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ORIGINAL PAPER

Evaluation of blood loss during limb salvage surgery for pelvic tumours

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Abstract As a large amount of blood loss is sometimes encountered in limb salvage procedures for pelvic tumours, it is essential to identify risk factors predicting the possibility of extensive haemorrhage. We retrospectively reviewed 137 patients who underwent pelvic tumour resections. Patients with an estimated blood loss greater than 3,000 ml were classified as having a large amount of blood loss. Sixty-one (44.53%) patients had blood loss greater than 3,000 ml. Tumours involving the acetabulum or sacrum, tumour volume greater than 400 cm^3, aorta occlusion, resection method, reconstruction and operative time were all associated with a large amount of blood loss. Pelvic tumours involving the acetabulum or sacrum (odds ratio: 4.837), tumour volume greater than 400 cm^3 (odds ratio: 3.005) and planned operation time of more than 200 min (odds ratio: 3.784) independently predicted a large amount of blood loss. Pelvic tumours with these characteristics were likely to have a large amount of blood loss during surgery.

Résumé Très souvent, la perte sanguine est très importante dans le traitement des tumeurs pelviennes, il est donc essentiel d'identifier les facteurs de risques pouvant laisser penser qu'il y ait possibilité d'une hémorragie importante. Nous avons revu de façon rétrospective 137 patients présentant une tumeur du pelvis. Les patients qui avaient une perte sanguine estimée supérieure à 3 litres ont été classés comme patients présentant une perte sanguine importante. 61 (44,53%) ont eu une perte sanguine supérieure à 3 litres. Les tumeurs incluant le cotyle et le sacrum, les tumeurs dont le volume était supérieur à 400 cm3 avec des lésions au niveau de l'aorte nécessitant des gestes de résections et de reconstruction et un temps chirurgical important, tous ces facteurs sont associés à une importante perte sanguine. Dans les tumeurs incluant l'accétulum et le sacrum l'odds ratio est de 4,837, pour les tumeurs dont le volume est supérieur à 400 cm3, l'odds ratio est de 3,005, quand il est prévu une intervention dont le temps opératoire est supérieur à 200 minutes l'odds ratio 3,784. Les tumeurs pelviennes présentant toutes ces caractéristiques peuvent présenter de façon préférentielle d'importantes pertes sanguines durant la chirurgie.

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Introduction

Approximately 10–15% of all primary malignant bone tumours and approximately 5% of soft tissue sarcomas are located in the pelvis [7, 11]. Chondrosarcoma is the most frequent primary malignant bone tumour that occurrs in this region, followed by osteosarcoma and Ewing's sarcoma [1]. Because of the complex anatomy of the pelvic region and the typically large tumour size at presentation, aggressive resection and limb salvage surgery for pelvic tumours are technically difficult. Wound infections, blood loss, pelvic instability, nerve and visceral damage are the main complications of internal hemipelvectomy [16]. Among these complications, extensive haemorrhage is a major concern and should be evaluated thoroughly.

The blood volume loss during limb salvage surgery for pelvic tumours varies from case to case. In one report [13] of 28 patients with internal hemipelvectomy and prosthetic reconstruction of pelvic tumours, the average blood loss was 4,793 ml (range: 1,500–12,000 ml). In another study

[22], the blood loss of 15 procedures of tumour resection about the acetabulum ranged between 500 and 35,000 ml. A wide variety of risk factors influence perioperative blood volume loss. For example, resection of massive pelvic tumours always requires a longer operative time, high-grade malignant neoplasms always have an abundant blood vessel supply and local recurrence distorts the normal anatomy; all of these factors may lead to a large amount of blood loss. The location of a pelvic tumour described by Enneking and Dunham [11] may be another factor determining blood loss. Both reconstruction of the acetabulum after type II resection and requirements for adequate surgical margins in type IV resection may induce haemorrhage [19]. The results of several studies [6, 18] suggest preoperative arterial embolisation and aortic balloon occlusion may reduce blood loss during tumour surgery; however, the indications for performing these procedures in internal hemipelvectomy remain uncertain.

The purpose of this study, therefore, was to evaluate the blood loss volume in limb salvage surgery for pelvic tumours and to identify the relative and independent risk factors for a large amount of blood loss to help surgeons discriminate which patients would be likely to require more transfused blood and in whom haemorrhage control may be necessary preoperatively.

Materials and methods

We retrospectively reviewed 187 patients with pelvic tumours treated surgically in our institute between July 2003 and June 2008. We reviewed the medical records (history, operative procedure) and histology slides. All patients had radiographic studies, including 45 patients who had computed tomography alone, while others had magnetic resonance imaging (MRI) or both. We excluded 13 patients who underwent hindquarter amputation and 37 patients with latent and active benign pelvic tumours. These exclusions left 137 patients, 83 of whom were men and 54 women. The age of the patients ranged from 13 to 79 years with an average age of 44.26 years. The pathological diagnoses included three chondroblastomas, two aggressive fibromatosis, ten giant cell tumours, 12 osteosarcomas, eight Ewing's sarcomas, five lymphomas, ten multiple myelomas, 12 soft tissue sarcomas and 35 metastatic bone tumours (Table 1). There were also 40 chondrosarcomas which consisted of 22 low-grade (grades 1 and 2) and 18 high-grade chondrosarcomas (grade 3, dedifferentiated and mesenchymal chondrosarcomas). Patients with osteosarcomas, Ewing's sarcomas, lymphomas and multiple myelomas received preoperative chemotherapy. Three patients with soft tissue sarcomas and eight patients with metastatic pelvic tumours had radiotherapy pre-operatively.

All of the operations were performed by two senior surgeons (GW, RLY) according to the surgical strategies as follows. Patients with a high-grade malignant tumour of large size and needing complicated reconstruction after tumour resection, usually received preoperative arterial embolisation and balloon dilation catheter (BDC) insertion. Except for patients with an easily accessible abdominal aorta, surgical occlusion was planned before operation. Complete or partial pelvic incisions [13] were adopted according to resection type. Before removal of the tumour, the ipsilateral internal iliac artery was ligated and the

Table 1 Blood loss volume of 137 pelvic tumours

Pathological diagnosis	No. of patients	Blood loss volume (ml)			
		Minimum	Maximum	Mean	SD
Aggressive benign tumour	15	200.00	12,410.00	2,936.00	3,165.39
Chondroblastoma	3	560.00	6,410.00	3,106.67	2,997.50
Aggressive fibromatosis	2	580.00	1,450.00	1,015.00	615.18
Giant cell tumour	10	200.00	12,410.00	3,269.00	3,548.87
Low-grade malignant tumour	23	700.00	10,760.00	4,165.00	2,675.69
Low-grade osteosarcoma	1	3,280.00	3,280.00	3,280.00	–
Low-grade chondrosarcoma	22	700.00	10,760.00	4,205.23	2,731.53
High-grade malignant tumour	64	110.00	16,300.00	3,813.44	3,078.97
High-grade chondrosarcoma	18	215.00	16,300.00	3,760.28	3,517.59
Osteosarcoma	11	1,050.00	11,770.00	5,461.82	3,110.64
Ewing's sarcoma	8	850.00	6,790.00	4,197.50	2,215.08
Lymphoma	5	700.00	3,000.00	1,338.00	989.23
Multiple myeloma	10	110.00	10,900.00	3,963.00	3,946.77
Soft tissue sarcoma	12	800.00	6,900.00	3,032.92	1,963.01
Metastatic tumour	35	100.00	8,020.00	2,712.86	2,026.24
Summary	137	100.00	16,300.00	3,495.22	2,814.78

abdominal aorta temporarily cross-clamped or obstructed by dilated balloon for occluding blood flow to control the haemorrhage during surgery. Routinely, intralesional curettage or marginal resection for primary benign and metastatic pelvic tumours was carried out; wide en bloc resection was used for malignant tumours. Reconstruction with a prosthesis, internal fixation systems and/or biological methods is necessary when pelvic stability is compromised after tumour resection.

The total blood volume loss consisted of the estimated intraoperative blood loss and the drainage volume on the first day after surgery. The intraoperative blood loss volume was estimated by surgeons and anaesthetists. It included the exact suction volume and the estimated volume absorbed by gauze and dressing. The volume of normal saline lavage was deducted. A volume greater than 3,000 ml was defined as a large amount of blood loss.

Tumour size, location, local recurrence, reconstruction technique, grade of malignancy, duration of the procedure and surgical margin were thought to have an influence on oncological and functional outcomes of pelvic tumours [3, 4, 8, 20, 24, 26]. Additionally, blood vessel control could reduce bleeding during tumour surgery. We thought all these patient and surgical factors would also have an influence on blood loss volume. The patient risk factors included age and gender, grade of malignancy, location of the tumour, whether the tumour was recurrent and the tumour volume. The surgical risk factors included the resection method (en bloc resection or intralesional curettage), the operative time and whether the patient had any kind of temporary aorta occlusion and/or pelvic reconstruction.

We estimated the length, breadth and height of the tumour by MRI or computed tomography. The tumour volume, which was calculated using the formula for a sphere [21], ranged from 7.85 to 9,745.22 cm^3 (mean: 597.85±990.84 cm^3). A tumour in which the volume was greater than 400 cm^3 was considered a large tumour. We classified the grade of malignancy into low (38 cases) or high (99 cases). The low-grade tumours included aggressive benign and low-grade malignant tumours. High-grade malignant tumours and metastatic bone tumours were considered as high-grade tumours. The mean tumour volume was 731.49±1,568.08 cm^3 for low-grade tumours and 546.55±651.55 cm^3 for high-grade tumours. The location of the pelvic tumour was allocated into two groups according to the zones described by Enneking and Dunham [11]. Tumours involving the acetabulum or sacrum (zone II or zone IV) were in location A, whereas tumours in the obturator area or iliac wing (zone I or zone III) were in location B.

The blood volume loss was analysed as a categorical variable with 3,000 ml as the cut off point. In order to identify which factors stated above related to a large amount of blood (>3,000 ml), univariate statistical analysis was done by chi-square tests. Fisher's exact test was used if the expected frequency in any one cell was less than five. Variables significant at the $p<0.20$ level were included in the multivariate Cox model to identify independent risk factors for a large amount of blood loss. All statistical analyses were done using the Statistical Package for the Social Sciences Version 12.0 (SPSS, Inc., Chicago, IL, USA).

Results

The overall estimated blood loss for 137 pelvic tumour resections (Table 1) ranged from 100 to 16,300 ml with a mean of 3,495.22±2,814.78 ml. Sixty-one (44.53%) cases had a blood loss greater than 3,000 ml. The mean blood loss volume in aggressive benign and low-grade malignant tumours was 3,705.39±2,910.12 ml, while in high-grade malignant and metastatic tumours it was 3,411.58± 2,786.76 ml. The median operative time ranged from 30 to 505 min with a mean of 233.72±90.33 min. The average operative time for patients with and without pelvic reconstruction was 137.22±71.04 min and 257.41±78.13 min, respectively. In patients who had pelvic reconstruction, the mean operative time for reconstruction was 54.23±16.66 min, while time spent for tumour resection and other procedures was 302.32±68.28 min. In 44 patients who received BCD or surgical cross-clamping of the aorta, the mean blood loss volume was 4,722.05±3,473.00 ml. Intraoperative or postoperative disseminated intravascular coagulation developed in six patients with a mean blood loss volume of 11,255.00±2,675.12 ml.

Using univariate analysis (Table 2), tumour location, tumour volume, aorta occlusion, reconstruction and operative time had an effect on blood loss. Tumours in zone II or zone IV had an association with a large amount of blood loss ($p<0.001$). A tumour volume greater than 400 cm^3 was associated with a large amount of blood loss ($p<0.001$). Patients who had temporary aorta occlusion had a greater ($p=0.018$) chance of excessive bleeding than patients who did not require occlusion. Reconstruction of the pelvis ($p=0.03$) or an operative time longer than 200 min ($p<0.001$) was associated with a large amount of blood loss. There was no difference in the risk of a large amount of blood loss between patients older and younger than 40 years of age (a large amount of blood loss developed in 34 of 76 patients older than 40 years of age compared with 27 of 61 patients younger than 40 years of age). There was no difference in male and female gender. Grade of malignancy and recurrent tumours had no effect on the amount of blood loss. There was no difference ($p=0.054$) in blood loss between patients with a tumour en bloc resection and piecemeal curettage.

Table 2 Results of univariate comparisons

Characteristics	No. of patients		*p* value
	≤3,000 ml blood loss (*N*=76)	>3,000 ml blood loss (*N*=61)	
Age			0.956
>40 years old	42	34	
≤40 years old	34	27	
Gender			0.284
Male	43	40	
Female	33	21	
Grade of malignancy			0.603
High	53	45	
Low	23	16	
Location			<0.001
A (zone II or IV)	53	59	
B (zone I or III)	23	2	
Recurrent tumour			0.513
Yes	14	14	
No	62	47	
Tumour volume			<0.001
>400 cm^3	23	41	
≤400 cm^3	53	20	
Aorta obstruction			0.018
No	58	35	
Yes	18	26	
Resection method			0.054
Piecemeal	36	19	
En bloc	40	42	
Reconstruction			0.030
Yes	56	54	
No	20	7	
Operation time			<0.001
>200 min	31	50	
≤200 min	45	11	

Using multivariate analysis to identify independent risk factors (Table 3), the location of the tumour had the strongest association with a large amount of blood loss with an adjusted odds ratio of 4.837 after controlling for other variables in the model. Other variables that remained independently associated with an increased risk of a large amount of blood loss included tumour volume greater than 400 cm^3 (odds ratio: 3.005) and operation time longer than 200 min (odds ratio: 3.784).

Discussion

Due to the improvement of imaging examinations, adjuvant therapy and reconstructive techniques, limb salvage procedures have become more common in the treatment of malignant pelvic tumours. Although with the advantage of better postoperative function, internal hemipelvectomy is accompanied by a high complication rate. The study of complications in pelvic tumour surgery concentrates on infection, implant failure and systemic complications [7, 26], while the amount of blood loss is only mentioned in part of the results in most studies. The purpose of our study was to evaluate the blood loss volume and to identify the relative and independent risk factors for a large amount of blood loss in limb salvage surgery of pelvic tumours.

The amount of blood loss in pelvic tumour surgery is influenced by many factors. The differences in patients' general condition, blood clotting ability, surgical stage of tumour, experience and skill of the surgical team as well as speed and volume of blood transfusion may influence brisk haemorrhage. It is impossible to evaluate all these factors in our retrospective study in which only risk factors associated with patients and surgery were considered. Additionally, surgeon bias may have resulted in aorta occlusion being used in patients with bleeding tendencies, thus making it a major risk factor associated with a large amount of blood loss.

Extensive bleeding has been reported during pelvic tumour resection and reconstruction. Satcher et al. [22] reported that in 15 patients with pelvic primary malignant tumour resections and autoclaved autografting reconstructions the mean blood loss was 7,061 cc (range: 500–35,000 cc). In another study [9] of 24 malignant pelvic bone tumours treated by local excision and allograft reconstruction, the average compensated blood loss during the hospital stay was 4,359±2,800 ml (range: 1,000–11,300 ml). A large amount of blood loss was also found in reconstruction with prostheses for pelvic tumours. The average blood loss of 4,793 ml (range: 1500–12,000 ml) was reported by Guo et al. [13]. In our large series of pelvic tumour surgery, the average blood loss was 3,495.22±2,814.78 ml. The options for blood management in orthopaedic surgery have been well established [14, 17] but are not suitable for pelvic tumour resections. In our experience in this study, however, although BDC or surgical cross-clamping of the aorta was carried out in 44 cases, more than half of the patients had a blood loss greater than 3,000 ml. Thus, the first and most important step in preventing a large amount of blood loss in pelvic tumour resection is to be aware of the salient independent risk factors.

Table 3 Multivariate logistic regression analysis

Characteristics	*p* value	Odds ratio	95% confidence interval
Location	0.050	4.837	1.001, 23.375
Tumour volume >400 cm^3	0.007	3.005	1.356, 6.657
Operation time	0.003	3.784	1.583, 9.047

Location of the tumour in zone II and zone IV was associated with the greatest independent risk (odds ratio: 4.837) for a large amount of blood loss. Generally, pelvic tumours involving the acetabulum or sacrum are always near to the iliac vessels and sciatic nerve, or the sacral nerve. Complete resection with a combined surgical approach and pelvic resection in these tumours is more difficult than simple tumour resection in zone I or zone III. Partial resection of the sacrum, especially the proximal part, results in large exposed bleeding bone and the sacrifice of large veins that drain the epidural plexus, which exit at the S1 and S2 foramina [10]. All these may contribute to the large amount of blood loss in type II and type IV resections. Additionally, some kind of reconstruction is required after tumour resection in these areas and may also result in increased bleeding. The result of a study [4] on iliosacral tumour resection has shown that pelvic reconstruction is related to greater surgical time and more blood loss. In that study, the average blood loss was 6,250 and 4,325 ml for patients with and without pelvic reconstruction, respectively. In our study, it was a risk factor for a large amount of blood loss in the univariate comparisons, but not an independent risk factor in the multivariate analysis.

Tumour volume greater than 400 cm^3 and operation time longer than 200 min were considered as other important independent risk factors associated with a 3.005-fold and a 3.784-fold increased risk of a large amount of blood loss, respectively. Pelvic tumours are difficult to diagnose at an early stage and tend to be large in diameter at the time of presentation [25]. Usually, the size of pelvic tumours is often much greater in the pelvis than in other sites. In two studies [12, 24] of pelvic tumours, the average tumour size was 520 ml (range: 50–1,550 ml) and 16×9×6 cm, respectively, whereas the mean volume of tumours was only 95 cm^3 in another study involving giant cell tumours of the extremities [21]. The large tumours always involve more than one resection area of the pelvis and have a soft tissue mass adhered to or invading the pelvic visceral organs, both of which make surgical resection difficult and lead to increased bleeding. Operation duration is also important to blood loss of pelvic tumour surgery. In most reports of primary or metastatic pelvic tumours, the average operation time was three to six hours and sometimes even more than ten hours [2, 5, 15, 23]. In our study, the mean operation time was nearly four hours and time for reconstruction was around one hour. In a report of pelvic tumour with allograft reconstruction [9], the amount of blood loss correlated with the duration of surgery but not with the area of bone resection (zone II compared with not zone II). For a complex pelvic tumour surgery with extensive exposed wound, longer operation time means more blood loss. Therefore, more practised surgical skill and a simple reconstruction method which would result in less operation time were essential for reducing blood loss during pelvic surgery.

Although as a usual concept, high-grade malignant tumours are more likely to induce ingrowth of abnormal capillary vessels and arterioles than low-grade malignant or benign tumours, the grade of malignancy had no effect on blood loss in our study. In spite of the maximum blood loss volume of 16,300 ml that occurred in a patient with pelvic osteosarcoma, the low-grade chondrosarcomas had the highest average blood loss volume compared with high-grade malignant and metastatic tumours. The low-grade chondrosarcomas and other aggressive benign tumours that occurr in the pelvic region usually grow slowly and silently to quite a large size. In our study, the mean tumour volume for low-grade and high-grade tumours was 731.49± 1,568.08 cm^3 and 546.55±651.55 cm^3, respectively. The large tumour size of low-grade tumours may be the reason for their bleeding tendency during surgery.

Our data indicate that blood volume loss during limb salvage surgery for pelvic tumours is mainly influenced by the location of the tumour, the tumour volume and the operation time. Pelvic tumours that involve the acetabulum or sacrum, have a volume greater than 400 cm^3 and an anticipated operation time of more than 200 min are likely to have a large amount of blood loss. In order to reduce blood loss in such patients, guidelines may be provided as follows: (1) large amounts of transfused blood and platelets should be prepared; (2) BDC or other blood vessel control should be considered before or during the surgery; and (3) surgical manipulation should be finished as soon as possible with simple pelvic reconstruction.

Contribution of authors XT: main investigator, first and final draft. WG: conceived the study and reviewed the data analysis. RY, ST, TJ: co-investigators for data collection, first draft, and statistical analysis.

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