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Patient survival after surgical resection of pelvic bone sarcomas: A nationwide cohort study

Preživetje bolnikov po kirurški resekciji sarkomov medeničnih kosti: nacionalna kohortna raziskava

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Abstract

Background: Pelvic bone sarcomas are extremely rare malignant tumours. Patients require a multidisciplinary approach to plan the treatment and complex surgical resections and limb-sparing reconstructions associated with complications, revisions, and functional limitations. The presented nationwide study in the Republic of Slovenia aims to analyse the oncological survival and functional outcomes of patients after primary resection of pelvic bone sarcomas.

Methods: The retrospective observational cohort included 21 consecutive patients who underwent limb-sparing pelvic resection at a specialized orthopaedic oncology centre in the Republic of Slovenia between 2004-2022. Patient survival, complication rates, and functional outcomes were analysed according to to the primary diagnosis.

Results: Wide margins with R0 resection were achieved in 16 (76%) cases. After a median follow-up of 5.7 (0.6-18.1) years, 7 (33%) patients died of oncological disease, 3 (14%) patients were alive with oncological disease, and 11 (53%) patients were alive with no evidence of disease. The estimated Kaplan-Meier survival probability at 2 years, 5 years, and 10 years after pelvic resection was 85%, 73%, and 45%, respectively. The major complication rate was 29%. The mean Musculoskeletal Tumour Society Score was 17.5 (range 2-29).

Conclusions: Patient survival after resection of pelvic bone sarcomas in Slovenia between 2004-2022 is comparable to previously published reports of European and North American countries. Wide resection of tumours with reconstruction provides a relatively good survival rate, although complications are common and functional outcomes are often poor.

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Izvleček

Izhodišča: Sarkomi kosti medenice so izjemno redki maligni tumorji. Zdravljenje bolnikov vključuje multidisciplinarno obravnavo in načrt zdravljenja z zahtevno kirurško resekcijo in po možnosti z rekonstrukcijo, ki ohrani spodnje ude. Takšni posegi so povezani z zapleti, revizijami in funkcionalnimi omejitvami. Namen prve nacionalne kohortne raziskave v Republiki Sloveniji je bil oceniti onkološko preživetje in funkcionalni izid pri bolnikih po primarni resekciji sarkomov kosti medenice.

Metode: Retrospektivna opazovalna kohorta je vključevala 21 zaporednih bolnikov, ki so jim v obdobju 2004–2022 v specializirani ortopedsko-onkološki ustanovi opravili resekcijo medenice z ohranitvijo spodnjih udov. Analizirali smo preživetje bolnikov, pogostost zapletov in funkcionalne izide glede na primarno diagnozo.

Rezultati: Široka resekcija R0 je bila dosežena v 16 (76 %) primerih. Po povprečnem obdobju spremljanja po operaciji 5,7 (0,6–18,1) let je 7 (33 %) bolnikov umrlo zaradi onkološke bolezni, 3 (14 %) bolniki so bili živi z onkološko boleznijo in 11 (53 %) bolnikov je bilo živih in brez znakov bolezni. Ocenjena verjetnost preživetja s Kaplan-Meierjevo metodo 2 leti, 5 let in 10 let po resekciji medenice je znašala 85 %, 73 % in 45 %. Stopnja večjih zapletov je znašala 29 %. Povprečna ocena funkcionalne zmogljivosti po lestvici *Musculoskeletal Tumour Society* je bila 17,5 (razpon 2–29).

Zaključki: Preživetje bolnikov po resekciji medeničnih tumorjev v Sloveniji v obdobju 2004-2022 je primerljivo z doslej objavljenimi poročili evropskih in severnoameriških držav. Široka resekcija tumorjev z rekonstrukcijo zagotavlja sorazmerno ugodno stopnjo preživetja, čeprav so zapleti pogosti in funkcionalni rezultati večinoma neugodni.

1 Introduction

Bone sarcomas of the pelvis are extremely rare lesions that are difficult to treat, with an incidence of 0.16% of all tumours (1). Surgical resection has become the mainstay of treatment, with the primary goal of radical removal of the tumour (2). Although this was once possible only by hindquarter amputation, limb-sparing techniques are now increasingly used (3). The current standard of care for pelvic girdle sarcomas includes biopsy, a multidisciplinary approach with wide limb-sparing surgical resection that often requires internal hemipelvectomy, and reconstruction, with or without (neo)adjuvant chemotherapy or radiotherapy, depending on the histologic nature of the tumour. Pelvic tumours tend to have a worse prognosis due to the delayed diagnosis being discovered late due to obscure location, which may be associated with nonspecific symptoms, inadequate surgical margins, and presence of distant metastases at the time of diagnosis (4-7). Preservation of muscle, bone and neurovascular structures may improve the surgeon's ability to achieve good reconstruction and reduce the likelihood of complications, thereby improving short- and long-term functional outcomes (8).

1.1 Surgical technique

Tumour surgery in the pelvic region has the highest rate of complications, infection, and mechanical failure of any anatomic site. Thorough knowledge of pelvic anatomy is crucial. Preoperative planning is critical for achieving an optional oncologic and functional surgical outcome. At our institution, contrast-enhanced magnetic resonance imaging (MRI) of the pelvis, computed tomography (CT) of the abdominal and thoracic cavity, and skeletal scintigraphy are performed. Imaging studies help to determine the stage of disease, the size and extent of the tumour, the involvement of critical adjacent structures, and the type of pelvic resection and reconstruction that may be performed. They can also be used for computer-assisted navigation during resection.

The biopsy should preferably be performed by the same surgeon who will perform the subsequent resection. Established guidelines for incision placement within the line of eventual resection line should be followed (from the pubic tubercle to the anterior iliac spine, then along the top of the iliac crest and behind towards the sacrum), and contamination of the surrounding area should be minimised. The purpose of the biopsy is to establish a tumour diagnosis. At our institution, a biopsy is usually performed using CT guidance.

Anatomic consideration about the extent of the pelvic tumour and the critical structures to be reviewed after imaging studies and diagnosis include (from posterior to anterior): sacrum with neural foramina and

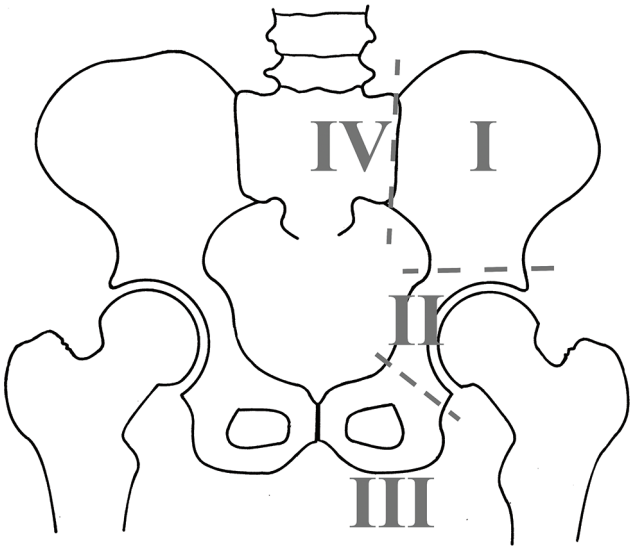

Figure 1: Four types of pelvic resections: iliac (I), periacetabular (II), pubis with the pelvic floor (III), and lateral part of the sacrum (IV).

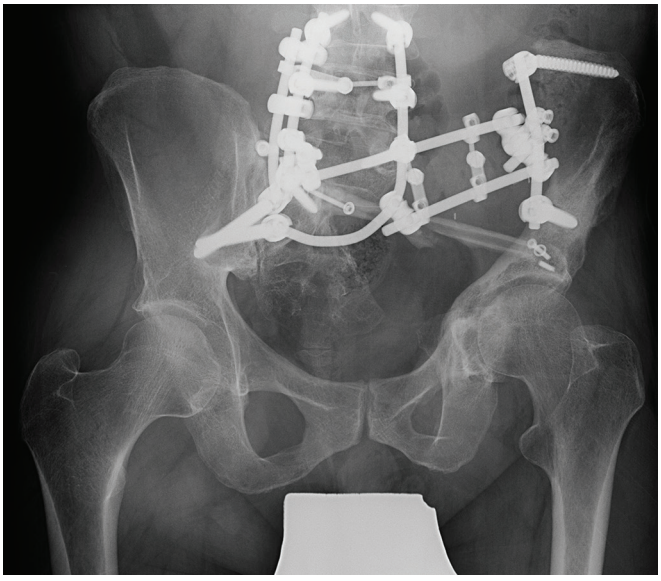

Figure 2: Postoperative radiograph of left iliac and sacral (I + IV) resection with reconstruction to the lumbar spine and contralateral ilium.

sacral nerve roots, sacral ala and sacroiliac joint, iliac artery and vein, the ureter, the sciatic notch which is a common landmark for osteotomy and is divided by the piriformis muscle, the iliac bone and iliac muscle, which is an important barrier for tumour spread, the pubic bone and the pubic rami, the femoral neurovascular bundle and finally the urethra, that passes under the symphysis pubis. Involvement of the pelvic viscera is rare. Nowadays, resection is possible with the help of CT guidance and intraoperative computer navigation.

Figure 1 shows four types of pelvic resections: iliac (I), periacetabular (II), pubic with the pelvic floor (III), and lateral part of the sacrum (IV). A combination of different types is possible. Internal hemipelvectomy includes type I + II + III. The utilitarian pelvic incision is used for most resections. The iliac resection includes a portion of the pelvic bone with the surrounding musculature and is the least extensive resection. Reconstruction is rarely required, and an allograft is used as an option. Periacetabular resection includes both the extra-pelvic and internal aspects of resection. The internal aspect includes identification of the iliac vessels, hypogastric artery, femoral nerve, and sciatic nerve, mobilization, and retraction. The external aspect involves gluteal and proximal femoral mobilization (in case of articular extension of the tumour). Osteotomies are then performed through the ilium, ischium, and ramus pubis with extraarticular osteotomy of the proximal femur. In most cases, endoprosthetic reconstruction of the pelvis and proximal femur with reattachment of the abductor mechanism is possible. A utilitarian pelvic incision with perineal extension is used to resect the pelvic floor. Large musculocutaneous flaps are elevated. The spermatic cord, bladder, and neurovascular bundle (artery, vein, and femoral nerve) are retracted. The origins of the pelvic floor muscles are transacted, and an osteotomy is performed through the symphysis pubis and pubic rami. Surgical wounds around the groin are associated with a high complication rate. Reconstruction of the pelvic floor is rarely required. Sacral resection may require stabilization of the spine to the remaining iliac crests (Figure 2). Hemipelvectomy combines some or most of the previously mentioned techniques, from the pubic symphysis to the sacroiliac joint, the sacrum, and sometimes even the lumbar spine. The procedure is highly demanding, with copious blood loss, challenging resection involving many vital structures, and complex reconstruction due to the insufficient remaining bone to anchor and properly align the arthroplasty. Early and late complication rates are very high (9).

1.2 Computer-assisted navigation

Computer-assisted navigation is a valuable tool for both, preoperative planning of resection and the resection itself. It has been increasingly introduced and used in recent years. The software (Ekliptik Ltd., Ljubljana, Slovenia) is used to create 3D models of bone from CT data. The bony extent of the tumour with its

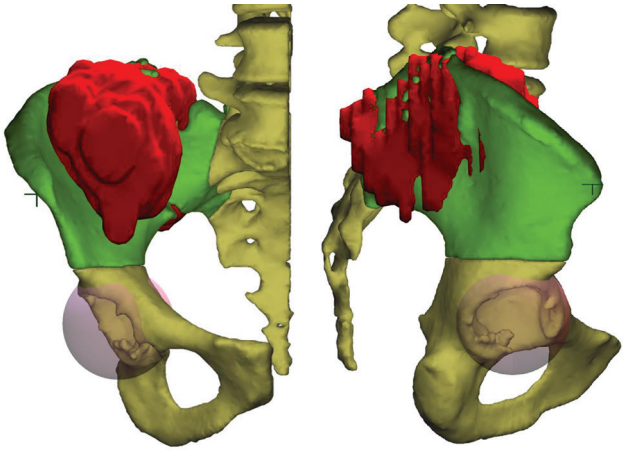

Figure 3: Preoperative plan for combined right iliac and sacral resection (coronal and sagittal plane). Tumour extension is marked in red.

soft tissue component is defined, and the virtual plane of osteotomy is performed on the images to create the postoperative 3D model (Figure 3). The surgeon-based preferences can be implemented at this stage, and data are exported and transferred to the surgical navigation platform GUIDING STAR® (Ekliptik Ltd., Ljubljana, Slovenia).

The navigation system consists of a computer and electromagnetic tracking hardware. The hardware uses magnetic pulses to determine the position of the probes and guides in real-time. The transmitter is attached to a flexible arm, and two tracking probes are used: a reference probe, which is firmly anchored in the bone, and the tool probe, which is attached to a pointing device or another instrument. Registration of the virtual model to the actual physical bone structure is performed by touching points distributed on the exposed bone surface. The system is ready for soft tissue navigation around the tumour and osteotomy at this stage. Instruments are advanced, and the entire procedure is monitored by the navigation system, with the resection area and depth shown on display in a real-time 3D view.

1.3 Study aim

So far, reports on pelvic resections have been either limited to single oncological centres covering an undefined referential territory (10,11) or based on cancer registries with pooled data from various hospitals and uncontrolled variability of decision making and surgical treatment performance (12-14). In the Republic of Slovenia, oncological patients' data has been systematically followed in the Cancer Registry since 1957 (15), but results of pelvic resections have not been published. The demographics of this country (2 million inhabitants on an area of 20,273 km2) represent a unique opportunity to evaluate nationwide results of surgical treatment in all pelvic tumours, treated at a single centre and evaluated by a single tumour board with uniform guidelines and centralized follow-up.

The presented observational nationwide study was aimed to estimate the postoperative survival probability of the entire cohort of patients in the Republic of Slovenia who had a limb-sparing primary resection for pelvic bone sarcoma in the period 2004-2022. Furthermore, we compared oncological survival and functional outcomes with the published data from other European and North American countries.

2 Methods

The retrospective observational cohort consisted of 21 consecutive patients with a limb-sparing primary resection of a pelvic bone sarcoma performed at a single tertiary tumour centre (Department of Orthopaedic Surgery, University Hospital Ljubljana, Slovenia) between July 1 2004 and June 30 2022. This is the only institution in Slovenia with facilities to perform oncologic resections of pelvic bone tumours. As part of the sarcoma multidisciplinary team at the Institute of Oncology Ljubljana, we form the only sarcoma team in the country. Therefore, the selected patient group represents the entire nationwide cohort of resected pelvic tumours in the observation period. Based on the histological diagnosis, patients were stratified into seven subgroups: osteosarcoma, chondrosarcoma, dedifferentiated chondrosarcoma, Ewing sarcoma, parosteal sarcoma, postradiation sarcoma, and others. A histological biopsy was performed in all patients, and treatment was planned at the sarcoma tumour board. The following data were collected for each patient: age, gender, date of resection, histological diagnosis, type of pelvic resection, implants used in reconstruction, resection margins, postoperative MSTS score (Musculoskeletal Tumour Society scoring system), length of follow-up and oncological outcome at the end of the follow-up period (alive, no evidence of disease, alive with oncological disease, died of oncological disease). The MSTS scoring system was developed in 1985 (revised in 1993) (3), completed by a treatment team member, and developed to measure functional outcome and quality of life after musculoskeletal tumour treatment. It contains six categories (0-5 points, maximum 30): pain, function, emotional acceptance, support, walking, and gait,

although studies show that it is not an adequate measure of overall quality of life (16).

The Kaplan-Meier survival analysis was performed with Office 365 Excel (Microsoft Corp. Redmond, WA, USA) and SPSS Statistics 27.0 for Windows (IBM Corp, Armonk, NY, USA).

The presented non-interventional observational retrospective study was approved by the National Medical Ethics Committee of the Republic of Slovenia on September 19, case No. 0120-486/2017/4). For this type of study, formal informed consent is not required. There was no funding and no conflict of interest.

3 Results

A total of 21 limb-sparing primary resections of pelvic bone sarcomas were performed at the Department of Orthopaedic Surgery, University Medical Centre Ljubljana (Table 1). The mean age of the patients at the time of surgery was 47 (range 12-74) years; 3 of them were children. Clear oncological surgical margins were achieved in 16 (76%) cases. Patients were divided into seven subgroups based on the histology with significant differences in mean age and one patient with metastatic disease at the time of index surgery. After the median

Table 1: General attitude towards mental disorder – statement blocks.

No.#	Age at diagnosis [years]	Gender [M / F]	Diagnosis	Type of pelvic resection	Implant	Margins	MSTS score	Follow-up [years]	Oncological Outcome*
1	12.4	M	osteosarcoma	I + II	femoral-pubic wire stablization	R0	16	18.1	Alive, NED
2	59.4	F	chondrosarcoma	I	none	R0	21	18.0	Alive, NED
3	71.5	M	chondrosarcoma	I + II + III	femoral-pubic wire stablization	R1	11	0.5	Died of disease
4	59.3	F	malignant peripheral nerve sheath tumor	I	none	R1	26	8.2	Died of disease
5	46.4	F	postradiation osteosarcoma	I + II + IV	femoral-pubic suture stabilization	R0	2	0.9	Died of disease
6	42.0	M	chondrosarcoma	I + II	MUTARS custom-made	R0	24	12.3	Alive, NED
7	27.9	M	parosteal osteosarcoma	I	none	R1	22	9.5	Died of disease
8	52.7	M	chondrosarcoma	I + II	MUTARS LUMiC	R0	17	2.6	Died of disease
9	48.8	M	chondrosarcoma	I	spondylodesis	R0	25	8.6	Alive, NED
10	39.2	M	chondrosarcoma	I + II	MUTARS LUMiC	R0	13	7.7	Alive, NED
11	35.7	F	parosteal osteosarcoma	I + II + III + IV	femoral-pubic suture stabilization	R1	10	6.7	Alive with disease
12	56.4	F	postradiation osteosarcoma	II + III	MUTARS LUMiC	R0	22	6.0	Alive, NED
13	70.6	M	dediff. chondrosarcoma	I + II + III	MUTARS LUMiC	R0	11	2.6	Died of disease
14	64.8	F	chondrosarcoma	III	none	R0	27	4.8	Alive, NED

No.#	Age at diagnosis [years]	Gender [M / F]	Diagnosis	Type of pelvic resection	Implant	Margins	MSTS score	Follow-up [years]	Oncological Outcome*
15	16.0	F	Ewing sarcoma	III	none	R0	29	4.4	Alive with disease
16	32.0	M	Ewing sarcoma	I + IV	spondylodesis and fibula	R0	11	4.3	Alive, NED
17	48.8	M	dediff. chondrosarcoma	II + III	MUTARS LUMiC	R0	12	0.6	Died of disease
18	74.7	F	postradiation fibrosarcoma	I + II	MUTARS LUMiC	R1	9	2.0	Alive with disease
19	49.9	F	chondrosarcoma	I + IV	spondylodesis and fibula	R0	25	0.8	Alive, NED
20	53.2	M	leiomyosarcoma	I + II + IV	femoral-pubic suture stabilization	R1	14	0.7	Alive, NED
21	17.2	M	Ewing sarcoma	II + III	MUTARS LUMiC	R0	21	0.6	Alive, NED

Legend: *NED – no evidence of disease.; M – male; F – female.

follow-up of 5.7 years (0.6-18.1), 7 (33%) patients died of oncological disease, 3 (14%) patients were alive with oncological disease, and 11 (53%) patients were alive with no evidence of disease (Table 1). All patients with dedifferentiated chondrosarcoma and all R1 resection patients with high-grade tumours died within 3 years after surgery. The estimated Kaplan-Meier survival probability at 2 years, 5 years, and 10 years after pelvic resection was 85%, 73%, and 45%, respectively (Figure 4).

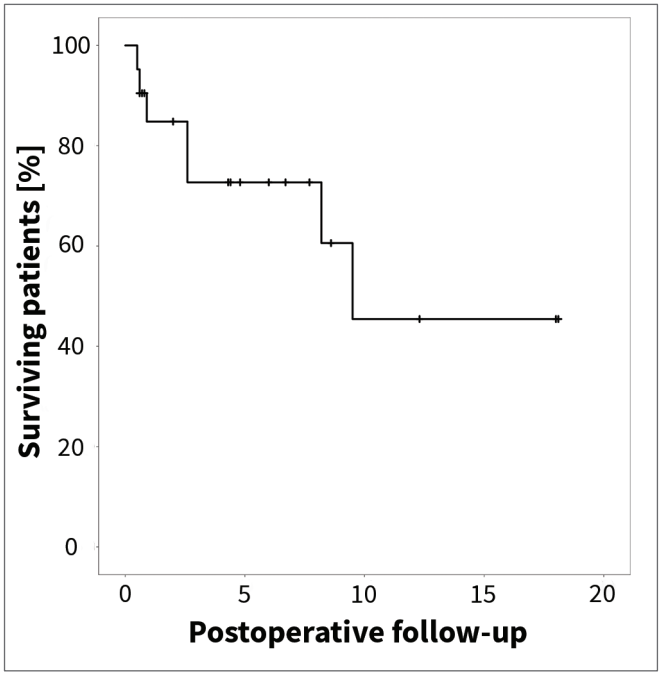

Figure 4: The estimated Kaplan-Meier survival probability at 2 years, 5 years and 10 years after a pelvic malignant tumour resection.

Postoperative complications were common. On average, 2.5 (range 0-15) revisions were performed due to various surgical complications (wound dehiscence, wound drainage, urethral reconstruction, vascular reconstruction or ligation, necrectomy and vacuum-assisted closure, open reduction, and revision of endoprosthesis). When only major complications were taken into account, there were 3 deep infections and 3 mechanical failures of reconstruction (femoral fracture and fracture of endoprosthesis). Four tumour recurrences were observed (19% overall local recurrence rate).

Functional outcomes and quality of life varied widely across the cohort. The mean MSTS score was 17.5 (range 2-29). Patients with more extensive resections during index surgery had considerably lower scores (Table 1).

4 Discussion

Surgical management of pelvic tumours with limb-sparing reconstruction is challenging. Clear oncological surgical margins must be achieved without compromising adjacent neurovascular and visceral

structures, requiring an extensive approach. Because of the massive bone defect, reconstruction and fixation are also challenging, requiring fixation sites as distant as the lumbar spine or contralateral ilium. Extraarticular and proximal femoral resection also requires endoprosthetic reconstruction. Besides, primary malignant mesenchymal tumours of the pelvic girdle occur rarely, and the variability of possible resection combinations is high. Therefore, only very large tumour centres can achieve a sufficiently high number of cases to perform such procedures routinely (17).

Directly comparing the presented data with previously published patient series in the scientific literature is difficult because of the high variability in histological diagnoses, oncological stages of the disease, reconstructions, and different decision-making protocols. Nevertheless, most reported 5- and 10-year survival rates and mean MSTS scores are close to our cohort. In a propensity-matched cohort study of 131 pelvic chondrosarcomas with limb-sparing surgery, the 5-year survivorship was 70%, and the 10-year survivorship was 60%. Older age, more comorbidities, higher chondrosarcoma grade, and positive surgical margins were associated with decreased survival (18). Similarly, a patient series of 27 cases with a mean follow-up of 45 months showed 60 % survival, 22 % local recurrence, 22% disease progression with metastases, and a mean MSTS score of 15 (19). In this context, the diagnosis of dedifferentiated chondrosarcoma in the pelvis exhibited a much worse overall survival of 15.4% for patients treated with palliative intent and 50% for those treated with surgery at 12 months after surgery, whereby hind-quarter amputations were better in achieving wide surgical margins and longer disease-free survival (20).

One of the largest single-centre studies of patient survival after limb-sparing pelvic sarcoma resections included 147 patients operated on over the period of 32 years (i.e., 4.6 cases per year) with highly variable diagnoses, stages, histological grades, resection types, and reconstructions. The estimated overall survival was 80%, 45%, and 37% at 1, 5, and 10 years, respectively. Univariate analyses revealed a statistically significant unadjusted influence of age, margin, and grade on overall survival. Cumulative incidence for major complications was 31% at 5 years (21). Comparably large single-centre studies of 104 Ewing sarcoma pelvic resections in 26 years (i.e., 4.0 cases per year) (1) or 270 pelvic sarcoma patients in 35 years (i.e., 7.7 cases per year) (22,23) have also shown high variability of postoperative patient survival depending on histological diagnoses and stage of the disease. With the estimated 5- and 10-year overall survival of 73% and 45% after pelvic resections in this nationwide cohort study in the Republic of Slovenia, our results are comparable with the results in the reported studies.

Postoperative complications and revision surgery are common. In our cohort study, there was an average of 2.5 revision procedures per case, but these were usually minor due to superficial infection or haematoma formation. Deep infections one of the most frustrating complications, is less common, occurring in 16%-25% of cases (24-26), which is similar to our group. Reports of mechanical failure of various types of fixations in the literature are 16%-31%, which is also comparable to our findings (24-29). Due to the small number of different types of tumours, we could not diretly compare the recurrence rate with the literature.

Functional outcomes are often poor after pelvic resection and vary in our cohort study. Lower limb function can be significantly affected by the loss of spinopelvic stability, transection of lumbosacral nerve roots, loss of gluteal muscles, and limited hip range of motion after reconstruction (30).

Computer-assisted surgery for pelvic resection was first described by Krettek (31) and Hufner (32). Wong et al. (33) described CT and MRI fusion for the computer model. Experimental studies report improved osteotomy accuracy (34,35), meaning less normal bone needs to be removed, leading to better reconstruction options. However, a significant learning curve, combined with a small sample size, can considerably affect the results (8).

There are some limitations of our study. First, this is a retrospective study. The patient sample size is small, and the heterogeneity of histological types is high because of the rarity of pelvic tumours. Second, the patients in our cohort have different involvement in pelvic structures, so different types of pelvic resections were performed, which greatly affected the complication rate, survival, and MSTS score. Third, there have been significant advances in resection and reconstruction techniques during the selected observation period of 18 years. Finally, the presented study shows a combined effect of uniform nationwide decision-making and surgical performance in a single bone tumour centre, and these two processes are impossible to separate in a retrospective analysis. If the tumour board were very restrictive when indicating surgery, the surgical results would be better, but the percentage of cases deemed to be *unresectable* would be higher - and vice versa. Therefore, a uniform controlled patient selection process is of utmost importance when comparing surgical results between different tumour centres.

5 Conclusion

To the authors' knowledge, this is the first nationwide cohort study to evaluate functional outcomes and patient survival after wide resection of pelvic bone sarcomas, with the decision-making process for surgery occurring at a single oncological institution. With a 76 % rate of achieved wide surgical margins and the estimated Kaplan-Meier survival probability of 85% at 2 years, 73% at 5 years, and 45% at 10 years after pelvic resection, the overall results of the Republic of Slovenia are not inferior to the published series of the largest sarcoma centres worldwide. Surgical resection of pelvic tumours remains the gold standard of treatment, and referral to a specialised orthopaedic oncology centre is essential. Computer navigation and new implants have enabled more precise resection and better clinical outcomes of reconstruction with less frequent need for hind-quarter limb amputations.

Conflict of interest

None declared.

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