Clinical results of surgery for retroperitoneal sarcoma with major blood vessel involvement

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Purpose: **The study was conducted to evaluate the clinical results of resection for retroperitoneal soft tissue sarcoma (STS) with vascular involvement.**
Methods: **The study group consisted of consecutive patients (mean age, 52 years) who underwent surgery for retroperitoneal STS with vascular involvement. The procedures were performed between 1988 and 2004. Vessel involvement by STS was classified as type I, artery and vein; type II, only artery; type III, only vein; and type IV, neither artery nor vein (excluded from the analysis). Patient data were prospectively gathered in a computerized database and retrospectively analyzed.**
Results: **Of 141 patients with retroperitoneal STS, 25 (17.7%) underwent surgery for tumors with vascular involvement. The most common vascular involvement pattern was vein only (type III) at 64%. Arterial and vein (type I) and arterial only (type II) involvement were observed in 16% and 20% of the cases, respectively. STS originating from the vessel wall (primary vessel involvement) was seen in eight patients, and 17 patients had secondary vascular involvement. Resection and vascular repair were done in 22 patients (no vascular repair in three patients due to ligation of the external iliac vein in one patient, and debulking procedures in two). All patients with arterial involvement (type I and II) had arterial reconstruction consisting of aortic replacement (Dacron, n = 3; and expanded polytetrafluoroethylene [ePTFE], n = 2), iliac repair (Dacron, n = 3), and truncal reimplantation (n = 1). The inferior vena cava (6 ePTFE tube grafts, 3 ePTFE patches, 2 venoplasties), iliac vein (1 ePTFE bypass, 1 Dacron bypass, 1 venous patch), and superior mesenteric vein (1 anastomosis, 1 Dacron bypass) were restored in 80% of the patients (n = 16) with either arterial and venous or only venous involvement (type I and type III setting). Morbidity was 36% (hemorrhage, others), and mortality was 4%. At a median follow-up of 19.3 months (interquartile range, 12.8 to 49.9 months) the arterial patency rate was 88.9%, and the venous patency rate was 93.8% (primary and secondary). Thrombosis developed in one arterial and venous (type I) iliac reconstruction due to a perforated sigmoid diverticulitis 12 months after surgery. The local control rate was 82.4%. The 2-year and 5-year survival rates were 90% and 66.7% after complete resection with tumor-free resection margins (n = 10 patients, median survival not reached at latest follow-up). The median survival was 21 months in patients with complete resection but positive resection margins (n = 7) and 8 months in patients with incomplete tumor clearance (n = 8, persistent local disease or metastasis).**
Conclusions: **Patency rates and an acceptable surgical risk underline the value of en bloc resection of retroperitoneal STS together with involvement of blood vessels. The oncologic outcome is positive, especially after complete resection with tumor-free resection margins. A classification of vascular involvement can be used to plan resection and vascular replacement as well as to compare results among reports in a standardized fashion. (J Vasc Surg 2006;44:46-55.)**

Recently, 77% of retroperitoneal sarcoma-related deaths were shown to be caused by local recurrence without concomitant metastasis.[1] Local control is therefore important in the treatment of adult patients with retroperitoneal soft tissue sarcoma (STS). Surgery is the mainstay of treatment.[2,3] In contrast, effective adjuvant chemotherapy regimens have not been identified yet, and radiotherapy is limited because of the toxicity to healthy adjacent structures.[4]

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Competition of interest: none.
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0741-5214/$32.00

doi:10.1016/j.jvs.2006.03.001

In a subset of patients, retroperitoneal STS involves major venous or arterial blood vessels.[5-13] In this clinical setting, sarcoma surgery represents a challenge in terms of treatment concept and technique. Planned vascular resection is essential to meet the oncologic standards of a complete tumor resection with microscopically negative resection margins and the prevention of tumor laceration during surgery.[14-16] Furthermore, detailed analysis has shown that only few clinical data are available to answer the question of how blood vessel involvement influences resectability, surgical approach, and the further course of the disease.[5-13] Owing to the restricted number of clinical series and the lack of multi-institutional or national registries, the significance of blood vessel involvement by retroperitoneal STS is not understood very well.

The aim of this study was to assess vascular involvement in retroperitoneal STS, to suggest a treatment algorithm, and to analyze the results of retroperitoneal sarcoma surgery that requires vascular resection. Immediate-term and

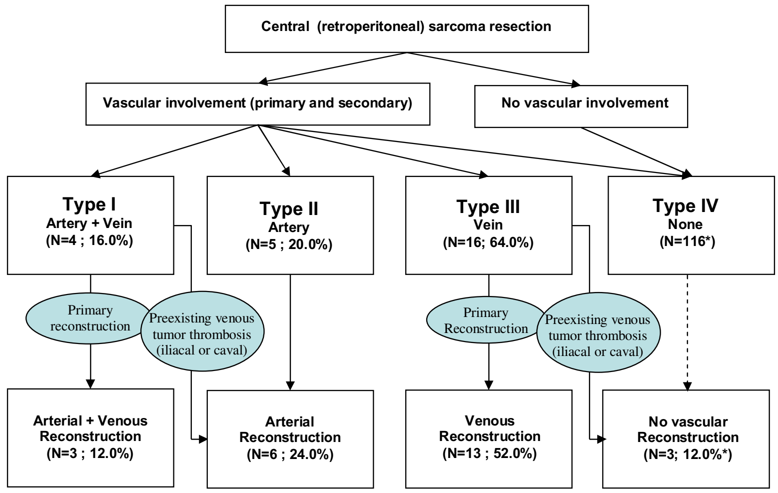

Fig 1. Type of vascular involvement and algorithm for vascular reconstruction in patients with retroperitoneal soft tissue sarcoma. *Number of patients with type IV soft tissue sarcomas treated during the respective study period who were excluded from further analysis for the purpose of this report.

long-term outcomes were analyzed for retroperitoneal sarcoma surgery performed during a 17-year period.

METHODS

Inclusion criteria. Consecutive adult patients treated at the University of Heidelberg Department of Surgery from January 1988 to December 2004 with the diagnosis of retroperitoneal STS involving major blood vessels were included in the analysis. Tumors were studied preoperatively by ultrasonography, magnetic resonance imaging (MRI), or computed tomography (CT), or a combination of these, with or without angiography.[17–20] The indications for STS resection en bloc together with major blood vessels were standardized and applied in patients with clear involvement of major blood vessels. Vascular involvement was diagnosed when MRI or CT scans did not show a rim of normal tissue in the tumor-to-vessel interface. One pathologist (G. M.) assessed the resected specimens histopathologically. Grade was determined by the degree of cellularity, differentiation, pleomorphism, necrosis, and mitotic activity and categorized into low-grade, intermediate-grade, and high-grade STS.[15]

Definitions. *Primary tumor* was defined as the initially diagnosed mass, including previously biopsied or incompletely resected lesions ≤12 weeks after the initial diagnosis. *Locally recurrent* disease was defined as the development of a mass of the same histologic subtype after prior complete resection. The clinical setting in which tumors originate from the vessel wall was considered *primary blood vessel involvement.* A tumor invading or embracing the vessel wall was referred to as *secondary vessel involvement.*

Complete resection was defined as the removal of all macroscopic disease, subdivided into complete resection with histologically negative margins and histologically positive margins. *Incomplete resection* (debulking) was defined as the removal of more than half of the tumor mass; otherwise, surgery was considered to be *exploration/biopsy.* A resection was called *multivisceral* if one or more organs adherent to the tumor were resected.

Classification of vascular involvement. Types of vascular involvement were assessed preoperatively by high-resolution CT scans or MRI.

Primary and secondary vessel involvement are indistinguishable by preoperative radiologic tomography or by clinical assessment. Therefore, both primary and secondary blood vessel involvement were classified as follows: type I, STSs involving major arteries and veins; type II, STSs affecting only arterial blood vessels; type III, sarcomas involving the veins without altering an artery; type IV, STSs without direct involvement of arterial or venous blood vessels (Fig 1). This classification of vascular involvement for retroperitoneal STSs was introduced previously for STSs in the extremities.[21]

Surgery, radiation, and vascular replacement. STSs were resected en bloc together with blood vessels according to the type of vascular involvement and the surgical standards.[15,21] An interdisciplinary tumor conference was established to evaluate whether additional therapeutic modalities such as radiotherapy or chemotherapy were required.[22] Radiotherapy was given in higher-grade and recurrent STSs according to an intraoperative and postoperative protocol, but only intraoperatively in patients who had received radiation treatment previously or selectively as an external beam radiotherapy.[23,24] Radiosensitive structures such as ureter or small bowel were spared from intraoperative radiation by dissection, mobilization, and positioning of the collimation tube.[24]

Blood flow was restored with respect to the resection site and the extent of the vascular defect and collateral blood flow (e.g., venous drainage). Arterial reconstructions were usually performed by the appropriate method, such as primary anastomosis, reinsertion, or synthetic prostheses (expanded polytetrafluoroethylene [ePTFE] or Dacron), preferably in an anatomic position. Autologous vein (reversed great saphenous vein) was not routinely used for arterial repair; however, it was considered in selective cases (visceral or iliac arteries). Circular venous defects of the inferior vena cava were reconstructed by ePTFE prostheses when a primary anastomosis was impossible. For localized defects of the inferior vena cava, either a synthetic or a venous patch was used or venoplasty (longitudinal suture) was performed. Veins occluded by thrombosis were not reconstructed (ligation of the proximal and distal venous stump).

Patients routinely received prophylactic antibiotic treatment (cephalosporin) both preoperatively and postoperatively. Bowel preparations were not routinely administered. Silver-containing prostheses or grafts with antibiotic pretreatment were preferred in case of large bowel resection. Subsequent to intestinal anastomosis, gloves were changed and protecting towels as well as instruments replaced. Perioperatively, a low-dose regimen of heparin was administered (unfractionated heparin intraoperatively and low-molecular-weight heparin in the postoperative phase). After discharge, oral anticoagulants (phenprocoumon) were not routinely administered.

Patient population. A total of 141 adult patients with retroperitoneal STS had surgery. In 25 of these patients, the STS involved major retroperitoneal blood vessels (17.7%). The median patient age was 52 years (interquartile range [IQR], 18 to 82 years), and 13 women and 12 men were treated. Various unspecific symptoms such as pain, loss of weight, or urinary obstruction were recorded (Table I). Vascular complications such as venous obstruction with lower limb edema or arterial occlusion (claudication) were rare (Table I).

In all, 18 patients (72%) were referred for primary STS and seven patients (28%) for local recurrence. One patient was diagnosed with the first, three with the second, two with the third, and one with the fourth local recurrence. Four patients (16%) had concomitant disseminated disease (Table I). The most common histologic diagnosis was leiomyosarcoma, followed by liposarcoma, malignant fibrous histiocytoma, and clear cell sarcoma (Table I); of these, 68% were high-grade STS, 20% intermediate-grade tumors, 8% low-grade, and 4% could not be classified. Most of the lesions were large, with a tumor diameter of ≥7 cm (Table I). Intraoperative radiotherapy combined with postoperative radiation was administered to 24% of the patients, and 12% received postoperative radiotherapy only. Chemotherapy was administered postoperatively to four patients and perioperatively to three patients (with radiation in one patient).

Arterial reconstruction. Arterial repair was done in nine patients, consisting of five aortic reconstructions, one reimplantation of the celiac trunk into the aorta, and three iliac reconstructions. In two patients, the resected infrarenal aorta (with ligation of the inferior mesenteric artery) was replaced by straight tube grafts, one 16-mm Dacron graft (Gelsoft®, Vascutek, Renfrewshire, Scotland, UK) and one 16-mm ePTFE prosthesis. In another patient, a 6-mm ePTFE axillobifemoral bypass was implanted after resection of the infrarenal aorta.

Table I. Clinicopathologic factors in 25 patients with soft tissue sarcomas of the retroperitoneum involving major blood vessels

Characteristics	Total (n = 25)	Rate (%)
Symptoms		
Pain	15	60
Weight loss	5	20
Limb edema	3	12
Urinary stasis	4	16
Claudication	1	4
Presentation status		
Primary tumor	16	64
Local recurrence	5	20
Primary tumor and metastasis	2	8
Local recurrence and metastasis	2	8
Histologic type		
Leiomyosarcoma	12	48
Liposarcoma	4	16
Malignant fibrous histiocytoma	2	8
Clear cell sarcoma	2	8
Malignant paraganglioma	1	4
Angiosarcoma	1	4
Malignant hemangiopericytoma	1	4
Ewing's sarcoma	1	4
Unclassified sarcoma	1	4
Tumor size [cm]		
<7	8	32
7 to 12	12	48
>12	5	20
Tumor grade*		
Low	2	8
Intermediate	5	20
High	17	68

*One tumor could not be graded.

A thoracoabdominal incision was required in two patients. One of these patients was treated with an 18-mm Hemashield® (Boston Scientific, La Garenne Colombes, Cedex, France) straight tube Dacron graft for bridging a thoracoabdominal defect. To preserve the spinal cord blood supply, a segmental costal artery was reconnected to the aorta by a venous bypass. The second thoracoabdominal aortic defect was reconstructed with a 16-mm Dacron straight Silver® (InterGard, La Ciotat, Cedex, France) prosthesis. One patient was treated by reimplantation of the celiac artery into the aorta. In the iliac arteries, reconstruction consisted of three 8-mm Dacron anatomic ileoileal tube grafts for interposition of the common iliac artery, the external iliac artery, and the internal iliac artery. In Table II, the arterial reconstructive procedures are summarized according to the type of vascular involvement.

Venous reconstruction. Venous repair consisted of reconstruction of the inferior vena cava in 11 patients, the iliac vein in three patients, and the superior mesenteric vein in two patients. In six patients, 16-mm to 20-mm ePTFE prostheses were used to bridge the caval defects. The left renal vein also had to be replaced with an 8-mm ePTFE prosthesis in one of these cases. A partial wall defect of the

Table II. Reconstruction and graft material according to the type of vascular involvement in 22 patients with retroperitoneal soft tissue sarcomas

Vascular reconstruction (n = 22)	Type I (n = 4) Artery	Vein	Type II (n = 5) Artery	Type III (n = 13) Vein
ePTFE prosthesis	2 axillofemoral (1) aortic (1)	2 iliac (1) caval (1)	—	5 caval (5)
Dacron prosthesis	2 iliac (2)	1 iliac (1)	4 aortic (3) iliac (1)	1 mesenteric (SMV) (1)
e PTFE patch	—	—	—	3 caval (3)
Venous patch	—	—	—	1 iliac (1)
Venoplasty	—	—	—	2 caval (2)
Reimplantation	—	—	1 coeliac trunk (1)	—
Anastomosis	—	—	—	1 mesenteric (SMV) (1)

ePTFE, Expanded polytetrafluoroethylene; *SMV,* superior mesenteric vein.

inferior vena cava was restored by an ePTFE patch in three patients and by venoplasty in two patients. Two reconstructions of the common iliac vein consisted of one 8-mm ePTFE bypass and one venous patch (contralateral great saphenous vein). The internal iliac vein was reconstructed by a Dacron graft in one patient. Two superior mesenteric vein reconstructions were accomplished by direct end-to-end anastomosis in one and by a Dacron bypass in one. One patient with resection of the iliac vein was not reconstructed due to massive scarring from previous operations. The different venous reconstructive procedures are summarized in Table II according to the type of vascular involvement.

Follow-up. Patients were seen regularly during the observation period at our outpatient clinic. The standard vascular follow-up was at 6 weeks and 6 months postoperatively and yearly thereafter. Patients were also seen according to the routine oncologic follow-up schedule. They were questioned about symptoms suggesting graft thrombosis, including pain and discomfort. Clinical examinations were usually combined with duplex ultrasonography to evaluate the patency of arterial and venous reconstructions. In addition, CT or MRI follow-up examinations for tumor staging were used to assess the patency of arterial and venous reconstructions.

Statistical analysis. SAS 9.1 software (SAS Institute, Inc, Cary, NC) was used for statistical analysis. The distribution of age at operation and tumor size as well as follow-up time were described as the median with an IQR. Kaplan-Meier estimations were used to analyze the survival rates from the date of surgery.[25] The 2-year and 5-year rates with a corresponding 95% confidence interval (CI) were presented for overall survival. Patients in whom no event was observed were censored at the last follow-up. The log-rank test was performed to compare survival time distributions between curves regarding margin of resection. Two-sided *P* values were always computed, and an effect was considered statistically significant at $P \leq .05$.

Table III. Resectability of retroperitoneal soft tissue sarcomas with blood vessel involvement in 25 patients

Characteristics	Total (n = 25)	Rate (%)
Resectability		
Complete resection	17	68
With negative margin	10	40
With positive margin	7	28
Incomplete resection	8	32
Vascular resection		
Artery	5	20
Vein	14	56
Artery and vein	4	16
None	2	8
Vessels resected		
Inferior vena cava	12	48
Iliac vein	4	16
Mesenteric vein	2	8
Aorta	6	24
Iliac artery	3	12
None	2	8

RESULTS

Resectability and vascular infiltration. In 25 patients who underwent surgery, resection was complete in 17 patients (68%). Surgery did not clear all macroscopic disease in eight patients (32%), either because of distant metastasis in six, including patients with subsequent resection of metastasis, or because of residual disease at the site of resection in two (Table III). Vascular resection was performed in 23 patients (92.0%). Two patients were not treated by vascular resection, one of whom was diagnosed with a primary leiomyosarcoma of the inferior vena cava,

Table IV. Results of histopathologic evaluation of the surgical specimen concerning vascular and organ involvement in 25 patients with retroperitoneal soft tissue sarcomas

Characteristics	Total* (n = 25)	Rate (%)
Primary involvement	8	32
Vascular origin	8	32
Artery (type II)	1	4
Vein (type III)	7	28
Secondary involvement	17	68
Vascular infiltration	11	44
Artery and vein (type I)	4	16
Artery (type II)	1	4
Vein (type III)	6	24
Vascular encasement	6	24
Artery and vein (type I)	0	0
Artery (type II)	3	12
Vein (type III)	3	12

*Includes two patients with incomplete resection

extending from the iliac bifurcation into the right atrium of the heart. The other patient presented with an unclassified large and infiltrating sarcoma of the inferior vena cava (27 cm in diameter) (Table III). Adherent organs or structures were resected in 11 (44%) of 25 patients; kidney (n = 6), large bowel (n = 3), and small bowel (n = 3) were the most commonly resected organs. Two patients each had cholecystectomy, omentectomy, and liver resection.

Resection was performed for four (16%) STSs with arterial venous involvement (type I), in five (20%) with only arterial involvement (type II), and in 16 (64%) with only venous involvement (type III) (Fig 1). Histopathologic examination of the specimens showed that eight (32%) STSs originated in the blood vessel wall, including seven leiomyosarcomas of the inferior vena cava and one angiosarcoma of the aortic wall (Table IV). All of the latter STSs were primary tumors and predominantly classified as high-grade lesions, and 17 (68%) secondarily involved major vessels. Of these, 11 sarcomas had infiltrated the vessel wall (four showed both arterial and venous infiltration, six venous infiltration only, and one arterial infiltration only) (Table IV). In the other six STSs with secondary involvement, vessel encasement without infiltration was observed. Diverse histologic subtypes (e.g., liposarcoma, malignant fibrous histiocytoma, and clear cell sarcoma) and either primary disease (n = 10) or locally recurring tumors (n = 7) were diagnosed for secondary vascular involvement (Table IV). Tumor growth also affected adjacent retroperitoneal or visceral organs. Of 11 patients in whom organs were resected, six presented with organ infiltration on histopathologic examination: kidney, 3; small bowel, 2; pancreas, 2; and 1 each large bowel, liver and spleen.

Morbidity and mortality. Morbidity was observed in nine (36%) of 25 patients. Hemorrhage (16%) was the most common complication. Wound infection, prolonged bowel dysfunction, ureter stenosis, neurologic deficit, or abscess occurred in 4% of the cases, respectively. All patients with wound infections were successfully treated conservatively, as was one patient with postoperative bleeding. Two patients with hemorrhage required revision surgery, leading to a reoperation rate of 8%. A thromboembolic complication and anastomotic leakage associated with blood vessel reconstruction were observed in one patient each.

The mortality rate was 4% owing to the death of one patient on the first postoperative day from massive intraoperative blood loss with subsequent multiorgan failure. In this patient, a large recurrent retroperitoneal tumor invading the infrarenal aorta, common iliac vessels, and inferior vena cava (type I) was resected together with adjacent organs. After ligation of the vena cava and aorta, an axillo-bifemoral bypass was implanted.

Arterial resection and graft function. Nine (36%) of the 25 patients were treated by arterial resection. Four arterial resections (16%) were performed for STSs that involved both arteries and veins (type I), and five arterial resections (20%) were for tumors that only involved arteries (type II). All arterial resections were followed by vessel reconstruction. In eight (88.9%) of nine reconstructions, synthetic grafts were used, and one reimplantation of the celiac trunk was done.

No patient was lost to follow-up. Median follow-up was 19.3 months for surviving patients (IQR, 12.4 to 49.9 months). The overall patency rate of arterial reconstructions was 88.9% (8 of 9 reconstructions).

Graft infection with septic thrombosis was diagnosed in one patient 12 months after surgery for a STS that involved the iliac artery and vein (type I). The underlying cause of late graft infection of the iliac prostheses (Dacron for arterial repair and ePTFE for venous repair) was a perforated sigmoid diverticulitis. Treatment consisted of explantation of the iliac grafts, ligation of the iliac vein, and implantation of a Dacron extra-anatomic femorofemoral bypass for arterial repair.

Venous resection and graft function. Twenty patients (80%) had venous involvement: four with arterial involvement also (type I STS) and 16 with only venous involvement (type III). In two cases, extensive tumor growth precluded venous resection. Venous resection was used in 18 patients (72%), four for type I involvement (16%) and 14 for type III involvement (56%). In the patients with both arterial and venous involvement, three venous resections (75%) were followed by venous reconstruction. In one patient with a pre-existing thrombotic occlusion of the inferior vena cava, only arterial repair was done. Resections were reconstructed in 13 of the patients (92.9%) with venous involvement alone. In one patient with resection of the external iliac vein, the vessels could not be reconstructed because of massive scarring in the operation field. Of the 18 patients with venous involvement and resection, venous repair was completed in 16 cases (88.9%).

One venous graft thrombosis occurred because of a perforated sigmoid diverticulitis, as described previously. Treatment consisted in explantation of the iliac ePTFE graft with ligation of the iliac vein. The venous ligation was

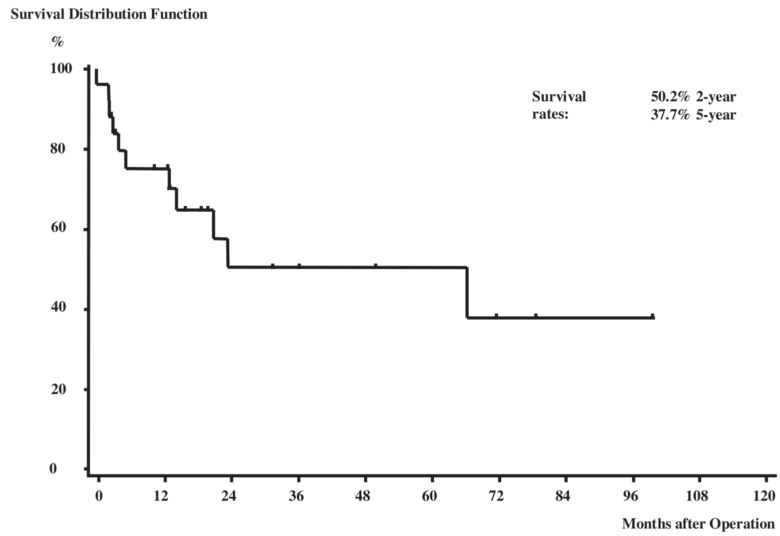

Fig 2. Disease-specific survival of all patients after resection of retroperitoneal soft tissue sarcoma with blood vessel involvement (25 patients). The median follow-up was 19.3 months (interquartile range, 12.8 to 49.9 months).

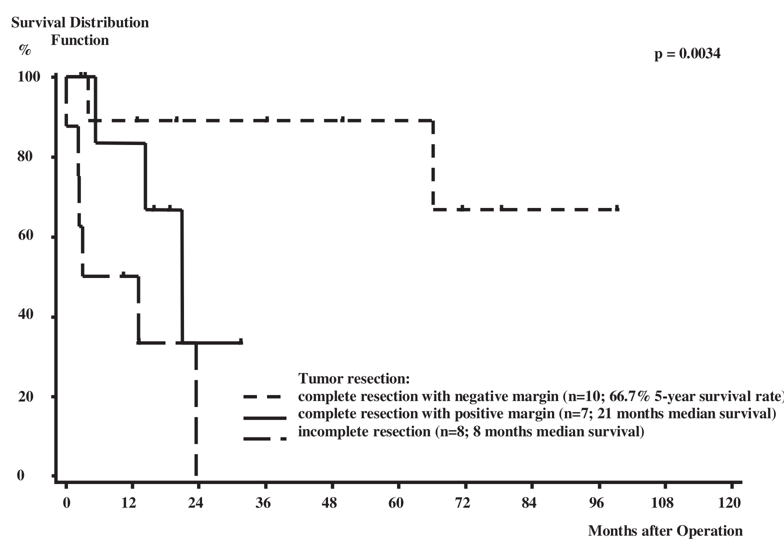

Fig 3. Disease-specific survival after complete resection with negative resection margin, complete resection with microscopically positive resection margin, and debulking surgery in 25 patients with retroperitoneal sarcoma involving major blood vessels. The median follow-up was 19.3 months (interquartile range, 12.8 to 49.9 months).

clinically well tolerated by the patient, who presented with mild limb edema at the most recent follow-up. Thus, all but one of the venous reconstructions (93.8%) remained patent during the observation period.

Tumor control and survival. After complete tumor resection, three of 17 patients presented with local recurrences (local tumor control rate, 82.4%). One (16.7%) of six patients who underwent debulking surgery was diagnosed with local tumor progression. At the last follow-up, 14 patients (56%) were alive (Fig 2). According to the type of vascular involvement, 25% (1 of 4) of the patients with type I STS survived during the observation period, and 60% (3 of 5) of the type II and 62.5% (10 of 16) of the type III patients were alive at the latest follow-up. In the group of patients with complete tumor resection, 13 (68%) survived and six (32%) died because of metastatic or local recurrent disease.

After complete resection with negative resection margins, the 2-year and 5-year survival rates were 90% and 66.7% (Fig 3). Patients diagnosed with macroscopically complete resection and positive resection margins presented with a median survival of 21 months. In the noncurative group (persistent local disease or metastasis), two of the patients were alive at the latest follow-up. The respective median survival in the noncurative group was 8 months (Fig 3). Univariate analysis determined that the margin of resection (complete resection with negative margin vs complete resection with positive margin vs incomplete resection, $P = .0034$) was a significant prognostic factor for survival.

DISCUSSION

Although complete resection is the mainstay of the treatment,[26–28] a systematic review showed that only 53% of the patients who underwent surgery for retroperitoneal STSs were treated by complete resection.[29] Removing surrounding organs (e.g., kidney, colon, small bowel), if necessary by multivisceral resection, contributes to an improved resectability rate.[26,30] In a subset of patients, however, organ resection alone is not sufficient. An STS that involves major retroperitoneal blood vessels, such as the inferior vena cava, aorta, or iliac, or visceral vessels requires planned vascular resection.[3] Resectability rates of 80% to 100% have previously been reported in patients with vascular involvement in extremity sarcomas.[21,31,32] By deliberately sacrificing retroperitoneal vascular structures, sharp dissection of the vessels becomes redundant, and the margins as well as resectability can be improved.

The number of patients with retroperitoneal STSs requiring major vascular resections is unknown. In the present analysis of a consecutive series, the frequency of retroperitoneal vascular involvement, at 17.7%, was considerable. In addition to leiomyosarcomas and liposarcomas, diverse other types of sarcomas were associated with vascular involvement.[33] Most studies, however, focus selectively on the very rare entity of primary leiomyosarcoma of the vena cava, neglecting all other sarcomas that involve blood vessels in the retroperitoneum.[5,6,7,9,11,34–36]

Our data show that most of the STSs secondarily involved vascular structures either by histologically proven vascular infiltration or by vascular encasement (Table IV). Only a few patients were noted with tumors originating from retroperitoneal blood vessels such as the caval leiomyosarcoma. Retroperitoneal sarcomas are usually large at diagnosis, and the differentiation between primary or secondary blood vessel involvement is not made before the pathologist examines the specimen.[15] This clinical situation implicates that the latter occurrences have to be treated by a common procedural algorithm and resection strategy.[11]

Here, we suggest a novel, four-stage classification that describes the pattern of vascular involvement by retroperitoneal STSs. This analysis clearly demonstrates that the most common type of vascular involvement is type III, venous involvement (Fig 1). This pattern also predominates in the literature, explained in particular by the large number of reports about leiomyosarcomas of the inferior vena cava (Table V).[5,6,9–11] In type III tumors, surgery usually has to be performed on the vena cava or iliac veins (Tables II and V).[5,6,9–11]

The present analysis also shows that isolated arterial involvement by retroperitoneal sarcomas (type II) occurs with a lower frequency (Fig 1). Chiche et al[12] reported on five patients with sole arterial growth pattern, representing the largest series apart from ours (Table V). Type II sarcomas especially impact on the aorta or the iliac arteries and uniformly require vascular reconstruction (Tables II and V).[7,12] Also less common, as shown here, is the simultaneous involvement of retroperitoneal arteries and veins by type I sarcomas (Fig 1).

Data on type I tumors have only been supplied by Dzsinich et al,[5] who reported on one (7.7%) of 13 leiomyosarcomas with both arterial and venous involvement . The analysis by Zheng et al[8] does not distinguish type I sarcomas by numbers, although both retroperitoneal arteries and veins were replaced.

Simultaneous arterial and venous resection in the retroperitoneum mainly concerns the aortoiliac or iliocaval vessels (Tables II and V).[7,8] The respective vascular reconstructive algorithm depends on the type of vascular involvement and the prevalence of venous thrombosis, which per se makes venous reconstruction redundant (Fig 1).

The decision of whether to resect blood vessels depends especially on preoperative radiologic imaging results.[15,21] CT angiography with a four-detector system is sufficient as the standard diagnostic procedure and can provide all the relevant data needed for planned vascular resection.[15] Another option is contrast-enhanced MRI using a standard magnetic field strength of ≥1.5 Tesla.[15,18–20] In patients with palpable pulses, routine angiography or MR angiography is not necessary, and venography is usually not required.[18–20] Intravascular ultrasound scans can be used as a complementary diagnostic tool. The value of positron emission tomography is unclear.[37,38]

Arterial replacement was usually accomplished by implanting a synthetic vascular prosthesis in anatomic position. Reconstructions are required, especially for aortic or the iliac repair. Straight 16-mm to 18-mm tube grafts (Gelsoft®, Hemashield®, or Silver®) are appropriate for aortic reconstruction. Straight 8-mm Dacron prostheses can be used for the iliac arteries. Visceral arteries have to be resected for tumors extending into the mesenteric root. In such cases, reconstruction can necessitate primary anastomosis, reinsertion, or bridging by small-diameter grafts (e.g., great saphenous vein, synthetic 6-mm ePTFE, or Dacron prostheses). Good long-term patency rates (88.9%) were observed in this analysis (Table V) when preferably synthetic grafts were used for arterial reconstructions. Apart from case reports, arterial bypass grafting after sarcoma surgery has only been recognized in the literature in few series (Table V).[12,39]

Central venous repair after resection prevents lower-limb edema and the clinical sequelae such as pain, swelling, tension, and skin alterations.[40] Expanded PTFE (16 mm to 20 mm) tube prostheses or ePTFE patches are preferred for reconstruction of the inferior and middle portion of the vena cava. Only in case of pre-existing venous thrombosis should caval ligation be done below the renal veins or in the iliac veins. If renal vein resection is necessary, reimplantation or bridging by a small-diameter graft (vein or synthetic graft) can become necessary. Venoplasty is used for recon-

Table V. Literature review of clinicopathologic data and results in patients undergoing surgery for retroperitoneal soft tissue sarcoma involving major blood vessels

Author	Cohort		Histopathologic and clinical tumor characteristics					Vascular reconstruction (region / method)			Clinical results				
Reference	Years studied	No. of patients/ STS	Histology	Grade	Size (cm)	Primary/ recurrent tumor	Type	Graft location	Arterial repair	Venous repair	Morbidity/mortality	Follow-up (months)	Arterial/Venous patency	Local/distant recurrence	Survival
Dzsinich 1992[5]	1957-1990	13 / 13	13 LMS	NS	NS	12/1	1 Type I 12 Type III	6 IVC 1 IV 1 IA	1	2 ePTFE BP 1 Dacron-patch 1 venous BP 3 suture	2/13 (15%)/ 1/13 (7.5%)	NS	NS 5/7 (71%)	2/13 (15%)/ 5/13 (38%)	l5/13(38%)†
Dong 1998[6]	1990-1997	11/9	5 LMS 1 FS 1 MS 1 MP 1 MM 1 seminoma 1 CA		12-30		11 Type III	9 IVC 1 IVC+RV 1 RV	0	NR suture NR anastomosis NR ligation	3/11 (27%)/ 0/11 (0%)	6	NS all repairs patent	NS	11/11(100%)†
Babatasi 1998[7]	NS	3/3	3 LMS	3 h.g.	NS	3/0	1 Type II 1 Type III 1 atrial	1 IVC 1 PA	1 synthetic BP	1 venous BP 1 HT	0/3 (0%) 0/3 (0%)	NS	1/1 (100%)/ 1/1 (100%)	1/3 (33%)/ 1/3 (33%)	1/3(33%)†
Zheng 1998[8]	NS	25 / 13	6 LMS 4 LS 1 NFS 2 FS 1 teratoma 11 benign	NS	NS	NS	NS	12 IA 8 IV 6 IVC 3 AO 7 others	7 suture 6 ven./syn.BP 3 anastomosis 1 ligation	8 suture 5 vein/synth.BP 5 anastomosis 4 ligation	0/25 (0%)/ 0/25 (0%)	NS	16/16 (100%) 18/18 (100%)	NS	25/25(100%)†
Ridwelski 2001[9]	1993-1999	5/5	5 LMS	2 l.g. 2 i.g. 1 NS	5-7	5/0	5 Type III	4 IVC 1 inoperable	NS	3 ePTFE-Patch 1 NS	0/5 (0%) 0/5 (0%)	NS	 3/3 (100%)	0/5 (0%)/ 2/5 (40%)	3/5(60%)†
Arii 2003[10]	1990-2001	11/1	1 LMS 3 HCC 4 CC 3 metastasis	NS	3-15	8/3	11 Type III	11 hep. IVC		11 ePTFE	1/11 (9%) 0/11 (0%)	NS	 11/11 (100%)	6/11 (55%)/ 2/11(18%)	25.5%*
Hollenbeck 2003[11]	1982-2002	25 / 25	25 LMS	25 h.g.	12	25/0	21 Type III	21 IVC		11 ligation 7 suture 2 ePTFE BP 1 venous patch	4/25 (16%)/ 2/25 (8%)	24	NS/ NS	7/25 (33%)/ 10/25(48%)	33%*
Chiche 2003[12]	1990-2000	5/5	1 LMS 1 MHE 2 intimal 1 NS	NS	NS	5/0	5 Type II	5 AO 2 AO/ SMA	6 synthetic BP 1 venous BP		2/5 (40%)/ 1/5 (20%)	NS	6/7 (86%)/ NS	0/5 (0%)/ 1/5 (20%)	8%*
Present series	1988-2004	25 / 25	12 LMS 4 LS 2 MFH 2 CCS 5 STS	2 l.g. 5 i.g. 17 h.g. 1 NS	10.5	18/7	4 Type I 5 Type II 16 Type III	11 IVC 3 IV 2 SMV 6 AO 3 IA	6 Dacron BP 2 ePTFE BP 1 reinsertion	7 ePTFE BP 3 ePTFE patch 1 venous patch 2 Dacron BP 2 venoplasty 1 anastomosis 2 ligation	9/25 (36%)/ 1/25(4%)	19,3	8/9 (89%)	3/9 NS	37.7*

NS, Not specified; *NR,* numbers not reported; *STS,* soft tissue sarcoma; *LMS,* leiomyosarcoma; *LS,* liposarcoma; *MFH,* malignant fibrous histiocytoma; *CCS,* clear cell sarcoma; *MHE,* malignant hemangioendothelioma; *FS,* fibrous sarcoma; *NFS,* neurofibrosarcoma; *MS,* malignant schwannoma; *ES,* Ewing's sarcoma; *MP,* malignant paraganglioma; *MM,* malignant mesenchymoma; *BP,* bypass; *CA,* carcinoma; *LR,* local recurrence; *DR,* distant recurrence; *PT,* primary tumor; *IVC,* inferior vena cava; *IV,* iliac vein; *SMV,* superior mesenteric vein; *IA,* iliac artery; *RV,* renal vein; *PA,* pulmonary artery; *HT,* heart transplantation; *SMA,* superior mesenteric artery; *AO,* aorta.

*5-year-survival rate.

†Absolute number of survivors.

struction of localized venous wall defects if the residual blood vessel diameter remains ≥70%. With respect to the literature, here we report the largest series of patients with retroperitoneal venous reconstructions after STS resection.[5–12]

We do not support the procedural concept of caval ligation as reported by Hollenbeck et al.[11] These authors presented data on 25 resected leiomyosarcomas with caval ligation in 11 cases (44%).[11] Routine ligation of the infrarenal vena cava should be reserved for emergent situations (eg, massive hemorrhage or stool contamination) or preexisting venous thrombosis. The excellent venous patency rate of 93.8% as observed in this series (Table V) sustains the concept of venous repair.

The morbidity and reoperation rates in our study were acceptable and thus further underline the concept of vascular resection with consecutive repair (Table V).[5–12] Bleeding was the most common complication; therefore, careful hemostasis and cautious intraoperative administration of heparin are mandatory. Because patients usually have an excellent peripheral run off, low-dose heparinization is sufficient.

The use of prosthetic vascular grafts after multivisceral resections or bowel surgery was not associated with an increased infectious morbidity as shown by our results. In case of large bowel resection, Silver® prostheses or grafts pretreated with antibiotics are recommended. Bowel resection should be performed without contamination of the abdominal cavity by using a separate set of instruments, gloves, towels, and a linear stapler with cutting device (GIA, Ethicon–Endosurgery, Inc., Cincinnati, OH). In case of major abdominal contamination, extra-anatomic arterial reconstruction as well as venous ligation has to be considered.

The 2-year and 5-year survival rates of 90% and 66.7% after complete resection with tumor-free resection margins were rewarding (Fig 3). Taking into consideration that most of the tumors showed adverse prognostic criteria such as vascular involvement, higher grade, deep subfascial location, or large size, these results are respectable (Table I and Fig 3). Patients in our series with retroperitoneal vascular involvement and positive resection margins were found to have a less favorable prognosis (median survival after 20 months). Poor oncologic outcome (median survival, 8 months) was observed in patients who could not be treated by complete resection.

Although a clinical benefit of improved survival and palliation of symptoms has been reported for incomplete resection of retroperitoneal liposarcoma by Shiabata et al,[41] its advantage is questionable in patients with vascular involvement. Local recurrence rates in this series are comparable with the results presented in the literature (Table V).

Data from own observational analyses and from the literature indicate that intraoperative radiotherapy, which was applied in selectively in our patients, improves local tumor control.[23,24] There is evidence in favor of adjuvant chemotherapy; however, this is still an individual and interdisciplinary decision.[22] Owing to the restricted numbers of patients in the respective vascular involvement subgroups (type I to type III) and the exclusion of type IV STS from this analysis, a prognostic assessment of the proposed stratification system can not done at this point of the analysis.

CONCLUSION

This analysis shows that complete resection with clear margins is important for long-term survival in patients with retroperitoneal soft tissue sarcomas. The use of vascular resection is the treatment of choice in sarcomas that involve major blood vessels in the retroperitoneum. With this technique, most patients with vascular involvement can be treated by complete resection with tumor-free resection margins. Primary sarcomas or local recurrences as well as tumors with primary vascular involvement (eg, leiomyosarcoma of the vena cava) or secondary vascular involvement (eg, caval infiltration by a retroperitoneal liposarcoma) require resection of diseased blood vessels. The extent of vascular resection and the appropriate vascular repair has to be assessed in the individual patient. The proposed classification and treatment algorithm can be used to plan resection and vascular replacement. Finally, the categorization of blood vessel involvement improves comparability and standardization among the data presented by different investigators and has to be evaluated for its prognostic value in the future.

We thank Frank Willeke and Christian Herfarth for initiation and continuous support in building up a prospective clinical database on soft tissue sarcoma patients operated at the Department of Surgery at the Univerity of Heidelberg. We thank Sheryl Sundell for her help preparing this manuscript.

AUTHOR CONTRIBUTIONS

Conception and design: MS, DB
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Writing the article: MS, YH
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Statistical analysis: UH
Obtained funding: Not applicable
Overall responsibility: MS

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Submitted Oct 20, 2005; accepted Mar 2, 2006.