

For distant metastasis, positive microscopic margins were again associated with a higher risk, but the difference was not statistically significant. The 1-year distant metastasis-free survival rates were 83.3% for patients with negative margins and 75.5% for those with positive margins. Due to the limited number of samples available, the 5-year distant metastases-free survival rates could not be accurately ascertained for statistical significance (Table 2 and Fig. 3(B)). Histological grade and AJCC stage were significantly associated with distant recurrence in overall comparisons but lost significance after correction using Bonferroni adjustment (Table 2 and Fig. 3(C)).

Disease-Specific Mortality

Interestingly, the presence of a positive microscopic margin was associated with a lower rate of tumour-related death (7.8%) compared to negative margins (15.6%) (Table 1). The 1-year disease-specific survival was 82.1% for positive margins and 74.2% for negative margins (Table 2). However, this difference was not statistically significant in univariate analysis (Table 3).

Significant predictors of disease-specific mortality included the type of hemipelvectomy ($p = 0.010$), histological diagnosis ($p = 0.012$), and tumour stage as per both the MSTS ($p < 0.001$) and AJCC ($p = 0.003$) systems. Pairwise comparisons with Bonferroni correction revealed significant survival differences between osteosarcoma and squamous cell carcinoma, as well as between MSTS stage III and lower-stage tumours. However, comparisons across AJCC stages did not yield statistically significant differences after correction (Table 3 and Fig. 4).

Discussion

Significance of Surgical Margins in Pelvic Tumour Resection

Achieving negative surgical margins in pelvic tumour resections remains challenging due to the anatomical complexity of the pelvis and the proximity of tumours to critical neurovascular and visceral structures. This study reinforces prior findings that positive microscopic margins are associated with increased local and distant recurrence rates (2,3,7). However, an unexpected observation was the lower disease-specific mortality among patients with positive margins, possibly due to selection bias, tumour biology, or intensified adjuvant therapy in those patients.

Although the Enneking classification is widely used to describe surgical margins and guide resection strategies (18,20,25),its compartment-based concept has limitations in anatomically complex regions like the pelvis. Kawaguchi and others have proposed more nuanced approaches that emphasise margin distance rather than anatomical compartments. This refinement was intended to reduce ambiguity in margin assessment, though its complexity has limited widespread adoption (28,29). While alternative systems such as the Union for International Cancer Control (UICC)/AJCC, Federation Nationale des Centres de Lutte Contre le Cancer (FNCLCC), and the Toronto Margin Context Classification (TMCC) offer broader frameworks for margin evaluation and staging, Enneking's system remains widely used due to its simplicity and adaptability. Accurate margin assessment, however, requires close collaboration between the surgeon and the pathologist to ensure consistency in interpretation and reporting.

Prognostic Factors and Patterns of Resection

Multiple prognostic factors were identified to influence oncologic outcomes, including tumour volume, histological subtype, staging, and type of surgery. Larger tumour volumes and advanced tumour stages

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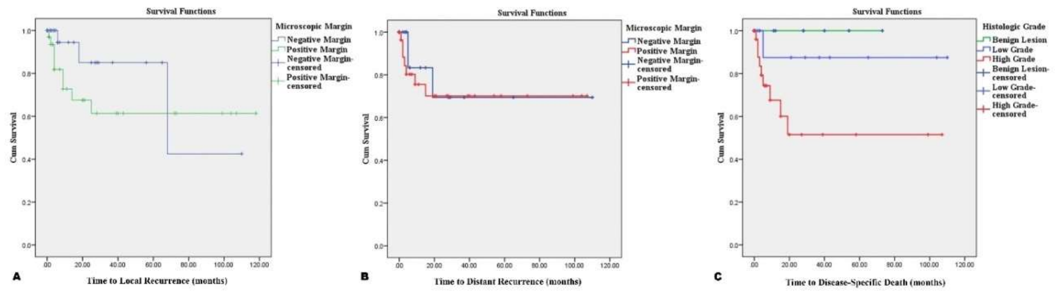

Fig. 3: Kaplan–Meier survival curves illustrating the impact of microscopic resection margin on (A) local recurrence-free survival and (B) distant metastasis-free survival, as well as (C) the influence of histological grading on distant metastasis-free survival following hemipelvectomy.

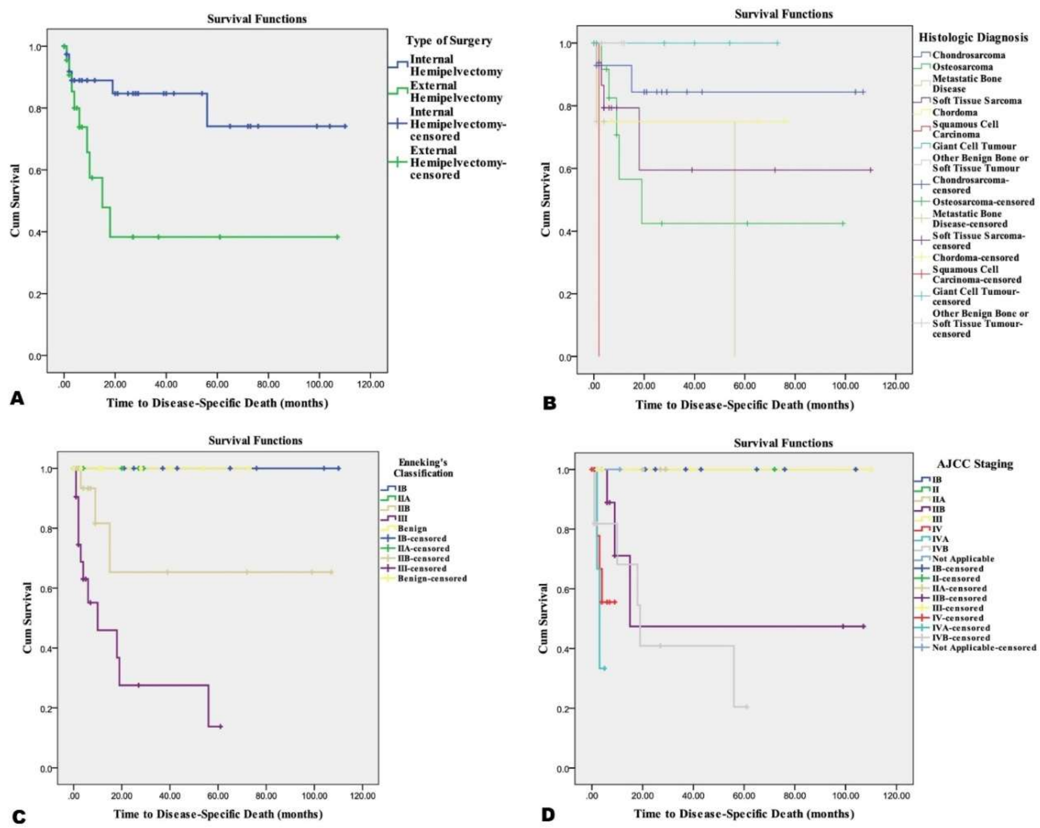

Fig. 4: Kaplan–Meier survival curves depicting the influence of key clinicopathological factors on disease-specific survival, including (A) type of hemipelvectomy performed, (B) histological diagnosis, (C) tumour stage according to the Musculoskeletal Tumor Society (MSTS) staging system, and (D) tumour stage based on the American Joint Committee on Cancer (AJCC) staging system.

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Table 2: One-year actuarial and crude rates of local recurrence-free and distantrecurrence-free survival according to clinical and pathological prognostic factors.

Variables	Local recurrence-free survival			Distant recurrence-free survival		
	p-value	Crude rate	1-year (%)	p-value	Crude rate	1-year (%)
Age (years)	0.834			0.834		
<50		34/43	74.4		34/43	77.1
≥50		18/21	79.4		20/21	94.7
Gender	0.431			0.321		
Male		26/33	77.1		28/33	76.6
Female		26/31	84.3		26/31	86.9
Types of surgery	0.247			0.783		
Internal hemipelvectomy		31/41	78.8		34/41	81.1
External hemipelvectomy		21/23	79.7		20/23	73.4
Histological diagnosis	0.736*			0.623*		
Chondrosarcoma (CS)		12/14	90.9		13/14	90.0
Osteosarcoma (OS)		10/13	64.6		10/13	75.0
Metastatic bone disease		4/4	100		4/4	100
Soft tissue sarcoma (STS)		12/17	62.5		12/17	40.0
Chordoma		4/5	66.7		4/5	66.7
Squamous cell carcinoma		2/2	100		2/2	100
Giant cell tumour (GCT)		5/6	80.0		6/6	100
Other benign tumours		3/3	100		3/3	100
Pairwise comparison**						
CS vs STS				0.013		
GCT vs STS				0.050		
Grade	0.267*			0.042*		
Low grade		16/18	90.9		17/18	87.5
High grade		28/37	73.7		28/37	67.6
Benign		8/9	87.5		9/9	100
Pairwise comparison**						
High grade vs benign				0.043		
Tumour volume (cm^3)	0.179*					
<1500		38/47	82.1		39/47	80.3
1500-3000		5/6	66.7		5/6	66.7
>3000		1/3	66.7		3/3	100
Volume not calculated		7/8	66.7		7/8	66.7
Anatomical site	0.454*			0.894*		
Iliosacral		11/15	73.0		12/15	71.1
Periacetabular		8/12	66.7		9/12	67.5
Ischiopubic		5/5	100		5/5	100
Hemipelvis		9/9	100		8/9	83.3

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Sacrum		12/16	84.4		13/16	82.5
Femur		7/7	100		7/7	100
Stage						
MSTS	0.345*			0.028*		
IB		9/10	100		9/10	87.5
IIA		2/4	100		4/4	100
IIB		15/19	64.3		13/19	57.5
III		18/22	76.4		20/22	66.7
Benign		8/9	87.5		9/9	100
Pairwise comparison**						
IB vs IIA	0.002					
Benign vs IIB				0.049		
Benign vs III				0.028		
AJCC	0.151*			<0.001*		
IB		8/9	100		8/9	85.7
II		1/1	100		0/1	0
IIA		2/4	100		3/4	100
IIB		9/12	64.0		10/12	77.8
III		5/5	100		4/5	75.0
IV		7/10	63.0		8/10	75.0
IVA		3/3	100		3/3	100
IVB		9/11	83.3		9/11	66.7
Pairwise comparison**						
IB vs II	0.005					
IB vs IIA				0.004		
IB vs IV				0.011		
II vs IIA	0.046					
II vs IIB	0.002					
II vs III	0.046					
II vs IV	0.046					
II vs IVB	0.046					
Surgical margin	0.680*			0.845*		
Wide		31/37	81.5		32/37	79.1
Wide contaminated		12/16	82.5		13/16	75.0
Marginal, intralesional		9/11	77.1		9/11	80.8
Microscopic margin	0.194*			0.634		
Negative		28/31	94.4		28/31	83.3
Positive		24/33	72.7		26/33	75.5

*p-value for overall comparison using Log Rank (Mantel-Cox).
**Results of p-value for pairwise comparison using Log Rank (Mantel-Cox), which are mostprobable for statistical significance after Bonferroni correction. However, p-value is onlyconsidered statistically significant after pairwise testing with multiple Bonferroni corrections.
AJCC: American Joint Committee on Cancer, MSTS: Musculoskeletal Tumor Society.

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Table 3: One-year actuarial and crude rates of disease-specific survival according to clinical and pathological prognostic factors.

Variables	Disease-specific survival		
	p-value	Crude rate	1-year (%)
Age (years)	0.333*		
<50		34/43	80.8
≥50		15/21	94.7
Gender	0.111*		
Male		23/33	71.9
Female		26/31	84.4
Types of surgery	0.010*		
Internal hemipelvectomy		35/41	88.9
External hemipelvectomy		14/23	57.4
Histological diagnosis	0.012*		
Chondrosarcoma (CS)		12/14	92.9
Osteosarcoma (OS)		8/13	56.6
Metastatic bone disease		2/4	75.0
Soft tissue sarcoma (STS)		13/17	79.3
Chordoma		4/5	75.0
Squamous cell carcinoma (SCC)		1/2	0
Giant cell tumour (GCT)		6/6	100
Other benign tumours		3/3	100
Pairwise comparison**			
CS vs SCC	0.019		
OS vs SCC	0.001		
STS vs SCC	0.006		
GCT vs SCC	0.025		
Grade	0.078*		
Low grade		15/18	86.5
High grade		25/37	82.4
Benign		9/9	100
Pairwise comparison**			
High grade vs benign	0.042		
Tumour volume (cm^3)	0.591*		
<1500		34/47	74.8
1500-3000		6/6	100
>3000		2/3	0
Volume not calculated		7/8	66.7
Anatomical site	0.152*		
Iliosacral (IS)		10/15	92.9
Periacetabular (P)		10/12	72.9
Ischiopubic (IP)		3/5	50.0
Hemipelvis (H)		5/9	51.9

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	Sacrum (S)		15/16	92.9
	Femur (F)		6/7	75.0
	Pairwise comparison**			
	IS vs S	0.033		
	IP vs S	0.048		
	H vs S	0.027		
Stage				
	MSTS	<0.001*		
	IB		10/10	100
	IIA		4/4	100
	IIB		16/19	81.7
	III		10/22	46.0
	Benign		9/9	100
	Pairwise comparison**			
	IB vs IIB	0.067		
	IB vs III	0.001		
	IIA vs III	0.046		
	IIB vs III	0.015		
	Benign vs III	0.004		
	AJCC	0.003*		
	IB		9/9	100
	II		1/1	100
	IIA		4/4	100
	IIB		9/12	71.1
	III		5/5	100
	IV		6/10	55.6
	IVA		1/3	33.3
	IVB		5/11	68.2
	Pairwise comparison**			
	IB vs IIB	0.028		
	IB vs IV	0.032		
	IB vs IVA	0.009		
	IB vs IV	0.005		
	IIB vs IVA	0.004		
	III vs IVA	0.093		
Surgical margin		0.194*		
	Wide		29/37	76.6
	Wide contaminated		10/16	70.7
	Marginal, intralesional		10/11	90.0
Microscopic margin		0.084*		
	Negative		21/31	74.2
	Positive		28/33	82.1
Neoadjuvant therapy		0.679*		

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	Chemotherapy		6/8	66.7
	Radiotherapy		5/5	100
	Both		2/3	50.0
	None		36/48	77.8
Adjuvant therapy		0.587*		
	Chemotherapy		8/10	71.1
	Radiotherapy		15/18	86.6
	Both		4/8	72.9
	None		22/28	76.5

*p-value for overall comparison using Log Rank (Mantel-Cox).
**Results of p-value for pairwise comparison using Log Rank (Mantel-Cox), which are mostprobable for statistical significance after Bonferroni correction. However, p-value is onlyconsidered statistically significant after pairwise testing with multiple Bonferroni corrections.
AJCC: American Joint Committee on Cancer, MSTS: Musculoskeletal Tumor Society.

were predictive of both margin positivity and poorer survival outcomes. These findings highlight the importance of early diagnosis, meticulous preoperative planning, and strategic surgical decision-making (17).

In this study, internal hemipelvectomy, typically reserved for less extensive disease, was associated with better disease-specific survivalcompared to external hemipelvectomy. This may reflect selection criteria, as internal hemipelvectomy was typically reserved for patients with more localised disease, amenable to limb salvage, and presumably better tumour biology (7). Internal hemipelvectomy also potentially allows more frequent or effective adjuvant treatment and postoperative monitoring, thus improving outcomes and quality of life.

The positive margin rate after attempted wide resection remained relatively high. When the wide margin was contaminated intraoperatively, the incidence of positive microscopic margins rose to 56.3%, highlighting the difficulty in achieving true wide margins, even when technically attempted (2).This supports the notion raised by Kawaguchi et al. that conventional margin definitions may be insufficient in certain anatomical contexts, and margin adequacy should be evaluated relative to both the tumour biology and anatomical limitations (28).

Tumour Distribution and Histological Trends

Chondrosarcoma remained the most common bone tumour in our series (2), but soft tissue sarcomas were more frequent overall. The predominance of sacral tumours likely reflects surgical preference for resectable lesions with better functional outcomes. Tumour volume was evaluated as a potential prognostic factor, but no statistically significant association was found. likely due to limited sample size. The use of tumour volume, rather than size alone, as a predictor of recurrence and metastasis has gained interest, as previously proposed (3,22,30).

Clinical Indications for Hemipelvectomy

The primary indication for hemipelvectomy in this cohort was sarcoma, accounting for 42.2% of cases. A unique feature of our study was the relatively high number of benign tumours (9 cases), including one case of an extensive aneurysmal bone cyst requiring external hemipelvectomy. Two patients underwent external hemipelvectomy for metastatic squamous cell carcinoma for palliative purposes. Both patients achieved negative surgical margins and short-term local control; however, they succumbed to disease within weeks. These findings illustrate the complex ethical and clinical considerations

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surrounding palliative hemipelvectomy. While such procedures may provide symptom relief, especially in cases of intractable pain, bleeding, infection, or fungation,their impact on overall survival is limited, and the decision must be weighed against the invasiveness of the surgery and expected life expectancy. As Baliski et al. noted, external hemipelvectomy with palliative intent remains controversial, particularly when survival is anticipated to be under 12 months (8).

Survival Analysis and Margin Paradox

The survival trends observed in our cohort reinforce previous reports (2). Long-term prognosis was notably better among patients with bone sarcomas, with disease-specific survival approaching 90% in selected cases. The 1-year and 5-year local recurrence-free survival rates for the overall cohort were 80.8% and 68.2%, respectively. The lowest survival rates were seen in patients with soft tissue sarcomas and sacral chordomas, in line with findings by Kawai et al. (15,16).

Among the prognostic factors evaluated, tumour stage and histological subtype were the most predictive of local recurrence, distant metastasis, and disease-specific mortality (17). The Enneking staging system, commonly applied to bone sarcomas, offers detailed musculoskeletal-specific stratification, particularly in distinguishing intra- versus extracompartmental spread. However, it is limited in scope across diverse histologies. In contrast, the American Joint Committee on Cancer (AJCC) staging system provides broader applicability, particularly for soft tissue sarcomas, and facilitates cross-comparison among tumour types. In this cohort, Enneking staging correlated more strongly with disease-specific mortality, whereas AJCC staging demonstrated better predictive accuracy for local and distant recurrence. Nonetheless, these differences lost statistical significance following Bonferroni correction, highlighting the need for integrated or context-specific staging frameworks in complex pelvic tumours.

Staging remains fundamental in pelvic oncology, informing treatment planning, surgical approach, and prognostic estimation. It integrates clinical assessment, cross-sectional imaging, and histopathological evaluation, with biopsy confirming tumour grade and extent. Accurate staging not only optimises surgical decision-making but also aids in determining the necessity and timing of neoadjuvant or adjuvant therapies. A dual-system approach, employing both Enneking and AJCC criteria where appropriate, may enhance risk stratification and multidisciplinary coordination in musculoskeletal oncologic care.

Despite higher recurrence rates with positive margins, their impact on disease-specific mortality was not statistically significant. The 1-year disease-specific survival was higher among those with positive margins (82.1%) than those with negative margins (74.2%), possibly reflecting delayed mortality following recurrence or variations in follow-up and treatment adherence (2).

Study Limitations and Future Directions

This study is limited by its retrospective design, single-centre setting, and relatively small cohort. Potential selection bias, tumour heterogeneity, and variability in surgical and adjuvant treatments may have influenced the outcomes. Future research should prioritise prospective, multicentre studies with standardised protocols and extended follow-up to better capture long-term oncologic endpoints. The integration of advanced imaging, intraoperative navigation, and contemporary margin classification systems, such as those proposed by Kawaguchi et al. or the TMCC (28), along with molecular profiling and targeted therapies, may refine surgical planning and improve outcomes in pelvic tumour management.

Conclusion

Hemipelvectomy remains a challenging but essential surgical option in the management of pelvic musculoskeletal tumours. Achieving negative margins is

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critical for effective local control yet is often limited by tumour extent and pelvic anatomy. In this cohort, internal hemipelvectomy was associated with better disease-specific survival, highlighting the value of appropriate patient selection and tailored surgical planning. Although positive margins were linked to higher recurrence, their impact on mortality may be mitigated by tumour biology and adjuvant therapies. When performed with curative intent, hemipelvectomy can yield acceptable oncologic outcomes. In palliative settings, the decision must balance surgical morbidity with expected symptom relief, warranting further studies focused on postoperative quality of life.

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Conflicts of Interest

The authors declare no conflicts of interest related to the conduct, authorship, or publication of this study

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